

Special Report

SERPENT-Brasil: a technological tool for snakebite management

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ABSTRACT

Objective. To report on the development and features of a mobile application (app) to guide the public and health professionals on pre-hospital emergency measures after snake envenomation.

Methods. This was a four-stage methodological study conducted from June 2020 to July 2022. The app development included creating a mobile resource to guide pre-hospital care and to direct victims to hospitals that have antivenom.

Results: The SERPENT-BRASIL app was developed for use on Android and IOS devices with an intuitive interface. It offers online and offline access to information on hospitals and mapping routes via Google Maps. In addition, it allows users to report snake sightings and to request emergency rescue.

Conclusion: The SERPENT-BRASIL app improves snakebite management and prevention, eases the burden on health services, and promotes health education. Collection of snake envenomation data contributes to public safety, making the app an essential resource for public safety in Brazil.

Keywords

Snake envenomation; emergency guidance; public health informatics; mobile health; specimen management; Brazil.

Accidents caused by venomous animals, particularly snakes, represent a substantial challenge to public health in several regions of the world, especially in nations with tropical and subtropical climates (1). These incidents are commonly overlooked, and are classified as neglected diseases by the World Health Organization, which aims to halve deaths and disabilities from snakebites by 2030 (2,3). Considering the seriousness of the situation, with 2.7 million annual cases of snakebite envenomation and 81 000 to 138 000 deaths globally plus approximately 400 000 cases of amputations and other disabling sequelae (4), effective prevention and treatment strategies are necessary.

In Brazil, more than 33 838 cases of snakebites accidents were reported to the *Sistema de Informação de Agravos de Notificação* (SINAN; Notifiable Diseases Information System) in 2020, highlighting the vulnerability of rural and remote populations that often face barriers in accessing appropriate medical care (5, 6). In some cases, victims of snakebite must travel to a hospital in the state capital or municipal center that offers adequate treatment, such as antivenom. This displacement can aggravate the situation, leading to delays in care and increasing the risk of serious complications (7). Many health care facilities are not equipped to treat poisoning victims; they lack the necessary antivenom, which delays the neutralization of the venom and

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increases the risk of severe complications, including death (6). In a context in which time is crucial for treatment success, these gaps in health care infrastructure worsen the impact of snakebite accidents.

In this setting, technological advancement and greater accessibility to mobile devices, such as smartphones, emerge as valuable allies in providing information and guidance for pre-hospital care in cases of snake envenomation. Technology applied to health has the potential to reduce response times during emergencies, allowing victims to receive prompt and appropriate guidance. Mobile apps have been successfully used in health care to manage medical emergencies, monitor diseases, and facilitate access to information, especially in hard-to-reach areas (8). In this context, the SERPENT-BRASIL app emerges as an innovative tool that facilitates access to medical care and promotes education on snakebite prevention and control.

In addition to aligning with the World Health Organization guidelines and the Sustainable Development Goals (3), SERPENT-BRASIL can work alongside local public health initiatives, complementing health education programs and raising awareness on how to avoid snakebites. The increasing use of emerging technologies in public health makes this app a promising solution for managing medical emergencies in remote areas.

Available for use on Android and IOS devices, the SERPENT-BRASIL app facilitates locating hospitals with antivenom, finding nearby first responders, and reporting the presence of snakes in inhabited areas, creating a real-time information network. It also contributes to accident prevention and management by filling the information gap regarding snake distribution. Thus, considering the lack of accessible and effective information on pre-hospital management of snakebite incidents, this study reports on the development of the SERPENT-BRASIL app, highlighting its development process and functionalities.

METHODS

This was a four-stage methodological study that focused on the development of the SERPENT-Brasil app, according to the technical standards of the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC 25040:2011) (9). It was developed at the Amazonas Tropical Medicine Foundation, Manaus, Brazil, from June 2020 to July 2022, and was divided into four sequential and complementary development stages. Ethics committee approval was waived because the study did not involve human subjects.

Stage 1: Diagnosis of the situation and identification of needs

Stage 1 of app development consisted of an in-depth assessment of the snakebite status in Brazil, focusing on populations residing in remote areas of the Amazon region, where these accidents comprise a substantial public health problem. These snakebite incidents, in addition to causing serious complications and sequelae in the victims, increase the costs of the public health sector. The lack of knowledge and information, both for the general population and among health professionals, compromises the immediate care needed to save victims

of snakebites. Based on a survey carried out by researchers from the Amazonas Tropical Medicine Foundation, it became apparent that both health professionals and patients had limited knowledge on snakebite management. We also found that there was a lack of effective technical tools for the prevention, control, or guidance in the pre-hospital care of these accidents. In view of these findings, the idea emerged to develop a mobile device app aimed at the proper management of snakebite accidents that would offer accessible and reliable information on first aid for the population and health professionals.

