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BOLON, Isabelle, et al.

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Background Snakebite envenoming is a major global health problem that kills or disables half a million people in the world's poorest countries. Biting snake identification is key to understanding snakebite eco-epidemiology and optimizing its clinical management. The role of snakebite victims and healthcare providers in biting snake identification has not been studied globally. Objective This scoping review aims to identify and characterize the practices in biting snake identification across the globe. Methods Epidemiological studies of snakebite in humans that provide information on biting snake identification were systematically searched in Web of Science and Pubmed from inception to 2nd February 2019. This search was further extended by snowball search, hand searching literature reviews, and using Google Scholar. Two independent reviewers screened publications and charted the data. Results We analysed 150 publications reporting 33,827 snakebite cases across 35 countries. On average 70% of victims/bystanders spotted the snake responsible for the bite and 38% captured/killed it and brought it to the healthcare facility. [...]

Reference

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Identifying the snake: First scoping review on practices of communities and healthcare providers confronted with snakebite across the world

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Background
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Objective
This scoping review aims to identify and characterize the practices in biting snake identification across the globe.

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Epidemiological studies of snakebite in humans that provide information on biting snake identification were systematically searched in Web of Science and Pubmed from inception to 2nd February 2019. This search was further extended by snowball search, hand searching literature reviews, and using Google Scholar. Two independent reviewers screened publications and charted the data.

Results
We analysed 150 publications reporting 33,827 snakebite cases across 35 countries. On average 70% of victims/bystanders spotted the snake responsible for the bite and 38% captured/killed it and brought it to the healthcare facility. This practice occurred in 30 countries with both fast-moving, active-foraging as well as more secretive snake species. Methods for identifying biting snakes included snake body examination, victim/bystander biting snake description, interpretation of clinical features, and laboratory tests. In nine publications, a
picture of the biting snake was taken and examined by snake experts. Snakes were identified at the species/genus level in only 18,065/33,827 (53%) snakebite cases. 106 misidentifications led to inadequate victim management. The 8,885 biting snakes captured and identified were from 149 species including 71 (48%) non-venomous species.

**Conclusion**

Snakebite victims and healthcare providers can play a central role in biting snake identification and novel approaches (e.g. photographing the snake, crowdsourcing) could help increase biting snake taxonomy collection to better understand snake ecology and snakebite epidemiology and ultimately improve snakebite management.

**Introduction**

An estimated 5.4 million snake bites occur globally every year. About half of these cause snakebite envenoming (SBE), killing 81,000–138,000 people and disabling 400,000 more in the poorest regions [1, 2]. In May 2019, the World Health Organization (WHO) launched a road map to halve these deaths and disabilities by 2030, particularly focusing on the development of antivenoms and on their adequate distribution in the most affected countries [3, 4]. For this, understanding what type of snakes and associated snake bites occur where is crucial, yet this depends first on the taxonomic identification (identification hereafter; i.e. family, genus and species) of these snakes [5–7]. At the clinical level, the identity of the biting snake (BSN) can help healthcare providers anticipate victims’ syndromes and support decision making when treating the patient (i.e. whether or not to administer antivenom or which type of antivenom) [8, 9]. This decision is important because not only are antivenoms effective against a limited number of venomous snakes but they have potentially lethal side effects such as fatal allergic reactions and should not be used to treat bites from non-venomous snakes. This is especially important in view of the scarcity and high costs of antivenom vials in many countries.

However, identifying the BSN is challenging due to the high diversity of snake species [10] in snakebite endemic countries (e.g. 310 snake species in India), and the limited herpetological knowledge of communities and healthcare providers confronted with snakebite. In rural areas, traditional healers are often the first to be consulted for snakebite at the community level [11] and they could play a role in BSN identification, yet this remains to be assessed. Different behaviours and practices exist across the world depending on the development of health systems, local culture and perception of snakes and snakebite, and snake diversity. There is no standardized protocol for identifying BSNs and recommended practices are often specific to certain regions. For instance, the WHO’s Regional Office for South-East Asia (2016) [12] recommends experts identify the BSN based on a photo (i.e. taken with a mobile phone) or the animal’s body, when killed by the victim or bystanders and brought to the health facility.

To our knowledge, no review has systematically explored the literature to identify and synthesize the nature and extent of information available on the practices and challenges in BSN identification across the world. The objective of this scoping review is to provide a global and comprehensive description of the diversity of behaviours and practices of communities and healthcare providers, and the implications of these, when confronted with snakebite and the need to identify BSNs. This review also assesses the capabilities of these communities and healthcare providers to identify the BSN, and the frequency and consequences of
misidentifications. Finally, it addresses aspects related to the BSNs, including their diversity and behaviour, and how this may influence their identification.

**Materials and methods**
We followed the scoping review methodology proposed by Arksey & O’Malley (2005) [13], Levac et al. (2010) [14], and Tricco et al. (2018) [15] (S1 File).

**Eligibility criteria**
Original epidemiological studies and clinical case report/series reporting snakebite cases in humans caused by wild snakes and including information on their taxonomic identification were considered. Studies from all geographical areas and publication dates were eligible.

**Search strategy**
*Web of Science* and *PubMed* were searched from inception to February 2, 2019 using the following key words: snakebite, snake bite, snake envenoming, snake envenomation, case, victim, event, patient, biting snake, culprit, offending snake, species, identif\(\text{\textsuperscript{a}}\), misidentif\(\text{\textsuperscript{a}}\), unidentif\(\text{\textsuperscript{a}}\), identity, and mistaking (see S1 Table for full search strategy). In addition to the database searches, we used extensive secondary search techniques, such as snowball search, hand searching literature reviews, and performing key word searches in Google Scholar. This secondary search was conducted in English, French, and Spanish by three of the authors (IB, SBM, AMD). With *PubMed*, we accessed primarily publications in the field of medicine and life sciences, while with *Web of Science* and Google Scholar we covered most scientific fields.

**Publication selection**
Searched publications were merged using citation software EndNote X7 and duplicates were removed. IB, an expert in the domain of snakebite, screened all the titles and abstracts and excluded those publications that did not match eligibility criteria. Eligible publications were read by IB and SBM, and their relevance was further assessed, particularly focusing on information pertaining to the BSN (i.e. number of snakes identified and methods used). A final set of publications was produced by discussion and consensus between IB and SBM. No quality assessment of the publications selected was made.

**Charting the data**
IB and SBM charted the data from selected publications independently. Their results were compared and discrepancies resolved through discussion and consensus. The variables extracted were: publication identifiers (authors, journal, year of publication, language); study characteristics (study design, country, setting, sample size); number of BSNs identified; number of victims that saw the BSN; number of BSNs captured or killed; taxonomic granularity of BSN identification (family, genus, or species); the way the BSNs were identified. We cross-referenced all common and scientific names of snakes reported in the publications with the Reptile Database [10] and kept track of changes in taxonomy where relevant. One of us (AMD) searched the literature for information on the activity time (diurnal/nocturnal/both), foraging strategy (active/passive/both), and general habitat (terrestrial, aquatic, arboreal, fossorial) of each species. Some species lacked species-specific information and their behaviour was extrapolated from those of congeners. We also gathered data on the number of snake species per country from the Reptile Database [10] and coded these as medically-important venomous snakes (MIVS) or not following the WHO. We used the pcor.test function in package ppcor.
(v. 1.1) in R (v. 3.5.1) to estimate partial correlation coefficients among the number of BSN species per country, the total number of snake species in that country, the total number of snake bites reported in publications from that country, and the MIVS status of the snake species.

Results

Selection and characteristics of publications

A total of 467 unique publications resulted from the initial search, and 150 of these were included in the review (Fig 1, S2 Table). These publications covered 35 countries on all continents (Table 1) and were mostly retrospective or prospective hospital-based epidemiological studies (76%), conducted in Asia (50%), published after 2000 (77%) in English (94%). In total,
33,827 snakebite cases were reported in these studies and the median number of cases per study was 90–91 (range 1–3,411).

### Spotting the BSN

Out of the total, twenty-three publications (15%) across 13 countries mentioned the number of victims that saw the BSN. In total, 2,723 victims out of 3,865 (70.5%) have seen the BSN (range 51.9% to 93.2% across studies) (Table 2). Factors associated with the circumstances/context of the bite were often described for those cases where the snake was not spotted. This includes, for example, bites that occurred at night, assumed to be caused by nocturnal snakes (e.g. *Trimeresurus* sp., *Bungarus* sp.) (e.g. Gabon, Hong Kong, Nepal, Saudi Arabia, Sri Lanka [16–20] or in habitats with tall grass and thick plantation vegetation (e.g. Papua New Guinea, Nepal, central hills of Sri Lanka [21–23]) or dense rain forest vegetation (e.g. Ecuador [24]).

### BSN captured/killed and brought to health facilities

A total of 114 (76%) publications in 30 countries described snakebite cases where victims or bystanders captured the BSN and brought it to the health facility (S2 Table). In 78 (68%) of these 114 publications and 24 countries, the BSN was killed. Globally, the BSN was captured/killed in 9,671/25,188 (38%) snakebite cases, but this practice varied among countries (Table 3). Cultural perceptions affected this behaviour. In Nepal, an Indian cobra (*Naja naja*) was not killed by the victim “in fear of revenge by its partner” [20]. In Sri Lanka “there may be a reluctance to capture or kill the animal because of fear or superstition” [44], and a snakebite victim “refrained from catching the snake due to religious ethics” [27]. In South Africa
In four publications, victims were bitten while attempting to kill a snake. This was the case for 53% and 100% of patients bitten on the fingers in two Australian studies [29, 30] and caused the death of an 80-year-old traditional healer in Cameroon [53] and a worker in Hong Kong [17].

**BSN identification methods**

From the methods section of selected publications, we extracted information on the way the BSNs were identified when victims reached a healthcare facility (S2 Table). One or a combination of the following methods were used:

i) examining the captured BSN brought to the healthcare facility (110 publications). The person who identified the BSN was not always reported. In 43 publications, and particularly in Brazil (n = 10), Australia (n = 7), Sri Lanka (n = 7), and India (n = 6), the identification was made by a snake expert. This occurred particularly for case report/case series to confirm unusual snakebite events [85, 87, 94] and for randomized controlled trials of antivenoms or epidemiological studies focusing on a particular snake species. The latter involves patients bitten by a specific snake species and therefore giving precise taxonomic attribution to the biting snake is key.

ii) verbal description of the BSN by victims/bystanders (52 publications). They described the colour (e.g. brown or black) or size (e.g. large) of the BSN. In some studies, photographs or preserved specimens in curated collections of local material were shown to victims or bystanders to assist in the identification. Several publications mentioned that a majority of patients were unable to recognize snake species based on photographs (e.g. [35, 45, 66, 110]). Victims claimed to have recognized the BSN in 16 publications.

iii) clinical features (26 publications). Distinctive clinical syndromes associated with bites by individual species have been defined and algorithms developed to infer the BSN species in India and Sri Lanka [44, 76, 111]. In Brazil, health care providers identified the BSN at the genus level (*Bothrops/Crotalus/Lachesis/Micrurus*) based on patients’ signs and symptoms [102, 112, 113]. In these studies, most patients were effectively treated, but two deaths occurred
(678,931),(973,970)
possibly caused by the use of non-specific antivenom according to the authors [113]. The practice of bringing the BSN to the health facility is uncommon in northeastern Brazil compared to other Brazilian regions [104, 113]. Two studies focusing on krait bites also took into account bite circumstances (i.e. bite at night while victims were asleep).

iv) laboratory methods (23 publications). Immunoassays (EIA, ELISA) that detect venom antigens of some snake species in victims’ blood were used in Australia, Bangladesh, Brazil, Ecuador, Myanmar, Sri Lanka, and Thailand mainly to retrospectively identify BSNs and for research purposes. A pilot study explored the use of molecular tools to identify snakes in Nepal [56].

v) examining a picture of the BSN (9 publications). This practice was reported in the US (n = 3), Morocco (n = 2), Malaysia (n = 1), Australia (n = 1), Colombia (n = 1) and Laos (n = 1). The picture of the BSN was taken by the victim/bystanders, some with a mobile phone, or by the medical staff when the dead snake was brought to the hospital. The picture was then sent to a herpetologist (Laos, USA) or a Poison Control Center (Colombia, Malaysia, Morocco, USA).

### Table 3. Geography and number of snakebite cases where the BSN was captured/killed by victims/bystanders.

| Geographical region | Country        | References          | Number of publications | Total snakebite cases | Number BSNs captured | BSN captured % |
|---------------------|----------------|---------------------|------------------------|-----------------------|----------------------|---------------|
| Africa              | Morocco        | [46, 47]            | 2                      | 905                   | 14                   | 1.5           |
|                     | Tanzania       | [48]                | 1                      | 85                    | 4                    | 4.7           |
|                     | Zimbabwe       | [32]                | 1                      | 250                   | 22                   | 8.8           |
|                     | South Africa   | [35, 49, 50]        | 4                      | 749                   | 98                   | 13.1          |
|                     | Nigeria        | [51, 52]            | 2                      | 103                   | 44                   | 42.7          |
|                     | Cameroon       | [33, 53, 54]        | 3                      | 118                   | 60                   | 50.8          |
| Asia                | Hong Kong      | [17]                | 1                      | 242                   | 2                    | 0.8           |
|                     | Bangladesh     | [55]                | 1                      | 484                   | 22                   | 4.5           |
|                     | Nepal          | [20, 25, 56]        | 4                      | 898                   | 74                   | 8.2           |
|                     | Taiwan         | [57, 58]            | 2                      | 71                    | 8                    | 11.3          |
|                     | Sri Lanka      | [23, 28, 44, 59–67] | 13                     | 8 677                 | 1 642                | 18.9          |
|                     | Laos           | [68, 69]            | 2                      | 179                   | 38                   | 21.2          |
|                     | Pakistan       | [70]                | 1                      | 90                    | 21                   | 23.3          |
|                     | India          | [37–40, 71–76]      | 10                     | 775                   | 189                  | 24.4          |
|                     | Saudi Arabia   | [19, 77]            | 2                      | 98                    | 26                   | 26.5          |
|                     | Thailand       | [78–82]             | 5                      | 378                   | 102                  | 27.0          |
|                     | Myanmar        | [83, 84]            | 2                      | 659                   | 229                  | 34.7          |
| Australo-Papua      | Papua New Guinea | [21]            | 1                      | 335                   | 10                   | 3.0           |
|                     | Australia      | [29, 85–90]         | 7                      | 667                   | 181                  | 27.1          |
| Central and South America | Peru      | [91]                | 1                      | 170                   | 10                   | 5.9           |
|                     | Ecuador        | [92]                | 1                      | 221                   | 29                   | 13.1          |
|                     | Brazil         | [93–106]            | 14                     | 1 133                 | 214                  | 18.9          |
|                     | Colombia       | [41]                | 1                      | 485                   | 232                  | 47.8          |
| Europe              | Croatia        | [42]                | 1                      | 542                   | 49                   | 9.0           |
|                     | Greece         | [43]                | 1                      | 147                   | 37                   | 25.2          |
| North America       | USA            | [107, 108]          | 2                      | 176                   | 27                   | 15.3          |
|                     | Puerto Rico    | [109]               | 1                      | 6                     | 5                    | 83.3          |
| Total/Average       |                |                     | 86                     | 18 643                | 3 389                | 18.2          |

*This includes only publications where number of BSN captured/killed was available and excludes studies whose inclusion criteria required BSN to be brought to the hospital (13 publications) and countries with only one study reporting only a single snakebite case (i.e. case report) (2 publications).

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BSNs were identified at the species or genus level in 18,065 out of 33,827 snakebite cases (53%) (S2 Table).

Capability of victims and healthcare providers to identify snakes

**Victims/bystanders.** In nine studies, victims claimed they could identify the BSN and reported its common or local name (Table 4). In a Bangladeshi hospital, most snakebite victims were too distressed to describe the BSN and often misidentified it even when it was brought to the health facility [55]. Victims may not know the name of the snake [24] or the diversity of vernacular names given to a single snake species and/or taxonomic synonymies generate confusion for doctors (e.g. in the Brazilian Amazon [103, 112, 114]). In South Africa the word ‘mamba’ is often used by the local population to mean ‘snake’ of any species [50]. A survey of 150 inhabitants in southern Nepal showed that respondents were generally unable to identify different snake species [20]. In many parts of the world, authors considered snake identification by victims too unreliable to assist in routine snakebite management or in clinical snakebite research [24, 28, 66, 110].

**Healthcare providers.** The identity and credentials of the person doing the identification of BSN brought to health facility was often not reported. This limits our assessment of healthcare provider capability in identifying snakes. In three studies in India, Sri Lanka, and Thailand, experts systematically re-examined dead snakes initially identified by hospital personnel and misidentifications were reported in respectively 17/44, 51/860, and 27/1631 cases [44, 117, 118]. In the US, pictures of the BSN were sent to a Poison Control Center and identification by a snake expert was compared to that of healthcare providers. Healthcare accuracy for copperhead (*Agkistrodon contortrix*) and cottonmouth (*A. piscivorus*) identifications was respectively 68% and 74% [119]. Many authors highlighted the lack of training of healthcare providers in identifying biting species including in Brazil, India, Nepal, Singapore, South Africa, and Thailand [34, 45, 56, 97, 113, 117, 118, 120, 121].

**BSN misidentifications**

The BSNs were misidentified in 106 snakebite cases in Australia (n = 3), Brazil (n = 10), Hong Kong (n = 1), India (n = 6), Malaysia (n = 1), Sri Lanka (n = 54), and Thailand (n = 31). The consequences for the victims are detailed in Table 5 according to three scenarios. Most
### Table 5. Cases of BSN misidentification published in the literature.

#### Scenario 1: The BSN is venomous but misidentified as another venomous snake

| Country     | References | Number of misidentified BSNs | Initial identification (incorrect) | Person who did the incorrect identification* | Final identification (correct) | Person who did the correct identification* | Consequences for the victim(s) |
|-------------|------------|------------------------------|-----------------------------------|---------------------------------------------|---------------------------------|-------------------------------------------|---------------------------------|
| Australia   | [30]       | 1                            | *Pseudonaja nuchalis*             | Park ranger                                 | *Notechis ater*                 | SVDK at hospital                           | Treated with Brown snake (*Pseudonaja sp*) antivenom and then Tiger snake (*Notechis sp*) antivenom. The 13-year old girl required prolonged ventilation and 53-day stay at hospital. |
| Australia   | [86]       | 1                            | *Pseudochis australis*            | Other patients at hospital                  | *Pseudonaja nuchalis*           | Flying Doctor at hospital                  | Treated with Black snake (*Pseudochis sp*) antivenom and then Brown snake (*Pseudonaja sp*) antivenom 7 hours after the bite. The patient died due to cerebral trauma (the patient had collapsed to the ground) aggravated by coagulation defect. |
| Brazil      | [122]      | 1                            | Viperidae                         | NR                                          | *Crotalus durissus terrificus*  | Physician expert in toxicology            | Treated with antithrombotic serum and then intravenous crotalid antivenom. The patient remained with a severe behavioral and cognitive impairment. |
| Hong Kong   | [17]       | 1                            | *Ophiophagus hannah*             | Physician at hospital & Hong Kong Government Agriculture and Fisheries Department | *Naja naja*                     | NR                                        | Below elbow amputation and death. Antivenom not administered due to uncertainty in snake species. |
| India       | [40]       | 1                            | *Echis ophiurus*                  | A colleague                                  | *Macrovipera lebetina*          | Experienced herpetologist                | Inappropriate treatment with serum institute of India polyvalent* that does not cover M. Lebetina, finger amputation. |
| India       | [117]      | 5                            | *Echis carinatus*                 | Hospital staff                               | *Hypnale hypnale*               | Snake experts                             | Inappropriate treatment with Indian polyvalent antivenom that does not cover *H. Hypnale* (2/3 developed anaphylactic antivenom reaction). |
| Sri Lanka   | [59]       | 1                            | *Hypnale hypnale*                | Native physician                             | *Daboia russelii*               | NR, at hospital                           | Delayed treatment with Indian polyvalent antivenom but patient died probably due to herniation of brain stem. |
| Sri Lanka   | [44]       | 36                           | *Daboia russelii*                 | Hospital staff                               | *Hypnale hypnale*               | Snake experts                             | Unnecessary use of antivenom. |
| Thailand    | [78]       | 8                            | *Bungarus fasciatus*              | Medical staff                                | *Bungarus candidus*             | Snake experts                             | Inappropriate treatment with *Bungarus fasciatus* antivenom. The patients died. |
| Thailand    | [79]       | 1                            | *Naja kaouthia*                   | Assumption by the victim (in the dark)       | *Bungarus fasciatus*            | ELISA confirmation                        | Inappropriate treatment with monospecific cobra antivenom. The patient died. |
| Thailand    | [118]      | 5                            | *Bungarus fasciatus*              | Hospital staff                               | *Bungarus candidus*             | Snake experts                             | Inappropriate treatment with *Bungarus fasciatus* antivenom. |

#### Scenario 2: The BSN is non or mildly venomous (opisthoglyphous) but identified as a venomous snake

| Country     | References | Number of misidentified BSNs | Initial identification (incorrect) | Person who did the incorrect identification* | Final identification (correct) | Person who did the correct identification* | Consequences for the victim(s) |
|-------------|------------|------------------------------|-----------------------------------|---------------------------------------------|---------------------------------|-------------------------------------------|---------------------------------|
| Australia   | [85]       | 1                            | Black snake the family & SVDK     | *Denisonia maculata*                        | Snake Experts                   | Inappropriate treatment with Australian Black Snake (*Pseudochis sp*) antivenom. |
| Brazil      | [123]      | 4                            | Bothrops sp.                      | Medical staff                                | *Tomodon dorsatus*              | Laboratório de Herpetologia and the Laboratório Especial de Coleções Zoológicas of Butantan Institute. | Inappropriate treatment with Bothrops antivenom. |
| Brazil      | [97]       | 1                            | Bothrops sp.                      | Medical staff                                | *Philodryas patagoniensis*      | NR                                        | Inappropriate treatment with Bothrops antivenom. |
| Brazil      | [94]       | 1                            | Bothrops sp. / clinical signs     | Medical staff / clinical signs               | *Glossa delta plumbea*          | Centra de Estudos e Pesquisas Biológicas at Universidade Católica de Goiás | Inappropriate treatment with Bothrops antivenom. |
| Brazil      | [124]      | 1                            | Bothrops sp.                      | NR                                           | *Drymarcon corais*              | NR                                        | Inappropriate treatment with Bothrops antivenom, nearly died of severe anaphylaxis. |
| Brazil      | [124]      | 1                            | Bothrops sp.                      | NR                                           | *Sibynomorphus mikanii*         | NR                                        | Inappropriate treatment with Bothrops antivenom, no side effect. |