Stage 2: Theorization

Based on the findings of the first stage, stage 2 focused on substantiating the content of the app through a comprehensive literature review. We searched for scientific evidence on the management of snakebite envenomation using manuals from the Brazilian Ministry of Health, scientific articles, specialized guides on Brazilian snakes, and other reliable resources.

We searched LILACS (Latin American and Caribbean Health Sciences Literature; BIREME) and PubMed (U.S. National Library of Medicine) databases, selecting articles and sources that addressed the clinical manifestations of snakebite envenomation, clinical and preclinical management, and the characteristics of venomous and non-venomous snakes of the Brazilian fauna. Additionally, we consulted websites specializing in reptile fauna, such as the Reptile Database (<http://www.reptile-database.org/>) and iNaturalist (<https://www.inaturalist.org/home>). We also collected information from a reference list of health institutions that provide care for accidents with venomous animals, available on the official website of the Ministry of Health of Brazil (<https://www.gov.br/saude/pt-br/assuntos/saude-de-a-a-z/a/animais-peconhentos/hospitais-de-referencia>).

Stage 3: Solution hypotheses

After consolidating the theoretical base, we started stage 3, in which we developed a prototype of the mobile app called SERPENT-BRASIL. The app design was structured around five main areas according to the evidence collected during the theoretical review and on the contributions of experts from the Clinical Research Group on Animal Envenomation. It was also linked to the Graduate Program in Tropical Medicine at the Amazonas State University, Snakebite Roraima Research Group, and the Butantan Institute. This multidisciplinary team composed of experts from different fields ensured a comprehensive approach to app development.

The prototype content was organized into five main areas that were directly reflected in the app's interface, which was designed with simple and intuitive language. The five areas were:

1. Listing of snakes of the Brazilian fauna (characteristics, biology, and habitat)
2. Clinical manifestations of snakebite envenomation
3. Management of injured people, with emphasis on pre-hospital care and non-recommended techniques
4. Accident prevention techniques
5. Geo-referencing and contact information for Brazilian hospitals that dispense antivenoms

To develop the app, we relied on the SERPENT (Snake Emergency Response Programme & Response Tool) model, which is widely used in India to manage snake emergencies (10). This model was adapted to the needs and specific context found in Brazil, including the characteristics of local snakes and the logistical challenges faced in remote regions of the Amazon.

Stage 4: Using the app in the community setting

During stage 4, the app prototype was developed and adapted to the Brazilian context, considering the characteristics of local snakes, the specific needs of the population, and the challenges of providing care in remote regions. The main guidelines directing app development were: usability, reliability, efficiency, manageability, and portability. The app was programmed for use with Android and IOS devices and was designed to be intuitive and accessible for diverse user profiles, from health care professionals to the public. To ensure the app was adequately adapted to the needs in Brazil, we relied on the collaboration of the Indian development team (10), whose expertise facilitated the customization of the app's functionalities and an exchange of experiences essential for its optimization.

The next step of the study involved the evaluation and validation of the app by experts in the fields of health, education, graphic design, and information technology, as well as conducting usability tests with the target population, including among residents of endemic areas and health professionals. This step was essential to ensuring that SERPENT-BRASIL would meet the real demands of the population and contribute effectively to the management of snakebites throughout the country.