(Continued)
### Table 5. (Continued)

| Country      | References | Number of misidentified BSNs | Initial identification (incorrect) | Person who did the incorrect identification* | Final identification (correct) | Person who did the correct identification* | Consequences for the victim(s) |
|--------------|------------|-----------------------------|-----------------------------------|---------------------------------------------|---------------------------------|----------------------------------|---------------------------------|
| Malaysia     | [125]      | 1                           | Bungarus Sp. / description of a photo of the snake | Chrysopelea pelias Snake Experts | Inappropriate treatment with Indian polyvalent antivenom |
| Sri Lanka    | [64]       | 1                           | Echis carinatus                   | Hospital staff | Boiga trigonata Snake expert / Faculty of Medicine, Peradeniya | NR |
| Sri Lanka    | [44]       | 2                           | Hypnale hypnale                  | Hospital staff | Boiga ceylonensis / B. trigonata Snake experts | Unnecessary use of antivenom |
| Sri Lanka    | [44]       | 3                           | Daboia russelli                  | Hospital staff | Boiga ceylonensis / B. trigonata Snake experts | Unnecessary use of antivenom |
| Sri Lanka    | [44]       | 1                           | Echis carinatus                  | Hospital staff | Boiga ceylonensis / B. trigonata Snake experts | Unnecessary use of antivenom |
| Sri Lanka    | [44]       | 2                           | Echis carinatus                  | Hospital staff | Pythons Snake experts | Unnecessary use of antivenom |
| Sri Lanka    | [44]       | 5                           | Bungurus caeruleus               | Hospital staff | Lycodon aulicus / L. striatus sinhalayus Snake experts | Unnecessary use of antivenom |
| Sri Lanka    | [44]       | 2                           | Cobras                           | Hospital staff | Rat snakes Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 2                           | Calloselasma rhodostoma          | Hospital staff | Oligodon dorsolateralis Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 1                           | Daboia russelli                  | Hospital staff | Oligodon cyclurus Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 1                           | Calloselasma rhodostoma          | Hospital staff | Oligodon cyclurus Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 7                           | Daboia russelli                  | Hospital staff | Boiga multomaculata Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 1                           | Bungurus candidus                 | Hospital staff | Lycodon loenesis Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 1                           | Calloselasma rhodostoma          | Hospital staff | Bhabrops subminiatus Snake experts | Unnecessary use of antivenom |
| Thailand     | [118]      | 4                           | B. fasciatus / B. candidus       | Hospital staff | Dryocalamus divisori Snake experts | Unnecessary use of antivenom |

**Scenario 3: The BSN is venomous but identified as non-venomous**

| Country   | References | Number of misidentified BSNs | Initial identification (incorrect) | Person who did the incorrect identification* | Final identification (correct) | Person who did the correct identification* | Consequences for the victim(s) |
|-----------|------------|-----------------------------|-----------------------------------|---------------------------------------------|---------------------------------|----------------------------------|---------------------------------|
| Brazil    | [98]       | 1                           | Nonpoisonous                      | Healthcare provider | Bothrops jararacussu NR | Delayed treatment with anti-Bothrops serum, intracranial bleeding and gradual improvement |
| Sri Lanka | [60]       | 1                           | Lycodon aulicus                   | Doctor | Bungurus caeruleus Identified by expert after patient death | Delayed administration of Indian polyvalent anti-venom, death 46 hours after the bite |

*a Identification done by examining the snake unless otherwise specified

*b Indian polyvalent antivenom is raised against the venom of B. caeruleus, Daboia russelli, Echis carinatus, and N. naja (the so-called Big Four).

NR: Not Reported

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frequently, a venomous species was confused with another venomous species or a non or mildly venomous (opisthoglyphous) species was misidentified as a venomous snake.

**Diversity of captured/killed BSN**

A total of 8,885 BSNs from 149 species in 12 families were captured and identified. Of these, 6,750 BSNs were identified to species, 2,082 to genus, and 53 as "non-venomous". In total, 7,628 individual snakes of 69 species were MIVS, 1,205 individuals of 71 species were non-venomous, and 52 individuals of 9 species were potentially dangerous but understudied species (species that lack specific data on clinical symptoms or venom toxicity but which are closely related to dangerous snakes and possess fangs and venom glands (see [126]) (Table 6 and S3 Table). The 149 species included 40 species in the family Viperidae, 35 species in the family Elapidae, 49 species in the family Colubridae, 4 species in the family Lamprophiidae, and 21 species from 8 other families (Acrochordidae, Boidae, Cylindrophiidae, Homalopsidae, Pareidae, Pythonidae, Typhlopidae, Xenopeltidae; S3 Table), as well as one amphisbaenid lizard (Amphisbaena mertensii)[101] and one serpentine amphibian (caecilian [118]) (not included in snake totals above). Of these 149 snake species, 32 were diurnal, 76 were nocturnal, and 41 were or could be active throughout the day, depending on the season. A total of 84 species were active foragers, 45 were ambush predators, 14 used both strategies, and 6 were unknown. General habitat use of 26 species was arboreal, 7 fossorial, 22 aquatic or semi-aquatic, and 94 were primarily terrestrial, with 4 of these partially aquatic, 5 partially arboreal, and 7 partially fossorial (S4 Table).

Within a country, the total number of snake bites across all publications was positively correlated with the number of species of BSNs reported (Panel A in S1 Fig; PPC = 0.55, p < 0.001), especially among non-venomous snakes, whereas the number of snake species per country was more weakly correlated with the number of species of BSNs reported (Panel B in S1 Fig; PPC = 0.36, p = 0.04).

A substantial number of snakes—1,859 (21%) individuals of 22 species—were reported in the literature using only the common name. Of those reported using the scientific name, 20 species (92 individuals) had been moved to another genus since the time of publication, 10 species (241 individuals) had experienced other taxonomic changes (splits or lumps) (e.g. Echis ocellatus in Cameroon has been renamed *E. romani* [127]), and the names of 3 species (6 individuals) contained minor misspellings as reported (S3 Table).

**Discussion**

Based on a final selection of 150 publications from across the world, this first scoping review on BSN identification practices of communities and healthcare providers confronted with snakebite shows that: (I) BSN identification is important for snakebite epidemiology and clinical management yet there is a diversity of practices depending on cultural, ecological and healthcare contexts and there are no official standards (II) the majority of victims see the BSN but they are unreliable in their identification (III) the practice of capturing or killing the BSN occurs in all continents, especially in Asian countries with a diversity of snakes, and (IV) healthcare providers struggle to identify a BSN presented in the health facility and misidentifications occur.

Snakebite victims/bystanders in many snakebite endemic countries are aware of the importance of BSN identification and can play an important role. We found that on average 70% of victims/bystanders spotted the BSN and 38% managed to capture or kill it and brought it to the health facility for identification. Although this is a dangerous practice (i.e. due to the risk of secondary bites [17, 29, 30, 53, 128–133]), it occurs worldwide but particularly in Asia (e.g.
Table 6. Diversity and abundance of BSNs captured/killed and identified.

| Geographical region | MIVS (n) | Non-venomous snakes (n) | Potentially dangerous snakes (n) |
|---------------------|----------|-------------------------|----------------------------------|
| **Africa**          |          |                         |                                  |
| Atractaspis bibronii (22) | Afromytrops schlegeli (1) | Causus defilippi (8) |
| Bitis arietans (8) | Buceedon capensis (2) | Causus rhombia (9) |
| Bitis atropos (1) | Crotaphopeltis hotamboeia (3) | |
| Daboia aspis (3) | Dusaphis scabra (1) | |
| Dendroaspis polyplei (12) | Phlotothamus spp. (2) | |
| Echis roman (103) | | |
| Hemachatus haemachatus (1) | | |
| Naja annulifera (3) | | |
| Naja melanoleuca (1) | | |
| Naja mossambica (18) | | |
| **Asia**            |          |                         |                                  |
| Bitis arietans (1) | Acrochordus javanicus (NR) | |
| Bungurus caudatus (623) | Ahaetulla nasuta (10) | |
| Bungurus candidus (17) | Ahaetulla prasina (NR) | |
| Bungurus fasciatus (6) | Argyvasia fasciulata (1) | |
| Bungurus hardas (3) | Atreitum schistosum (1) | |
| Bungurus multicorn (6) | Boiga ceylonensis (10) | |
| Bungurus niger (1) | Boiga cyanea (NR) | |
| Bungurus spp. (20) | Boiga cyanod (NR) | |
| Calloselasma rhodostoma (448) | Boiga forstenii (8) | |
| Cerastes cerastes (7) | Boiga multimaculata (NR) | |
| Cerastes gaspapelli (7) | Boiga sp. (4) | |
| Cerastes vipera (1) | Boiga trigonata (4) | |
| Daboia russelli (985) | Chrysopelea ornata (1) | |
| Daboia siamensis (383) | Chrysopelea pelias (1) | |
| Echis carinatus (229) | Coelognathus helena (5) | |
| Echis coloratus (5) | Coelognathus radiatus (4) | |
| Hydrophis cyanocinctus (2) | Cylindrophis maculatus (1) | |
| Hydrophis platyrhincus (2) | Cylindrophis rhaffsi (NR) | |
| Hydrophis schistosus (2) | Enhydris enhydris (NR) | |
| Hydrophis spiralis (1) | Enhydris jagore (NR) | |
| Hypnale hypnale (502) | Gonyosoma oxycephalum (NR) | |
| Hypnale nepa (5) | Homaloias buccata (NR) | |
| Hypnale spp. (190) | Hypsicopus plumbeus (NR) | |
| Hypnale zara (17) | Indotyphlops binominus (NR) | |
| Macrovipera lebetina (1) | Lycodon aulicus (57) | |
| Naja atra (1) | Lycodon buphæus (NR) | |
| Naja kassabia (108) | Lycodon daviromeni (NR) | |
| Naja najia (328) | Lycodon lusens (NR) | |
| Naja siamensis (118) | Lycodon spp. (3) | |
| Naja sp. (8) | Lycodon striatus (13) | |
| Naja somatoma (1) | Malpolon maletia (4) | |
| Orodips monticola (1) | Malpolon maliens (53) | |
| Rhabdophis subminatus (5) | Oligodon arnensis (7) | |
| Trimeresurus albolabris (344) | Oligodon cypriformis (NR) | |
| Trimeresurus albolabris (20) | Oligodon spp. (7) | |
| Trimeresurus kamburensis (1) | Oligodon taeniatus (NR) | |
| Trimeresurus macrops (23) | Oligodon taeniolatus (2) | |
| Trimeresurus malabaricus (26) | Pareas carinatus (NR) | |
| Trimeresurus pneupaxiangularis (1) | Psammodactylus pulverulentus (2) | |
| Trimeresurus spp. (36) | Ptyas mucosa (13) | |
| Trimeresurus subminatus (19) | Ptyas spp. (2) | |
| Trimeresurus trigoniceps (19) | Ptyas spp. (2) | |
| Trimeresurus vittatus (2) | Ptyas mutica (2) | |
| Walrinius legg (1) | Subheziore bocoueri (NR) | |
| Xenochrophis asperimutus (2) | | |
| Xenochrophis flavomaculatus (1) | | |
| Xenochrophis flavomaculatus (NR) | | |
| Xenochrophis piscator (12) | | |
| Xenochrophis spp. (2) | | |
| Xenopeltis unicolor (NR) | | |

(Continued)
Table 6. (Continued)

| Geographical region | MIYS (n) | Non-venomous snakes (n) | Potentially dangerous snakes (n) |
|---------------------|---------|------------------------|-------------------------------|
| Australo-papua      | Acanthophis sp. (13) | Antaresia childreni (12) | Bothrops irregularis (3) |
|                     | Notechis scutatus (NR) | Dendrelaphis punctulatus (2) | Cryptopsis pallelae (4) |
|                     | Oxyuranus microlepidotus (1) | Fordia leucobalata (1) | Demansia olivacea (5) |
|                     | Oxyuranus scutatus (1) | Liias fascia (9) | Demansia sp. (17) |
|                     | Pseudochis australis (18) | Liias olivacea (4) | Denisonia maculata (1) |
|                     | Pseudochis guttatus (1) | Morelia spilota (8) | Pseudovermata ornata (3) |
|                     | Pseudonaja nuchalis (13) | Pseudovermata pylepis (1) | Hemiadina signata (2) |
|                     | Pseudonaja sp. (20) | Stegometus australis (10) | Tropidolepis mairi (2) |
| Central and South America | Bothrops alternatus (6) | Apostolepis asimilis (1) | |
|                     | Bothrops atrox (45) | Boa constrictor (2) | |
|                     | Bothrops bilineatus (12) | Cebus plumisc (1) | |
|                     | Bothrops erythromelas (35) | Dipaspis mikanii (6) | |
|                     | Bothrops jararaca (779) | Drymarchon corais (1) | |
|                     | Bothrops jaracazus (1) | Erythrolamprus poecilogyrus (2) | |
|                     | Bothrops mossiens (70) | Erythrolamprus spp. (1) | |
|                     | Bothrops neuwiedi (30) | Functes murinus (1) | |
|                     | Bothrops sp. (13) | Oxyrhynus trigeminus (3) | |
|                     | Bothrops taeniatus (2) | Palaeophis bifossatus (3) | |
|                     | Crotalus durissus (14) | Philodryas matthewsensis (1) | |
|                     | Micrurus frontalis (2) | Philodryas ophirani (4) | |
|                     | Micrurus laticinctus (2) | Philodryas patagoniensis (300) | |
|                     | Micrurus spp. (2) | Symphis rhinostoma (2) | |
|                     | | Tomodon dorsatus (86) | |
|                     | | Xenodon merremi (3) | |
| Europe              | Vipera ammodytes (83) | | |
|                     | Vipera berus (3) | | |
| North America       | Agkistrodon contortrix (26) | Borkhniophis portoricensis (5) | |
|                     | Crotalus cerastes (1) | | |

In this table, snake scientific names follow the taxonomy of the Reptile Database as of October, 2019 [10].

NR: Not reported

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Myanmar, India, and Sri Lanka). Communities in these snakebite endemic countries believe that bringing the BSN to the health facility for identification is essential for treating the victim [11, 134]. Myths and beliefs regarding snakes are present in many societies (e.g. [135, 136]) and could prevent victims/bystanders from killing the snake, yet the influence of these cultural aspects on BSN identification was rarely addressed in the selected publications and would deserve more research. Traditional healers may have a good knowledge on the type of snakes in their local environment, their distribution and behaviours. Yet, in this review, we did not find articles that report their role in BSN identification. Further studies could explore if their snakebite remedies are species-specific and assess their knowledge of local snake diversity.

Overall, traditional healers can act as partners with healthcare providers promoting prompt referral to health facilities in case of snake bites inflicted by venomous snakes.

Photographing the BSN (e.g. with mobile phones) is an emerging practice in snakebite endemic countries worldwide. This was described for Australia, Colombia, Laos, Malaysia, Morocco, and the US, where snake experts are involved in snake photo identification (e.g. at Poison Control Center). This procedure is recommended by the WHO [12], the Snakebite Healing and Education Society in India [137] and the African Snakebite Institute [138] among others and it is certainly less dangerous than killing or capturing the snake. Even fast-moving, active-foraging snakes (e.g. *Demansia, Dendroaspis, Naja*) and secretive, fossorial species (e.g.
Atractaspis, Micrurus, Xenopeltis) were captured/killed in our review and could have been photographed instead. The advantages of using photos for BSN identification are numerous. Firstly, photos are less subject to interpretations and thus more reliable than victim descriptions. We showed that victims in general described the BSN colour or size, which is of limited value for the identification, and their identification of the BSN is often unreliable even with the assistance of preserved specimens or local snake photographs. Secondly, photos can be rapidly shared between victims, healthcare providers, and snake biologists, accelerating the identification process and improving its accuracy. Snake identification services based on snake photos have been developed in India [139], Sri Lanka [140], or Thailand [141] and are provided by poison control centres in the US [142] and Colombia [143]. This could be developed in other countries and, in low-resource settings, snake identification could be even crowdsourced involving online communities of snake experts (e.g. open biodiversity platforms like HerpMapper, iNaturalist, or snake identification Facebook groups) [144, 145]. Thirdly, photos can be securely and indefinitely stored building a digital dataset. Besides the ecological and epidemiological value of such a dataset, it could serve to train healthcare providers and machine learning algorithms in snake classification [146, 147].

BSN identification is particularly important in certain SBE endemic regions where monovalent or bi-/trivalent antivenoms are the only affordable treatment. This is the case, for example, in Myanmar, Taiwan, and Thailand in East and South East Asia, but also in many Sub-Saharan Africa regions where Echis snake bites are prevalent [12]. Besides this, BSN identification is important for ecological and epidemiological purposes and subsequently for an optimal antivenom coverage [146] (e.g. Hump-nosed viper (Hypnale hypnale) causes frequent bites with morbidity and mortality in Sri Lanka and southwest India but currently lacks effective antivenom) [117, 148]. Healthcare providers should be encouraged to photograph and archive images of BSN brought to health facilities to help build national or regional BSN photo repositories for further epidemiological studies.

BSN identification could also complement syndromic approach to snakebite [36, 44, 76], particularly in those cases where symptoms caused by venoms of different snake species overlap (e.g. Russell’s viper causes paralytic signs suggesting elapid neurotoxicity in Sri Lanka) [12].

Snake species diversity and the fact that bites from some “non-venomous” snakes can cause signs of envenoming (e.g. Clelia plumbea and Philodryas ofersi in Brazil) [64, 94, 124, 126] complicate snakebite clinical management and have led to snake misidentifications. Snake identification can be challenging for communities and healthcare providers (i.e. diversity of snakes, mimicry). In two villages in rural Tanzania, most of the respondents to a survey could not precisely differentiate between venomous and non-venomous snakes [149]. In a cross-sectional survey of 119 healthcare providers in Laos, 86 participants (72.3%) had inadequate knowledge of snake identification [150]. Although healthcare providers could be trained to recognize locally prevalent snake species (e.g. at the Damak Snakebite Treatment Center in Nepal [151]), reinforcing the collaboration between communities at risk, healthcare providers and snake experts could be a more effective approach to increase the number of BSNs correctly identified.

With this review, we retrospectively collated all the species names of the 8,885 BSN that were captured and identified and we have built a first extensive global list of snakes having bitten humans. This list includes 69 MIVS and 71 non-venomous snake species, as well as nine that are potentially dangerous but understudied species [126]. MIVS species are already listed by the WHO (2010) [152]. This review extends this list to non-venomous snakes, although there is significant bias in which non-venomous snakes are brought to health facilities and the number of non-venomous BSN species was strongly correlated with the number of snake
bites, suggesting that many more species of non-venomous BSNs exist and a limit has not been reached within epidemiological data. Nevertheless, this confirms that many snake bites globally are caused by non-venomous snakes, although victims may not always realize this immediately or at all.

Limitations of this study

Many publications had to be excluded from the review because the way the BSN identification was done was unclear or not reported even though the BSN genus or species was mentioned. The list of BSN species we built is limited to the publications we retrieved and included in the review. It could have been extended, had more publications met the eligibility criteria. We recommend that future epidemiological studies on snakebite clearly describe the method(s) used to identify the BSN, including the credentials of the person who did the identification and their confidence in the identification. We used key words related to ‘identification’ to specifically gather snakebite publications describing snake identification, although we may have missed relevant publications that do not mention these keywords or that are published in other languages (e.g. Russian, Chinese). Information on snake identification was reported in an inconsistent and fragmented manner. We managed this problem by involving two authors in data extraction and comparing data collected until a consensus was reached. Some publications, particularly prospective studies, applied specific inclusion criteria (e.g. a specific snake species, dead snake brought to hospital). These were excluded from analyses where they were sources of bias (e.g. calculation of proportion of captured snakes). The selected publications are mainly hospital-based studies with very few community-based studies. We missed the behaviour of snakebite victims who did not seek treatment at hospitals because of asymptomatic bite or use of traditional healers. Snake taxonomy is constantly changing and an average of 30 new species per year have been described since the year 2000. Although we were always able to definitively decide which species/genera were meant, rare or newly-described species may be missed by all identification methodologies, and taxonomic instability further complicates an already-challenging situation [153, 154]. Finally, we cannot account for situations where snake misidentification was never discovered and incorrect names have been published, which seems likely in a subset of cases.