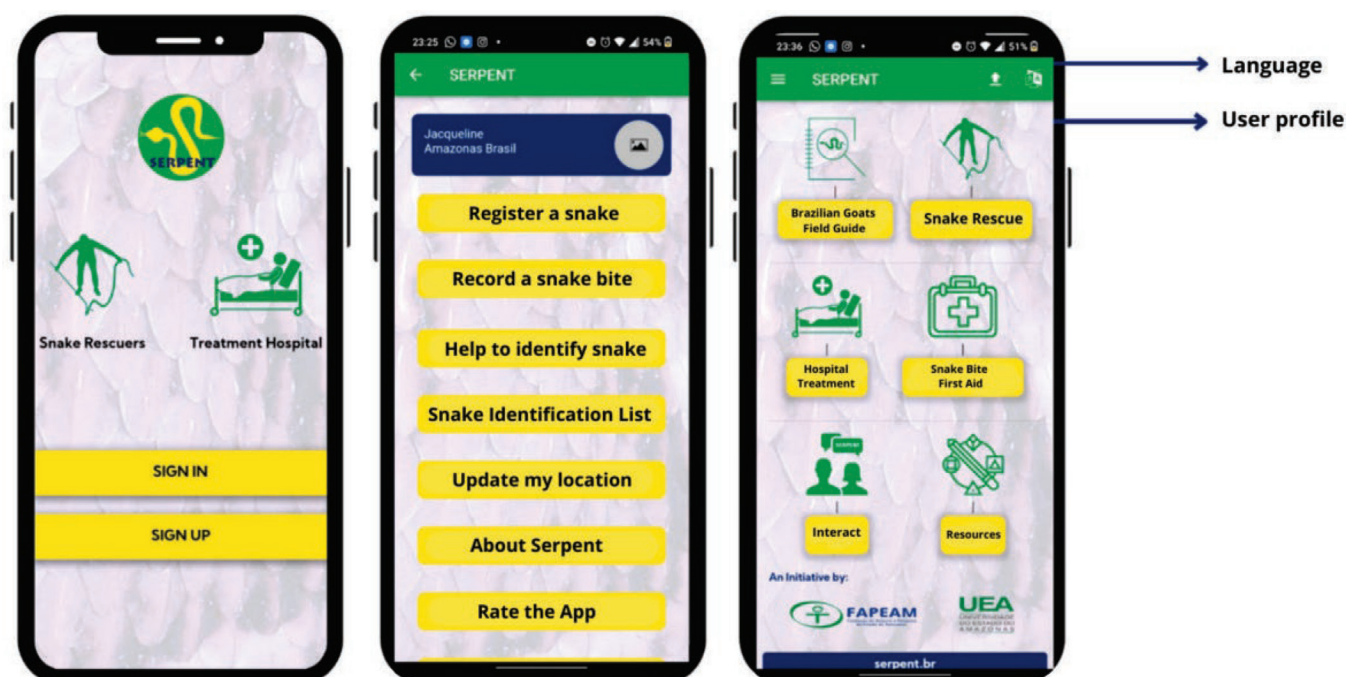
RESULTS

The SERPENT-BRASIL mobile app was developed in its initial version with an intuitive and easy-to-navigate interface. From the prototyping of 16 screens, the app was designed to assist in the management of victims of snakebites, with an emphasis on pre-hospital care. The "Hospital Treatment" icon on the home screen provides immediate access to the user, even when the user is offline, to the nearest hospital that has antivenom. By selecting this option, the app uses the Google Maps interface to trace the route to the chosen hospital, ensuring quick and efficient access to treatment.

For users in online mode, the app provides the option to either *SIGN IN* (for users already registered) or *SIGN UP* (for new users), allowing for more personalized navigation. After logging in, the user is directed to the main screen, where they can access their user profile, select the preferred language (Portuguese or English) and explore various features, including:

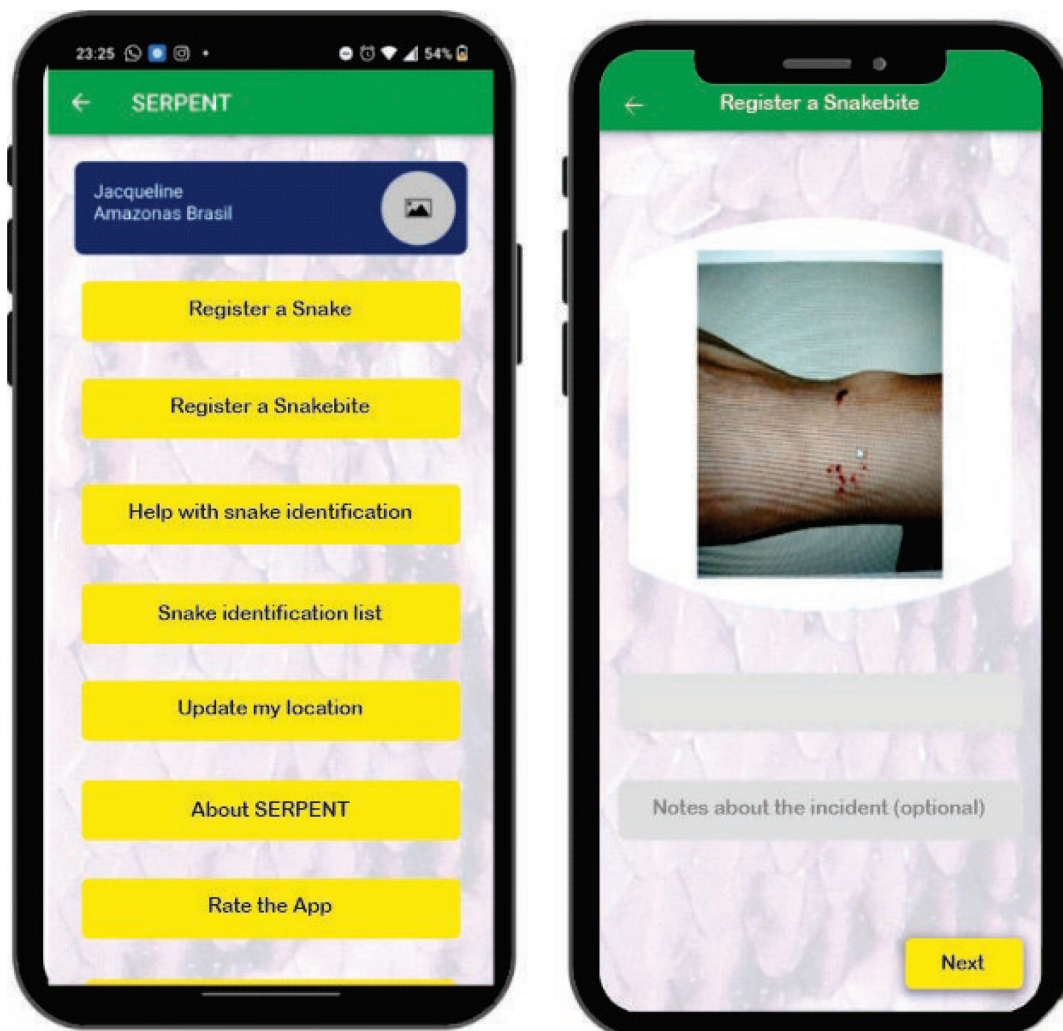
1. Brazilian snakes field guide: a descriptive and illustrative list of Brazilian snakes
2. Snake rescue: detailed guidance on how to proceed in cases when snake capture and/or extraction is necessary
3. Hospital treatment: information on places that offer treatment with antivenoms
4. Snakebite first aid: instructions on how to proceed immediately after the bite
5. Interact: function that allows the user to share information and experiences with the application's community
6. Resource: quick access to teaching and pedagogical materials (Figure 1).

Figure 1. Display screens of the SERPENT-BRASIL mobile app



Source: SERPENT-BRASIL, Manaus, Amazonas, Brazil, 2023.

Figure 2. “Report a snakebite” screen in the SERPENT-BRASIL app



Source: SERPENT-BRASIL, Manaus, Amazonas, Brazil, 2023.

In addition, on the main screen, by clicking on the icon located in the upper left corner (represented by three horizontal dashes), the user sees seven additional options (Figure 1):

1. Register a snake
2. Register a snakebite
3. Snake identification help
4. Snake identification list
5. Update my location
6. About SERPENT
7. Evaluate the app
8. Sign out