Conclusion

This global scoping review showed that BSN identification in snakebite endemic countries includes a diversity of methods and practices: capturing/killing the BSN and examination of its body, description of the BSN by victim/bystanders, interpretation of clinical features, laboratory tests, and photographing the BSN. The capacity of snakebite victims, bystanders and healthcare providers to spot and identify the BSN is context-specific and depends on circumstances of the bite, the local snake diversity, and their own knowledge of local snakes. BSN misidentifications occur and lead to inappropriate management of the victims. The influence of cultural perceptions about snakes and role of traditional healers in snake identification are largely unexplored in the literature and urges for further research. Victims/bystanders managed to capture a diversity of BSNs, including fast-moving nervous snakes. This is dangerous and not recommended, and photographing the snake could be an alternative option [12]. We provided the first evidence-based list of venomous and non-venomous snake species involved in bites to humans. This list could be further extended by implementing snake identification as part of the clinical practice. Such a systematic collection of the taxonomy of BSNs at the global level is of considerable interest to better understand snake ecology and snakebite epidemiology and ultimately improve SBE management.
Supporting information

S1 Table. Search strategy syntax for each bibliographic database.
(DOCX)

S2 Table. Dataset—Scoping review identification.
(XLSX)

S3 Table. Taxonomic identification of captured biting snakes.
(XLSX)

S4 Table. Behaviour and ecology of captured biting snakes.
(XLSX)

S1 Fig. Correlation between number of snake bites and occurring snake species with number of biting snake species. Correlations between A) the total number of snake bites across all publications and B) the total number of snake species occurring in a country with the number of species of BSNs reported. Each dot represents a country. Thailand is missing from the non-venomous panel in part A because quantitative data are not given for non-venomous BSNs in [31]. MIVS = medically-important venomous snakes.
(TIFF)

S1 File. PRISMA-ScR checklist.
(PDF)

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References

1. Gutiérrez JM, Calvete JJ, Habib AG, Harrison RA, Williams DJ, Warrell DA. Snakebite envenoming. Nat Rev Dis Primers. 2017; 3:17063. https://doi.org/10.1038/nrdp.2017.63 PMID: 28905944

2. WHO. Snakebite envenoming—Key Facts 2019 [cited 5 November 2019]. Available from: https://www.who.int/news-room/fact-sheets/detail/snakebite-envenoming

3. Williams DJ, Faiz MA, Abela-Ridder B, Ainsworth S, Bullone TC, Nickerson AD, et al. Strategy for a globally coordinated response to a priority neglected tropical disease: Snakebite envenoming. PLoS Negl Trop Dis. 2019; 13(2):e0007059. https://doi.org/10.1371/journal.pntd.0007059 PMID: 30789906

4. WHO. Snakebite envenoming—A strategy for prevention and control. 2019. Available from: https://www.who.int/snakebites/resources/9789241515641/en/

5. Isbister G. Snake antivenom research: the importance of case definition. Emerg Med J. 2005; 22(6):399–400. https://doi.org/10.1136/emj.2004.022251 PMID: 15911943

6. Williams DJ, Habib AG, Warrell DA. Clinical studies of the effectiveness and safety of antivenoms. Toxicon. 2018; 150:1–10. Epub 2018/05/11. https://doi.org/10.1016/j.toxicon.2018.05.001 PMID: 29746978.

7. Ralph R, Sharma SK, Faiz MA, Ribeiro I, Rijal S, Chappuis F, et al. The timing is right to end snakebite deaths in South Asia. BMJ. 2019; 364:k5317. https://doi.org/10.1136/bmj.k5317 PMID: 30670457

8. Alirol E, Sharma SK, Bawaskar HS, Kuch U, Chappuis F. Snake bite in South Asia: a review. PLoS Negl Trop Dis. 2010; 4(1):e603. Epub 2010/02/04. https://doi.org/10.1371/journal.pntd.0000603 PMID: 20126271; PubMed Central PMCID: PMC2811174.

9. Williams HF, Layfield HJ, Vallance T, Patel K, Bicknell AB, Trim SA, et al. The Urgent Need to Develop Novel Strategies for the Diagnosis and Treatment of Snakebites. Toxins (Basel). 2019; 11(6):363.

10. Uetz. The Reptile Database 2019 [cited 5 November 2019]. Available from: http://reptile-database.reptarium.cz

11. Schioldann E, Mahmood MA, Kyaw MM, Halliday D, Thwin KT, Chit NN, et al. Why snakebite patients in Myanmar seek traditional healers despite availability of biomedical care at hospitals? Community perspectives on reasons. PLoS Negl Trop Dis. 2018; 12(2):e0006299. https://doi.org/10.1371/journal.pntd.0006299 PMID: 29489824

12. WHO. Regional Office for South-East Asia, Guidelines for the management of snakebite 2nd edition 2016. Available from: https://www.who.int/snakebites/resources/9789290225300/en/

13. Arksey H, O’Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005; 8(1):19–32.

14. Levac D, Colquhoun H, O’Brien KK. Scoping studies: advancing the methodology. Implementation Sci. 2010; 5(1):89.

15. Tricco AC, Lillie E, Zarin W, O’Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018; 169(7):467–73. https://doi.org/10.7326/M18-0850 PMID: 30178033

16. Tchoua R, Raouf A, Ogandaga A, Mouloun gui C, Mbanga Loussou J, Kombila NND, et al. Analyse des envenimati ons par morsures de serpent au Gabon. Bull Soc Pathol Exot. 2002; 95(3):188–90. PMID: 12404868

17. Cockram CS, Chan JC, Chow KY. Bites by the white-lipped pit viper (Trimeresurus albolabris) and other species in Hong Kong. A survey of 4 years' experience at the Prince of Wales Hospital. J Trop Med Hyg. 1990; 93(2):79–86. Epub 1990/04/01. PMID: 2325197.

18. Ariaratnam CA, Sherriff MHR, David R, Theakston G, Warrell DA. Distinctive epidemiologic and clinical features of common krait (Bungarus caeruleus) bites in Sri Lanka. Ann J Trop Med Hyg. 2008; 79(3):458–62. https://doi.org/10.4269/ajtmh.2008.79.458 WOS:000259307800027 PMID: 18784244

19. Al Durhim H, Al Husaini M, Bin Salih S, Hassan I, Harakali M, Al Hajjaj A. Snake bite envenomation: experience at King Abdulaziz Medical City, Riyadh. 2010. East Mediterr Health J Apr; 16 (4):438–41

20. Pandey DP, Vohra R, Stalcup P, Shrestha BR. A season of snakebite envenomation: presentation patterns, timing of care, anti-venom use, and case fatality rates from a hospital of southcentral Nepal. J Venom Res. 2016; 7:1–9. MEDLINE:26998219. PMID: 26998219

21. Lalilo D, Trevett A, Sawyer A, Naraqi S, Theakston R, Warrell D. The epidemiology of snake bite in Central Province and National Capital District, Papua New Guinea. Trans R Soc Trop Med Hyg. 1995; 89(2):178–82. https://doi.org/10.1016/0035-9203(95)00485-9 PMID: 7778143
22. Hansdak SG, Lallar KS, Pokharel P, Shyangpa P, Karki P, Koirala S. A clinico-epidemiological study of snake bite in Nepal. Trop Doct. 1998; 28(4):223–6. Epub 1998/11/06. https://doi.org/10.1177/00494759802800412 PMID: 9803844.

23. Kularatne K, Budagoda S, Maduwage K, Naser K, Kumarasiri R, Kularatne S. Parallels between Russell’s viper (Daboia russelli) and hump-nosed viper (Hypnale species) bites in the central hills of Sri Lanka amidst the heavy burden of unidentified snake bites. Asian Pac J Trop Med. 2011; 4(7):564–7. Epub 2011/08/02. https://doi.org/10.1016/s1995-7654(11)60147-8 PMID: 21803310.

24. Praba-Egge AD, Cone SW, Araj M, Freire I, Paida G, Escalante J, et al. Snakebites in the rainforests of Ecuador. World J Surg. 2003; 27(2):234–40. Epub 2003/03/05. https://doi.org/10.1007/s00268-002-6552-9 PMID: 12616443.

25. Heap BJ, Cowan GO. The epidemiology of snake bite presenting to British Military Hospital Dharan during 1989. J R Army Med Corps. 1991; 137(3):123–5. Epub 1991/10/01. https://doi.org/10.1136/jramc-137-03-03 PMID: 1744818.

26. Rathnayaka RN, Ranathunga P, Kularatne S. Epidemiology and clinical features of Green pit viper (Trimeresurus trigonocephalus) envenom in Sri Lanka. Toxicon. 2017; 137:99–105. https://doi.org/10.1016/j.toxicon.2017.07.017 PMID: 28735968.

27. Rathnayaka RN, Kularatne S, Ranathunga P. Coagulopathy and extensive local swelling following Green pit viper (Trimeresurus trigonocephalus) envenom in Sri Lanka. Toxicon. 2017; 129:95–9. https://doi.org/10.1016/j.toxicon.2017.02.011 PMID: 28216410.

28. Kularatne AM, Silva A, Maduwage K, Ratnayake I, Walatharach C, Ratnayake C, et al. Victims’ response to snakebite and socio-epidemiological factors of 1018 snakebites in a tertiary care hospital in Sri Lanka. Wilderness Environ Med. 2014; 25(1):35–40. https://doi.org/10.1161/wem.2013.10.009 PMID: 24412659.

29. Jelinek GA, Hamilton T, Hirsch RL. Admissions for suspected snake bite to the Perth adult teaching hospitals, 1979 to 1988. Med J Aust. 1991; 155(11–12):761–4. Epub 1991/12/02. PMID: 1745167.

30. Jelinek GA, Breheny FX. Ten years of snake bites at Fremantle Hospital. Med J Aust. 1990; 153(11–12):658–61. Epub 1990/12/03. PMID: 2246987.

31. Munro J, Pearson JH. Snake bite in children: a five year population study from South-East Queensland. J Paediatr Child Health. 1978; 14(4):248–53.

32. Blaylock R. Snake bites at Triangle hospital: January 1975 to June 1981. Cent Afr J Med. 1982; 28(1):1–11. PMID: 7083313.

33. Chippaux J-P, Amadi-Edeline S, Fagot P. Diagnostic et surveillance des hémorragies dues aux venimeuses papouilles en savane africaine. Bull Soc Pathol Exot. 1999; 92(2):109–13. PMID: 10399601.

34. Tan HH. Epidemiology of snakebites from a general hospital in Singapore: a 5-year retrospective review (2004–2008). Ann Acad Med Singapore. 2010; 39(8):640–7. Epub 2010/09/15. PMID: 20838707.

35. Blaylock R. Epidemiology of snakebite in Eshowe, KwaZulu-Natal, South Africa. Toxicon. 2004; 43(2):159–66. https://doi.org/10.1016/j.toxicon.2003.11.019 PMID: 15019745.

36. Pattinson JP, Kong VY, Bruce JL, Oosthuizen GV, Bekker W, Laing GL, et al. Defining the need for surgical intervention following a snakebite still relies heavily on clinical assessment: The experience in Pietermaritzburg, South Africa. SAMJ. S Afr. Med J. 2017; 107(12):1082–5. https://doi.org/10.7196/samj.2017.v107i12.12628 WOS:000418339200021. PMID: 29262961.

37. Rathnayaka RN, Ranathunga P, Kularatne S. Epidemiology and clinical feature s of Green pit viper (Trimeresurus trigonocephalus) envenom in Sri Lanka. Toxicon. 2017; 137:99–105. https://doi.org/10.1016/j.toxicon.2017.02.011 PMID: 28216410.

38. Green pit viper (Trimeresurus trigonocephalus) envenom in Sri Lanka. Toxicon. 2017; 137:99–105. https://doi.org/10.1016/j.toxicon.2017.02.011 PMID: 28216410.

39. Manosalva-Sánchez C, Zuleta-Dueñas LP, Castañeda-Porras O. Estudio descriptivo del accidente ofídico, Casanare-Colombia, 2012–2014. MedUNAB. 2018; 20(3):338–48.

40. Lukić B, Bradarić N, Prgomet S. Venomous snakebites in southern Croatia. Coll Antropol 2006; 30(1):191–7. PMID: 16617597.