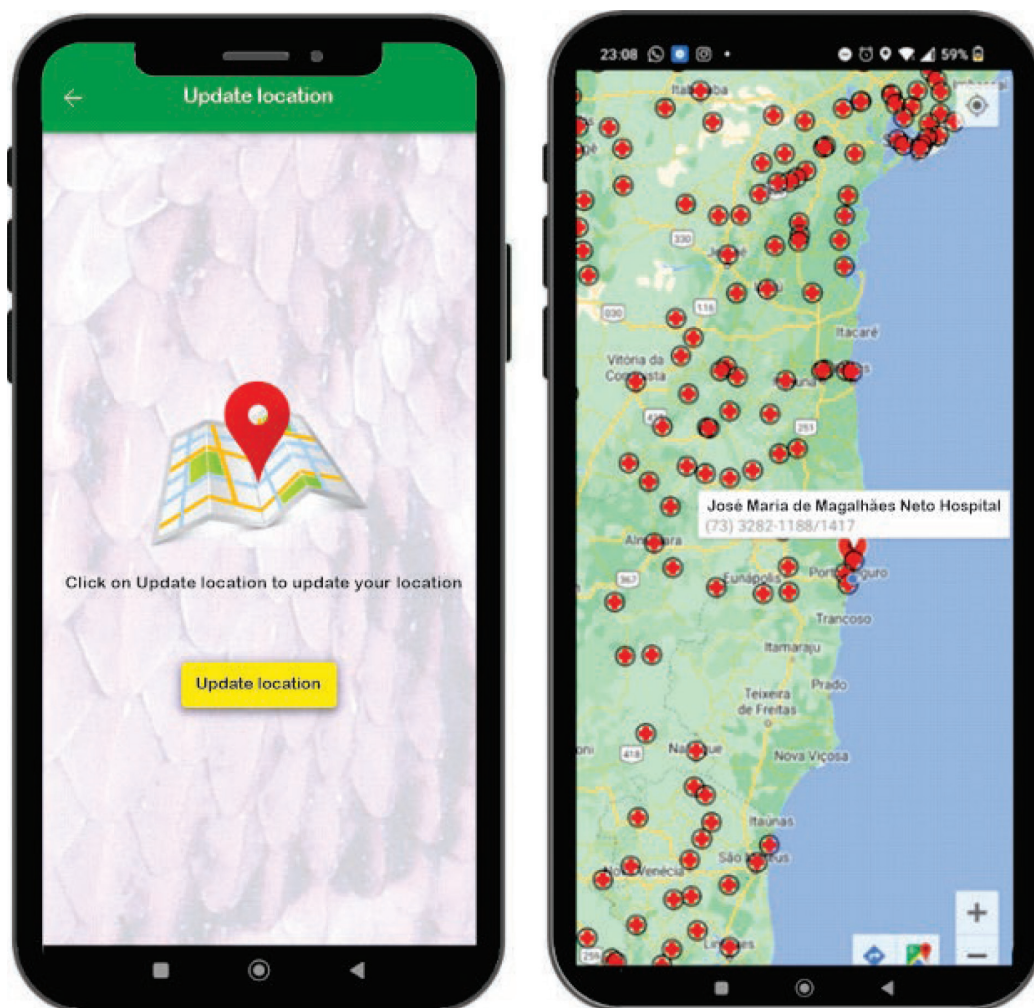
These features provide a complete and integrated experience for the management of snakebites, from the registration of occurrences to access to essential information for the safety of the user and the community. All these commands were developed with simple and intuitive language, making them easy to use for different user profiles.

The module “record a snakebite” allows the insertion of relevant information to assist in the pre- and intra-hospital care of victims of snakebites. Through this feature, users upload an image (photograph) of the bite on the body, as well as add detailed notes about the accident, such as the time and circumstances of the occurrence (Figure 2).

The “update my location” function (Figure 1) allows the user to keep update their geographic position in real time. This feature is important to ensure that the SERPENT-BRASIL app automatically identifies the user’s geographic position, and based on this location, offers a list of the nearest hospitals and/or specialized treatment centers through the “hospital treatment” module (Figure 3).

In addition to the features aimed at locating hospitals that offer treatment, the SERPENT-BRASIL app offers several educational materials to guide users on first aid for snakebites. The “resources” module offers a variety of informative and educational materials, as illustrated in Figure 4. These materials, prepared by Rock et al. (11), are presented in a clear and

Figure 3. Instructional display on how to locate a health care facility for anti-venom care using the SERPENT-BRASIL mobile app



Source: SERPENT-BRASIL, Manaus, Amazonas, Brazil, 2023.

accessible way, facilitating the dissemination of important knowledge for the initial management of snakebites.

DISCUSSION

The development of the SERPENT-BRASIL mobile app represents an important advancement in the management of snakebite accidents in Brazil. According to data from SINAN, approximately 33 838 cases of snake envenomation are reported each year in Brazil. Although the mortality rate has decreased in recent decades, snakebite accidents still require constant attention, especially in remote and hard-to-access areas where health care resources are limited (5, 6).