41. Frangides CY, Koulouras V, Kouni SN, Tzortzatos GV, Nikolaou A, Pneumatics J, et al. Snake venom poisoning in Greece. Experiences with 147 cases. Eur J Intern Med. 2006; 17(1):24–7. https://doi.org/10.1016/j.ejim.2006.10.001 PMID: 16378881.
44. Ariaratnam CA, Sheriff MHR, Arambe pola C, Theaks ton RDG, Warrell DA. Syndromic Approach to Treatment of Snake Bite in Sri Lanka Based on Results of a Prospective National Hospital-Based Survey of Patients Envenomed by Identified Snakes. Am J Trop Med Hyg. 2009; 81(4):725–31. https://doi.org/10.4269/ajtmh.2009.09-0225 WOS:000270474000035. PMID: 19815895

45. Coetzee PW, Tilbury CR. The epidemiology of snakebite in northern Natal. S Afr Med J. 1982; 62(7):206–12. Epub 1982/08/07. PMID: 7101072.

46. Elayoubi S. Envenimation par morsure de vipère en milieu pédiatrique 2015.

47. Chafiq F, El Hattimy F, Rhalem N, Chippaux J-P, Soulaymani A, Mokhtari A, et al. Snakebites notified to the poison control center of Morocco between 2009 and 2013. J Venom Anim Toxins incl Trop Dis. 2016; 22. https://doi.org/10.1186/s40409-016-0065-8 WOS:000372121400001. PMID: 26985186

48. Yates VM, Lebas E, Orpiay R, Bale BJ. Management of snakebites by the staff of a rural clinic: the impact of providing free antivenom in a nurse-led clinic in Meserani, Tanzania. Ann Trop Med Parasitol. 2010; 104(5):439–48. Epub 2010/09/08. https://doi.org/10.1179/136485910X12743554760306 PMID: 20819312.

49. Wagener M. Haemotoxic snakebite in rural KwaZulu-Natal, South Africa: A case presenting with haematemesis. S Afr Med J. 2016; 106(5):44–5. Epub 2016/05/04. https://doi.org/10.1016/j.samj.2016.v106i5.9124 PMID: 27138661.

50. McNally S, Reitz C. Victims of snakebite. A 5-year study at Shongwe Hospital, Kangwane, 1978–1982. South Afr Med J. 1987; 72(12):855–60.

51. Pugh RN, Theakston RD. A clinical study of viper bite poisoning. Ann Trop Med Parasitol. 1987; 81(2):135–49. Epub 1987/04/01. https://doi.org/10.1080/00034983.1987.11812106 PMID: 3689023.

52. Michael GC, Thacher TD, Shehu MI. The effect of pre-hospital care for venomous snake bite on outcome in Nigeria. Trans R Soc Trop Med Hyg. 2011; 105(2):95–101. Epub 2010/11/03. https://doi.org/10.1016/j.trstmh.2010.09.005 PMID: 21035155.

53. Tianyi FL, Agbor VN, Tochie JN, Kadia BM, Nkwescuhe AS. Community-based audits of snake envenomations in a resource-challenged setting of Cameroon: case series. BMC Res Notes. 2018; 11(1):317. Epub 2018/05/20. https://doi.org/10.1186/s13104-018-3409-3 PMID: 29776445; PubMed Central PMCID: PMC5960191.

54. Einterz EM, Bates ME. Snakebite in northern Cameroon: 134 victims of bites by the saw-scaled or carpet viper, Echis ocellatus. Trans R Soc Trop Med Hyg. 2003; 97(6):693–6. Epub 2005/08/25. https://doi.org/10.1016/s0035-9203(03)80105-0 PMID: 16117965.

55. Harris JB, Faiz MA, Rahman MR, Jalil MM, Ahsan MF, Theakston RDG, et al. Snake bite in Chittagong Division, Bangladesh: a study of bitten patients who developed no signs of systemic envenoming. Trans R Soc Trop Med Hyg. 2010; 104(5):320–7. https://doi.org/10.1016/j.trstmh.2009.12.006 PMID: 20096910

56. Sharma SK, Kuch U, Hoede P, Bruhse L, Pandey DP, Ghimire A, et al. Use of Molecular Diagnostic Tools for the Identification of Species Responsible for Snakebite in Nepal: A Pilot Study. PLoS Negl Trop Dis. 2016; 10(4). https://doi.org/10.1371/journal.pntd.0004620 WOS:000375376700054. PMID: 27105074

57. Su H-Y, Huang S-W, Mao Y-C, Liu M-W, Lee K-H, Lai P-F, et al. Clinical and laboratory features distinguishing between Deinagkistrodon acutus and Daboia siamensis envenomation. J Venom Anim Toxins incl Trop Dis. 2018; 24. https://doi.org/10.1186/s40409-018-0179-2 WOS:000454502200001. PMID: 30607144

58. Mao Y-C, Liu P-Y, Chiang L-C, Liao S-C, Su H-Y, Hsieh S-Y, et al. Bungarus multicinctus multicinctus Snakebite in Taiwan. Am J Trop Med Hyg. 2017; 96(6):1497–504. https://doi.org/10.4269/ajtmh.17-0005 PMID: 28719273

59. Ratnayake RN, Kularatne S, Kumarasinghe K, Ranaweera J, Ranathunga PN. Ischemic brain infarcts and intracranial haemorrhages following Russell’s viper (Daboia russelli) bite in Sri Lanka. Toxicon. 2017; 125:70–3. https://doi.org/10.1016/j.toxicon.2016.11.253 PMID: 27871786

60. Silva A, Gamlaksha D, Waidyaratne D. Medico-le gal significance of the identification of offending snake in a fatal snake bite: a case report. J Forensic Leg Med. 2013; 20(8):965–7. Epub 2013/11/19. https://doi.org/10.1016/j.jflm.2013.09.009 PMID: 24237800.

61. Senanayake MP, Ariaratnam CA, Abeywickrema S, Belligaswatte A. Two Sri Lankan cases of identified sea snake bites, without envenoming. Toxicon. 2005; 45(7):861–3. Epub 2005/05/21. https://doi.org/10.1016/j.toxicon.2005.02.018 PMID: 15904661.

62. Seneviratne U, Dissanayake S. Neurological manifestations of snake bite in Sri Lanka. J Postgrad Med. 2002; 48(4):275–8; discussion 8–9. Epub 2003/02/07. PMID: 12571382.
63. Kularatne S, Budagoda B, Gawarammana I, Kularatne W. Epidemiology, clinical profile and management issues of cobra (Naja naja) bites in Sri Lanka: first authenticated case series. Trans R Soc Trop Med Hyg. 2009; 103(9):924–30. https://doi.org/10.1016/j.trstmh.2009.04.002 PMID: 19439335

64. Kularatne SAM, Sivansuthan S, Medagedara SC, Maduwage K, de Silva A. Revisiting saw-scaled viper (Echis carinatus) bites in the Jaffna Peninsula of Sri Lanka: distribution, epidemiology and clinical manifestations. Trans R Soc Trop Med Hyg. 2011; 105(10):591–7. https://doi.org/10.1016/j.trstmh.2011.07.010 WOS:000295771300009. PMID: 21868049

65. Shahmy S, Kularatne SAM, Rathnayake SS, Dawson AH. A prospective cohort study of the effectiveness of the primary hospital management of all snakebites in Kurunegala district of Sri Lanka. PLoS Negl Trop Dis. 2017; 11(8):e0005847. Epub 2017/08/23. https://doi.org/10.1371/journal.pntd.0005847 PMID: 28927807; PubMed Central PMCID: PMC5578683.

66. Seneviratne SL, Opanaya CK, Ratnayake NS, Kumara KE, Sugathadasa AM, Weerasingha N, et al. Use of antivenom serum in snake bite: a prospective study of hospital practice in the Gampaha district. Ceylon Med J. 2000; 45(2):65–8. Epub 2000/10/29. https://doi.org/10.4038/cmj.v45i2.8003 PMID: 11051703.

67. Kularatne SA. Common krait (Bungarus caeruleus) bite in Anuradhapura, Sri Lanka: a prospective clinical study, 1996–98. Postgrad Med J. 2002; 78(919):276–80. Epub 2002/08/02. https://doi.org/10.1136/pmj.78.919.276 PMID: 12151569; PubMed Central PMCID: PMC1742360.

68. Blessmann J, Khonesavanh C, Outhaithit P, Manichanh S, Somphanthavong K, Siboualiphanh P. Venomous snake bites in Lao PDR: a retrospective study of 21 snakebite victims in a provincial hospital. Southeast Asian J Trop Public Health. 2010; 41(1):195–202. Epub 2010/06/29. PMID: 20578499.

69. Vongphoumy I, Chanthilath P, Vilayvong P, Blessmann J. Prospective, consecutive case series of 158 snakebite patients treated at Savannakhet provincial hospital, Lao People’s Democratic Republic with high incidence of anaphylactic shock to horse derived F(ab’)2 antivenom. Toxicon. 2016; 117:13–21. Epub 2016/03/21. https://doi.org/10.1016/j.toxicon.2016.03.011 PMID: 26995210.

70. Asif N, Akhtar F, Kamal K. A study of ninety snake bite cases at Pakistan Air Force (PAF) Hospital, Shorkot, Pakistan. Pak Armed Forces Med J. 2015; 65(3):333–8.

71. Tripathy S, Routray PK, Mohapatra AK, Mohapatra M, Dash SC. Acute demyelinating encephalomyelitis after anti-venom therapy in Russell’s viper bite. J Med Toxicol. 2010; 6(3):318–21. Epub 2010/03/08. https://doi.org/10.1007/s13181-010-0015-8 PMID: 20237970; PubMed Central PMCID: PMC3550494.

72. Bawaskar HS, Bawaskar PH. Envenoming by the common krait (Bungarus caeruleus) and Asian cobra (Naja naja): clinical manifestations and their management in a rural setting. Wilderness Environ Med. 2004; 15(4):257–66. Epub 2005/01/08. https://doi.org/10.1580/1080-6032(2004)015[257:ebtkbk]2.0.co;2 PMID: 15636376.

73. Kumar V, Sabitha P. Inadequacy of present polyspecific anti snakevenom—a study from central Kerala. Indian J Pediatr. 2011; 78(10):1225–8. Epub 2011/03/04. https://doi.org/10.1007/s12098-011-0396-y PMID: 21369925.

74. Farooqui JM, Mukherjee BB, Manjhi SNM, Farooqui AAJ, Dattr S. Incidence of fatal snake bite in Loni, Maharashtra: An autopsy based retrospective study (2004–2014). J Forensic Leg Med. 2016; 39:61–4. https://doi.org/10.1016/j.jflm.2016.01.013 WOS:000371791700010. PMID: 26854851

75. Vaiyapuri S, Vaiyapuri R, Ashokan R, Ramasaamy K, Nattamaisundar K, Jeyaraj A, et al. Snakebite and its socio-economic impact on the rural population of Tamil Nadu, India. PLoS One. 2013; 8(11):e80090. https://doi.org/10.1371/journal.pone.0080090 PMID: 24278485

76. Gopalakrishnan M, Vinod KV, Dutta TK, Shaha KK, Sridhar MG, Saurabh S. Exploring circulatory shock and mortality in viper envenomation: a prospective observational study from India. QJM. 2018; 111(11):799–806. Epub 2018/08/15. https://doi.org/10.1093/qjmed/hcy175 PMID: 3017433.