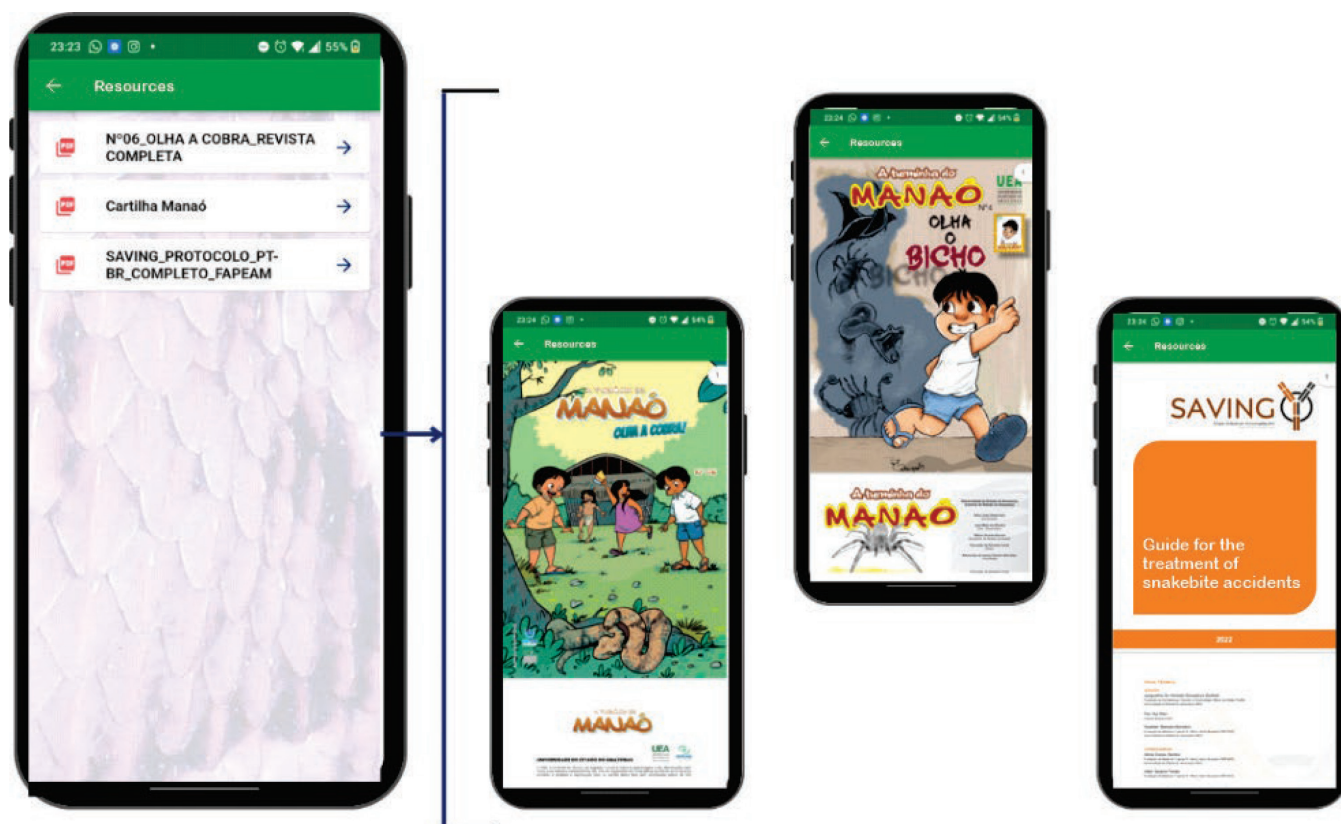
In this context, SERPENT-BRASIL was designed to provide guidance and immediate assistance in case of snake envenomation, improving emergency response and preventing severe complications. The app enables the rapid identification of health care centers that provide antivenom and offers first aid instructions, substantially reducing the time between the accident and the start of appropriate treatment, a decisive factor for patient prognosis (12). With the introduction of this innovative tool, it

is expected that not only will emergency care improve, but the model may also be replicated for other health emergencies that would benefit from integrating health services and technology for more complete and expeditious management (13).

Among the main features, the app enables users to report snake sightings, request the rescue of these reptiles (i.e., their safe extraction from human-populated areas by designated authorities), and identify the nearest health centers that provide antivenom and the destination of rescued snakes depends on local wildlife management policies. Available for free on Google Play and Apple Store, the app's easy accessibility promotes its widespread use and download in any country. Continuous adjustments will be implemented based on feedback received during the validation phase to ensure its practicality and effectiveness.

In addition to assisting in the diagnosis and choice of the most appropriate therapy, SERPENT-BRASIL offers essential information that can support health professionals in the management of accidents, including the diagnosis and the choice of the most appropriate therapy. The app also contributes to the proper notification of cases to SINAN (5). This function is

Figure 4. Examples of educational materials available on the SERPENT-BRASIL mobile app



Source: SERPENT-BRASIL, Manaus, Amazonas, Brazil, 2023.

important not only because it allows the individual monitoring of victims, but also because it provides important epidemiologic data for health surveillance, facilitating the development of more efficient public policies for the prevention and control of snakebites (14, 15).