77. Mahaba HM. Snakebite: Epidemiology, prevention, clinical presentation and management. Ann Saudi Med. 2000; 20(1):66–8. https://doi.org/10.5144/0256-4947.2000.66 PMID: 17322751

78. Looareesuwan S, Viravan C, Warrell DA. Factors contributing to fatal snake bite in the rural tropics: analysis of 46 cases in Thailand. Trans R Soc Trop Med Hyg. 1988; 82(6):930–4. Epub 1988/01/01. https://doi.org/10.1016/0035-9203(88)90046-6 PMID: 3257001.

79. Viravan C, Veeravut U, Warrell M, Theakston R, Warrell D. ELISA confirmation of acute and past envenoming by the monocellate Thai cobra (Naja kaouthia). Am J Trop Med Hyg. 1986; 35(1):173–81. https://doi.org/10.4269/ajtmh.1986.35.173 PMID: 3946735

80. Hutton RA, Looareesuwan S, Ho M, Silamut K, Chanthavanich P, Karbwang J, et al. Arboreal green pit vipers (genus Trimeresurus) of South-East Asia: bites by T. albolabris and T. macrops in Thailand and a review of the literature. Trans R Soc Trop Med Hyg. 1990; 84(6):866–74. Epub 1990/11/01. https://doi.org/10.1016/0035-9203(90)90111-9 PMID: 2096527.
81. Rojnuckarin P, Intragumtorntchai T, Sattapiroon R, Muanpapisrnom C, Pakmanee N, Khow O, et al. The effects of green pit viper (Trimeresurus albolabris and Trimeresurus macrops) venom on the fibrinolytic system in human. Toxicon. 1999; 37(5):743–55. Epub 1999/04/29. https://doi.org/10.1016/s0041-0101(98)00214-1 PMID: 10219986.

82. Buranasri P. Snakebites at Maharat Nakhon Ratchasima Regional Hospital. Southeast Asian J Trop Med Public Health. 1993; 24(1):186–92. Epub 1993/03/01. PMID: 8362295.

83. Aye K-P, Thanachartvet V, Soe C, Desakorn C, Chammanchant S, Sahassananda D, et al. Predictive Factors for Death After Snake Envenomation in Myanmar. Wilderness Environ Med. 2018; 29(2):166–75. https://doi.org/10.1016/j.wem.2018.01.001 WOS:000435429100004. PMID: 29572088.

84. Warrell D. Bites by Russell’s vipers (Daboia russelii siamensis) in Myanmar: effect of the snake’s length and recent feeding on venom antigenaemia and severity of envenomation. Trans R Soc trop Med Hyg. 1991; 85(6):804–8. https://doi.org/10.1016/s0035-9203(91)90464-a PMID: 1839340.

85. Isbister GK, Gault A, Tasoulis T, O’Leary MA. A definite bite by the Ornamental Snake (Denisonia maculata) causing mild envenoming. Clin Toxicol (Phila). 2016; 54(3):241–4. Epub 2016/02/09. https://doi.org/10.3109/15563650.2015.1128545 PMID: 26852775.

86. Sprivulis P. Fatal intracranial haematomas in two patients with brown snake envenomation. Med J Aust. 1995; 162(10):557–5. Epub 1995/06/23. https://doi.org/10.5694/mja162.10.557 PMID: 8586159.

87. Isbister GK, Dawson AH, Whyte IM. Two cases of bites by the black-bellied swamp snake (Hemiaspis signata). Toxicon. 2002; 40(3):317–9. Epub 2001/11/17. https://doi.org/10.1016/s0041-0101(01)00221-5 PMID: 11711130.

88. Allen GE, Brown SG, Buckley NA, O’Leary MA, Page CB, Currie BJ, et al. Clinical effects and anti-venom dosing in brown snake (Pseudonaja spp.) envenoming—Australian snakebite project (ASP-14). PLoS One. 2012; 7(12):e53188. Epub 2013/01/10. https://doi.org/10.1371/journal.pone.0053188 PMID: 23300888; PubMed Central PMCID: PMC3532501.

89. Razavi S, Weinstein SA, Bates DJ, White J. The Australian mulga snake (Pseudonaja australis): Elapidae: report of a large case series of bites and review of current knowledge. Toxicon. 2014; 85:17–26. Epub 2014/04/15. https://doi.org/10.1016/j.toxicon.2014.04.003 PMID: 24726467.

90. Currie BJ. Snakebite in tropical Australia: a prospective study in the “Top End” of the Northern Territory. Med J Aust. 2004; 181(11–12):693–7. Epub 2004/12/14. PMID: 15588215.

91. Villanueva M, Maquíañ C, Cabada M, De Marini J, Alvarez H, Gotuzzo E. Oftidismo en la provincia de Chanchamayo, Junín: revisión de 170 casos consecutivos en el Hospital de Apoyo de La Merced. Rev Soc Bras Med Trop. 2010; 43(3):336–8. https://doi.org/10.1590/s0036-46651993000400014 PMID: 15596665; PubMed Central PMCID: PMC527684.

92. Bucarechó F, De Capitani EM, Branco MM, Fernandes LC, Hyslop S. Coagulopatía as the main systemic manifestation after envenomation by a juvenile South American rattlesnake (Crotalus durissus terrificus): case report. Clin Toxicol (Phila). 2013; 51(6):505–8. Epub 2013/05/30. https://doi.org/10.1080/10548870.2013.820796 PMID: 23713821.

93. Pinto RN, Dassistha NJ, Aird SD. Human envenomation by the South American opisthoglyph Celia clela plumbea (Wied). Toxicon. 1991; 29(12):1512–6. https://doi.org/10.1016/0041-0101(91)90008-f WOS:A1991GY76200009. PMID: 18013282.

94. Brandao EO, de Bastos HC, Nishioka Sde A, Silveira PV. Lance-headed viper (Bothrops moojeni) bite wounding the eye. Rev Inst Med Trop Sao Paulo. 1993; 35(4):317–3. Epub 1993/07/01. https://doi.org/10.1590/s0041-0101(93)90008-f WOS:A1991GY76200009. PMID: 18013282.

95. Correia JM, Santana Neto PdL, Sabino Pinho MS, da Silva JA, Porto Amorim ML, Costa Escobar JA. Poisoning due to Philodryas orfassii (Lichtenstein, 1823) attended at Restauracão Hospital in Recife, State of Pernambuco, Brazil: case report. Rev Soc Bras Med Trop. 2010; 43(3):336–8. https://doi.org/10.1590/s0036-08622010000300010 WOS:0002790117000025. PMID: 20563508.

96. Nishioka SA, Silveira PV. Philodryas patagoniensis bite and local envenomation. Rev Inst Med Trop Sao Paulo. 1994; 36(3):279–81. Epub 1994/05/01. https://doi.org/10.1590/s0036-46651994000300013 PMID: 79854593.

97. Silveira GG, Machado CR, Tuyama M, Lima MA. Intracranial Bleeding Following Bothrops sp. Snakebite. Neurologist. 2016; 21(1):11–2. Epub 2015/12/26. https://doi.org/10.1097/NRL. 0000000000000867 PMID: 26703063.

98. Pardal PPD, Souza SM, Monteiro M, Fan HW, Cardoso JLC, Franca FOS, et al. Clinical trial of two antivenoms for the treatment of Bothrops and Lachesis bites in the north eastern Amazon region of Brazil. Trans R Soc trop Med Hyg. 2004; 98(1):28–42. https://doi.org/10.1016/s0036-9203(03)0005-1 WOS:000187423600004. PMID: 14702836.
100. Bucaretchi F, Hyslop S, Vieira RJ, Toledo AS, Madureira PR, de Capitani EM. Bites by coral snakes (Micrurus spp.) in Campinas, State of Sao Paulo, Southeastern Brazil. Rev Inst Med Trop Sao Paulo. 2006; 48(3):141–5. Epub 2006/07/19. https://doi.org/10.1590/s0036-46652006000300005 PMID: 16847503.

101. Silveria PV, Nishioka Sde A. Non-venomous snake bite and snake bite without envenoming in a Brazilian teaching hospital. Analysis of 91 cases. Rev Inst Med Trop Sao Paulo. 1992; 34(6):499–503. Epub 1992/11/01. https://doi.org/10.1590/s0036-46651992000600002 PMID: 1342117.

102. Roriz K, Zaqueo KD, Setubal SS, Katsuragawa TH, Silva RRD, Fernandes CFC, et al. Epidemiological study of snakebite cases in Brazilian Western Amazonia. Rev Soc Bras Med Trop. 2018; 51(3):338–46. Epub 2018/07/05. https://doi.org/10.1590/1518-8787-0489-2017 PMID: 29972565.

103. Waldez F, Vogt RC. Aspectos ecológicos e epidemiológicos de acidentes ofídicos em comunidades ribeirinhas do baixo rio Purus, Amazonas, Brasil. Acta Amazonica. 2009; 39(3):681–92. https://doi.org/10.1590/s0044-59672009000300025 SCIELO:S0044-59672009000300025.

104. Oliveira FN, Brito MT, Oliveira de Morais IC, Lia Fook SM, de Albuquerq ue HN. Accidents caused by Bothrops and Bothropoides in the State of Paraíba: epidemiological and clinical aspects. Rev Soc Bras Med Trop. 2010; 43(6):662–7. https://doi.org/10.1590/S0037-86822010000600012 WOS:000285513300012. PMID: 21181019.

105. Nishioka SD, Silveira PVP. A clinical and epidemiologic study of 292 cases of Lance-headed viper bite in a Brazilian teaching hospital. Am J Trop Med Hyg. 1992; 47(6):805–10. WOS:A1992 KF92000012.

106. Nishioka Sde A, Silveira PV, Bauab FA. Bite marks are useful for the differential diagnosis of snakebite in Brazil. Wilderness Environ Med. 1995; 6(2):183–8. Epub 1995/05/01. https://doi.org/10.1580/1080-6032(1995)006[0183:bm auft]2.3.co;2 PMID: 11995906.

107. Bosak AR, Ruha AM, Graeme KA. A case of neurotoxicity following envenomati on by the Sidewinder rattlesnake, Crotalus cerastes. J Med Toxicol. 2014; 10(2):229–31. Epub 2014/01/15. https://doi.org/10.1007/s13181-013-0373-0 PMID: 24414250; PubMed Central PMCID: PMC4057548.

108. Thorson A, Lavonas EJ, Rouse AM, Kerns WP, 2nd. Copperhead envenomati ons in the Carolinas. J Toxicol Clin Toxicol. 2003; 41(4):353–6. Epub 2003/12/21. https://doi.org/10.1080/10806032(2003)041[0353:ceic]2.0.co;2 PMID: 14687990.

109. Garcia-Gubern C, Bello R, Rivera V, Rocafort A, Colon-Rolon L, Acosta-Tapia H. Is the Puerto Rican racer, Alsophis portoricensis, really harmless? A case report series. Wilderness Environ Med. 2010; 21(4):353–6. Epub 2010/12/21. https://doi.org/10.1016/j.wem.2010.07.001 PMID: 21168790.