A powerful innovation in the app is the ability to upload images of snakes and snakebites and add specific details about the accident. This gives the health care provider a more complete picture of the situation before the patient arrives at the hospital. Recent studies show that the use of images generated by mobile devices can facilitate remote assessments, optimizing emergency care (16, 17). This functionality is particularly important in emergency situations, where the ability to quickly locate the nearest health center can be decisive for the patient's prognosis and outcomes. Some studies have been evaluating the use of body images generated by smartphone devices for health assessment (18-20). Regarding dermatologic evaluations using only images of parts of the skin, the promising results favor remote evaluation.

SERPENT-BRASIL was designed to operate anywhere in Brazil, both online and offline, an essential characteristic for remote and hard-to-reach areas, such as the Amazon, where internet access is often limited and health care infrastructure is precarious, dispersed, or nonexistent. In addition, this functionality is particularly important where weather conditions, such as heavy rains and seasonal floods, can worsen the isolation of

communities and make transportation to hospitals difficult. By allowing use offline, the app offers crucial information for managing snakebite incidents, regardless of connectivity, ensuring that both victims and health care professionals have first aid instructions and the location of nearest hospitals with antivenom in hand, even in the most adverse situations. In this way, SERPENT-BRASIL represents a technological solution that plays a vital role in reducing the time between the accident and the start of treatment, contributing to a quicker and more effective response in areas where transportation logistics and weather conditions pose major challenges (6, 7, 21).

In addition to providing information about the nearest hospital, SERPENT-BRASIL ensures that, even in isolated regions, users can access educational content that provides guidance on first aid for snakebite envenomation. These materials are important to train the population to respond appropriately before professional help arrives, especially in situations where timely actions and knowledge can affect survival outcomes and reduce complications. Thus, the app plays a paramount role not only in emergency care but also in ongoing education, prevention of complications, and enhancing community safety (7, 22).

Furthermore, in addition to the educational and informative resources available in the SERPENT-BRASIL app, it is important to adopt a comprehensive approach to reduce complications resulting from inappropriate and/or delay in care.

The availability of tools such as SERPENT-BRAZIL, which facilitate the rapid identification of the nearest health facilities and trained first responders, play a key role in the proper management of these accidents (23). Moreover, promoting research that evaluates the response of health authorities to these incidents is essential for developing effective strategies that enhance the use of technological tools and solutions aimed at preventing and treating snakebites in Brazil and worldwide (1, 25).

The SERPENT-BRASIL app will proceed to the next stage, evaluation and validation by experts in the field. This will include usability testing with the target population, following recommendations from the literature and the Brazilian technical standards for this type of technology (26, 27). The assessment of the technical-scientific dimension will be conducted by expert evaluators in health and biology, particularly those specializing in venomous fauna. For the evaluation of the didactic-illustrative or communication-interface dimension, expert evaluators from education, social communication, graphic design, human sciences, and information technology will also be involved. Semantic validation will take place in both institutional and non-institutional settings to ensure the broad applicability and effectiveness of the application.

Thus, SERPENT-BRASIL not only offers an innovative resource for managing snakebite incidents but also stands as a crucial tool for advancing public health in Brazil. It promotes a comprehensive approach that integrates treatment, education, and research.

Impact and future prospects

The development of the SERPENT-BRASIL app is an important advancement in improving the treatment of snakebite incidents in Brazil, especially in remote regions where access to immediate care is limited. With an intuitive interface and comprehensive features, the app facilitates access to information, promotes health education, and encourages community interaction. By empowering local communities, SERPENT-BRASIL can reduce incidents of improper handling of snakebites before reaching the hospital, thereby minimizing serious complications.

The next steps are evaluation and validation of the app by experts in health, education, graphic design, and information technology. Usability tests will be conducted with the target population, including residents of endemic areas and health care professionals, ensuring that SERPENT-BRASIL meets real demands and effectively contributes to the management of snakebite incidents across the country. The app's robustness and its adaptation to different local realities are essential for ensuring its long-term effectiveness.

The technical quality of the app will be evaluated in terms of its functionality, costs, productivity, and safety in both the short and long term (28). Validation will follow the standards set by the Brazilian regulations (Norm ABNT ISO/IEC 25062:2011), which regulate the evaluation of software for educational and health technologies (26, 27).