110. Leite Rde S, Targino IT, Lopes YA, Barros RM, Vieira AA. Epidemiology of snakebite accidents in the municipalities of the state of Paraíba, Brazil. Cien Saude Colet. 2013; 18(5):1463–71. Epub 2013/05/15. https://doi.org/10.1590/s1413-81232013000500032 PMID: 23670475.

111. Bawaskar HS, Bawaskar PH, Punde DP, Inamdar MK, Dongare RB, Bhoite RR. Profile of snakebite envenomining in rural Maharashtra, India. J Assoc Physicians India. 2008; 56:88–95. Epub 2008/05/14. PMID: 18472507.

112. Bernarde PS, Gomes JdO. Venomous snakes and ophidism in Cruzeiro do Sul, Alto Jurua, State of Acre, Brazil. Acta Amazonica. 2012; 42(1):65–72.

113. Leite Rde S, Targino IT, Lopes YA, Barros RM, Vieira AA. Epidemiology of snakebite accidents in the municipalities of the state of Paraíba, Brazil. Cien Saude Colet. 2013; 18(5):1463–71. Epub 2013/05/15. https://doi.org/10.1590/s1413-81232013000500032 PMID: 23670475.

114. Leiter Rde S, Targino IT, Lopes YA, Barros RM, Vieira AA. Epidemiology of snakebite accidents in the municipalities of the state of Paraíba, Brazil. Cien Saude Colet. 2013; 18(5):1463–71. Epub 2013/05/15. https://doi.org/10.1590/s1413-81232013000500032 PMID: 23670475.

115. Pierini S, Warrell D, De Paulo A, Theakston R. High incidence of bites and stings by snakes and other animals among rubber tappers and Amazonian Indians of the Jurua Valley, Acre State, Brazil. Toxicol. 1996; 34(2):225–36. https://doi.org/10.1007/BF01202309 PMID: 8711756.

116. Sharma SK, Chappuis F, Jha N, Bovier PA, Loutan L, Koiraal S. Impact of snake bites and determinants of fatal outcomes in southeastern Nepal. Am J Trop Med Hyg. 2004; 71(2):234–8. PMID: 15306717.

117. Habila I. Factors associated with snake bite and health seeking behavior among residents of Kaltungo Iga, Gombe State, Nigeria. Doctoral dissertation, Ahmadu Bello University, Zaria, 2014.

118. Hama SK, Chappuis F, Jha N, Bovier PA, Loutan L, Koiraal S. Impact of snake bites and determinants of fatal outcomes in southeastern Nepal. Am J Trop Med Hyg. 2004; 71(2):234–8. PMID: 15306717.

119. Joseph JK, Simpson ID, Menon NCS, Jose MP, Kulkarni KJ, Raghavendra GB, et al. First authenti- cated cases of life-threatening envenoming by the hump-nosed pit viper (Hypnale hypnale) in India. Trans R Soc Trop Med Hyg. 2007; 101(1):85–90. https://doi.org/10.1016/j.trstmh.2006.03.008 WOS:000242759400011. PMID: 16839578.

120. Viravan C, Looareesuwan S, Kosakarn W, Wuthiekanun V, McCarth y CJ, Stimson AF, et al. A national hospital-based survey of snakes responsible for bites in Thailand. Trans R Soc Trop Med Hyg. 1992; 86(1):100–6. https://doi.org/10.1016/0035-9203(92)90463-m WOS:A1992HH64200040. PMID: 1566285.
119. Cox RD, Parker CS, Cox ECE, Marlin MB, Galli RL. Misidentification of copperhead and cottonmouth snakes following snakebites. Clin Toxicol (Phila). 2018; 56(12):1195–9. https://doi.org/10.1080/15563650.2018.1473583 MEDLINE:29792342. PMID: 29792342

120. Ogunbanjo GA. Management of snakebites at a rural South African hospital. South African Fam Pract. 2009; 51(3).

121. de Medeiros CR, Hess PL, Nicoleti AF, Sueiro LR, Duarte MR, de Almeida-Santos SM, et al. Bites by the colubrid snake Philodryas patagoniensis: a clinical and epidemiological study of 297 cases. Toxicon. 2010; 56(6):1018–24. Epub 2010/07/21. https://doi.org/10.1016/j.toxicon.2010.07.006 PMID: 20643156.

122. Vale TC, Leite AF, Correa MR, Dionne JE, Kleyer DE. “Venomous Bites from Non-Venomous Snakes: A Critical Analysis of Risk and Management of ‘Colubrid Snake Bites: Elsevier; 2011.

123. Trape JF. Partition d’Echis ocellatus Stemmler, 1970 (Squamata: Viperidae), avec la description d’une espèce nouvelle. Bull Soc Herp Fr. 2018; 167:13–34.

124. Cockrell M, Swanson K, Sanders A, Prater S, von Wenckstern T, Mick J. Safe Handling of Snakes in an ED Setting. J Emerg Nurs. 2017; 43(1):21–3. Epub 2016/11/16. https://doi.org/10.1016/j.jen.2016.07.009 PMID: 27842799.

125. Suchard JR, LoVecchio F. Envenomations by rattlesnakes thought to be dead. N Engl J Med. 1999; 340(24):1930–. https://doi.org/10.1056/NEJM199906173402420 PMID: 10375322

126. Griffin D, Donovan JW. Significant envenomation from a preserved rattlesnake head (in a patient with a history of immediate hypersensitivity to antivenin). Ann Emerg Med. 1986; 15(8):955–8. https://doi.org/10.1016/s0196-0644(86)80685-0 PMID: 3740586

127. Willhite LA, Willenbring BA, Orozco BS, Cole JB. Death after bite from severed snake head. Clin Toxicol (Phila). 2018; 56(9):864–5. Epub 2018/02/20. https://doi.org/10.1080/15563650.2018.1439951 PMID: 29457505.

128. Emswiler MP, Griffith 4th FP, Cumpston KL. Clinically significant envenomation from postmortem copperhead (Agkistrodon contortrix). Wilderness Environ Med. 2017; 28(1):43–5. https://doi.org/10.1016/j.wem.2016.09.007 PMID: 27876196

129. Silva AMd Monteiro WM, Bernarde PS. Envenomation by a juvenile pit viper (Bothrops atrox) presumed to be dead. Rev Soc Bras Med Trop. 2019; 52.

130. Silva A, Marikar F, Murugananthan A, Agampodi S. Awareness and perceptions on prevention, first aid and treatment of snakebites among Sri Lankan farmers: a knowledge practice mismatch? J Occup Med Toxicol. 2014; 9(1):20.

131. Price L., Governance and Ecology: Managing the Menace of Venomous Snakes in Colonial India. Cult Soc Hist. 2017; 14(2):201–17.

132. Fita DS, Neto ECM, Schiavetti A. ‘Offensive’snakes: cultural beliefs and practices related to snakebites in a Brazilian rural settlement. J Ethnobiol Ethnomed. 2010; 6(1):13.

133. Snakebite Healing and Education Society [cited 5 November 2019]. Available from: http://www.she-india.org/

134. African Snakebite Institute [cited 5 November 2019]. Available from: https://www.africansnakebiteinstitute.com/snakebite/

135. BIG 4 Mapping Project [cited 5 November 2019]. Available from: http://snakebiteinitiative.in/snake/

136. Maduwage K. Snake Identification Service of Sri Lanka 2017 [cited 5 November 2019]. Available from: https://snakesidentification.org/

137. Thailand snakes. 2019 [cited 5 November 2019]. Available from: https://www.thailandsnakes.com/thailand-snake-id/
142. Florida’s. Florida’s Poison Control Centers—Snakes 2019 [cited 5 November 2019]. Available from: https://floridapoisoncontrol.org/poisoning-in-florida/snakes/

143. Ciemto UdA-FdM-. 2019 [cited 5 November 2019]. Available from: http://ciemto.medicinaudaea.co/

144. Geneviève LD, Ray N, Chappuis F, Alcobas G, Mondardini MR, Bolon I, et al. Participatory approaches and open data on venomous snakes: A neglected opportunity in the global snakebite crisis? PLoS Negl Trop Dis. 2018; 12(3):e0006162. https://doi.org/10.1371/journal.pntd.0006162 PMID: 29518075

145. Ruiz de Castañeda R, Grey F, Williams D. Citizen science could map snakebite risk. Nature. 2019; 571(7766):478.

146. Ruiz de Castañeda R, Durso AM, Ray N, Fernández JL, Williams DJ, Alcoba G, et al. Snakebite and snake identification: empowering neglected communities and health-care providers with AI. The Lancet Digital Health. 2019; 1(5):e202–e3.

147. ITUNews. Artificial Intelligence for Health: ITU and WHO accept 8 new use cases 2018 [cited 5 November 2019]. Available from: https://news.itu.int/artificial-intelligence-health-new-use-cases/

148. Ariaratnam CA, Thuraiingam V, Kularatne SA, Sheriff MH, Theakston RD, de Silva A, et al. Frequent and potentially fatal envenoming by hump-nosed pit vipers (Hypnale hypnale and H. nepa) in Sri Lanka: lack of effective antivenom. Trans R Soc Trop Med Hyg. 2008; 102(11):1120–6. Epub 2008/05/06. https://doi.org/10.1016/j.trstmh.2008.03.023 PMID: 18455743.

149. Kipanyula MJ, Kimaro WH. Snakes and snakebite envenomation in Northern Tanzania: a neglected tropical health problem. J Venom Anim Toxins Incl. Trop Dis. 2015; 21. https://doi.org/10.1186/s40409-015-0033-8 WOS:000359977800001. PMID: 26309444

150. Inthanomchanch V, Reyer JA, Blessmen J, Phrasisombath K, Yamamoto E, Hamajima N. Assessment of knowledge about snakebite management amongst healthcare providers in the provincial and two district hospitals in Savannakhet Province, Lao PDR. Nagoya J Med Sci. 2017; 79(3):299–311. Epub 2017/09/08. https://doi.org/10.18999/nagjms.79.3.299 PMID: 28878435; PubMed Central PMCID: PMC5777016.

151. Sharma SK. Venomous snakes of Nepal: a photographic guide: BP Koirala Institute of Health Sciences; 2013. Available from: http://www.bik-f.de/files/publications/kuch_venomous_snakes_of_nepal_-_english_edition.pdf

152. WHO. Venomous snakes and antivenoms search interface 2010 [cited 5 November 2019]. Available from: http://apps.who.int/bloodproducts/snakeantivenoms/database/snakeframeset.html

153. Carrasco PA, Venegas PJ, Chaparro JC, Scrocchi GJ. Nomenclatural instability in the venomous snakes of the Bothrops complex: Implications in toxicology and public health. Toxicon. 2016; 119:122–8. https://doi.org/10.1016/j.toxicon.2016.05.014 PMID: 27242040

154. Williams D, Wüster W, Fry BG. The good, the bad and the ugly: Australian snake taxonomists and a history of the taxonomy of Australia’s venomous snakes. Toxicon. 2006; 48(7):919–30. https://doi.org/10.1016/j.toxicon.2006.07.016 PMID: 16999982