The evaluation will be divided into three dimensions:

1. Technical-scientific analysis by health and biology experts
2. Didactic-illustrative evaluation of the app's visual presentation by communication and graphic design professionals

3. Semantic validation in institutional and non-institutional contexts to ensure that the app is understandable among different audiences

This process will verify that SERPENT-BRASIL meets user needs and contributes to health education and the management of snakebite incidents in Brazil.

Conclusions

The SERPENT-BRASIL app is an innovative tool for preventing and managing snakebites, providing guidance on pre-hospital care and reducing complications from snakebites. By enhancing access to information and antivenom-equipped hospitals, the app eases the burden on health services and expedites care for the victim of a snakebite.

In addition to its immediate public health benefits, SERPENT-BRASIL serves as a valuable data collection platform that supports future research on snakebite envenomation and epidemiologic mapping. The data recorded can help identify high-risk areas, contributing to more effective public policies and surveillance strategies. By integrating technology with health, SERPENT-BRASIL represents a meaningful advancement in tropical medicine. Future enhancements could further expand its capabilities, solidifying its role as a key resource for public health.

Author contributions.

JAGS, GSR, MBP, and WMM contributed to the conception and design of the study; JAGS, GSR, ES, AGACM, HSP, VCPRS, KMPC, MBP, and WMM contributed to the acquisition, analysis, and interpretation of the data; JAGS, GSR, ES, PFB, LLS, MBP, and WMM contributed to the writing of the manuscript and critical review of the intellectual content. All authors reviewed and approved the final version.

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Conflicts of interest. None declared.

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SERPENT-Brazil: una herramienta tecnológica para casos de mordeduras de serpiente

RESUMEN

Objetivo. Informar sobre el desarrollo y las características de una aplicación móvil que tiene como objetivo orientar al público y a los profesionales de la salud sobre medidas de emergencia prehospitales tras el envenenamiento por mordedura de serpiente.

Métodos. Se realizó un estudio metodológico en cuatro fases entre junio del 2020 y julio del 2022. El desarrollo de la aplicación incluyó la creación de un recurso móvil para brindar orientación sobre la atención prehospitalaria y dirigir a las víctimas a los hospitales que tienen antídotos.

Resultados: La aplicación SERPENT-Brazil se desarrolló para su uso en dispositivos Android e iOS por medio de una interfaz intuitiva. Ofrece acceso en línea y fuera de línea a información sobre hospitales y mapas de rutas a través de Google Maps. Además, permite a los usuarios informar sobre avistamientos de serpientes y solicitar rescates de emergencia.

Conclusiones: La aplicación SERPENT-Brazil mejora el manejo y la prevención de las mordeduras de serpiente, alivia la carga en los servicios de salud y promueve la educación en materia de salud. Recopilar datos sobre envenenamiento por mordedura de serpiente contribuye a mejorar la seguridad pública, por lo que esta aplicación es un recurso esencial para la seguridad pública en Brasil.

Palabras clave

Envenenamiento por serpiente; orientación de emergencia; informática en salud pública; salud móvil; gestión de muestras; Brasil.

SERPENT-BRASIL: ferramenta tecnológica para o manejo de picadas de cobras

RESUMO

Objetivo. Descrever o desenvolvimento e as funcionalidades de um aplicativo móvel para orientar o público e os profissionais de saúde sobre as medidas de emergência pré-hospitalares após o envenenamento por picada de cobra.

Métodos. Trata-se de um estudo em quatro etapas realizado de junho de 2020 a julho de 2022. O desenvolvimento do aplicativo incluiu a criação de um recurso móvel para orientar a atenção pré-hospitalar e direcionar as vítimas a hospitais que tenham soro antiofídico.

Resultados: Desenvolvido para uso em dispositivos Android e iOS, o aplicativo SERPENT-BRASIL tem uma interface intuitiva e oferece acesso on-line e off-line a informações sobre hospitais e as melhores rotas para chegar até eles por meio do Google Maps. Além disso, permite que os usuários comuniquem o avistamento de cobras e solicitem resgate de emergência.

Conclusão: O aplicativo SERPENT-BRASIL melhora o manejo e a prevenção de picadas de cobras, alivia a carga sobre os serviços de saúde e promove a educação em saúde. A coleta de dados sobre envenenamento por cobras contribui para a segurança pública, o que torna o aplicativo um recurso essencial nessa área no Brasil.

Palavras-chave

Envenenamento por cobra; orientação de emergência; informática em saúde pública; gestão de amostras; Brasil.
