

Healthcare workers' prioritization of snake antivenoms for the treatment of snakebite envenoming: Perspectives from Ghana

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Abstract

Introduction: In low- and middle-income countries (LMICs) with tropical or subtropical climate and a high poverty rate the risk for snakebite envenoming (SBE) is high. Although patients ultimately receive antivenom treatment, healthcare workers are the primary end-users rather than the patients themselves. This study aimed to assess healthcare workers' antivenom prioritization by providing quantitative evidence to guide policymakers to make better decisions to improve the procurement and supply of antivenoms, enhance the effectiveness of snakebite treatment, and improve patient care quality in health facilities in Ghana and other LMICs where SBE is common.

Method: We collected data by conducting an interview-based survey using questionnaires. We randomly selected 203 healthcare workers from the Kwahu Afram Plains North and South districts in the Eastern Region of Ghana in August 2023. We used the best-worst scaling experiment design method to assess healthcare workers prioritization of snake antivenoms available for use in sub-Saharan Africa.

Result: Among the antivenoms available for use in sub-Saharan Africa, participants highly prioritized Inoserp Pan-Africa polyvalent antivenom. Snake Venom Antiserum -PanAfrica is also commonly prioritized, followed by ASNA antivenom D, ASNA antivenom C, Snake Venom Antiserum African - 10, Anti Snake Venom Serum Pan Africa – 10, and Fav-Afrique. However, some antivenoms are least commonly prioritized, such as SAIMR Echis, Combipack of Snake Venom Antiserum, Anti Snake Venom Serum Central Africa -6, Anti-Snake Venom Serum Central Africa, Snake Venom Antiserum Echiven Plus, Antivipmyn-Africa, Menaven, Snake Venom Antitoxin, Snake Venom Antiserum (Echiven), Anti Snake Venom Serum Monovalent Echis ocellatus, EchiTabG, and Snake venom antiserum Echis ocellatus (VINS-Echis). In comparison to other antivenoms, Inoserp Pan-Africa is more frequently prioritized. At the same time, Snake Venom Antiserum -PanAfrica is less frequently prioritized but still more likely than other options. EchiTabPlus (ET-Plus) is more likely to be prioritized than other antivenom options.

Conclusion: Our findings offer valuable insights to guide policy discussion on available antivenoms in treating SBE. There is an urgent need to implement regulations on antivenom products, improve

procurement and supply, offer ongoing education, and provide training to healthcare workers to combat the burden of SBE.

Keywords: Best-worst scaling, Snakebites, Snakebite envenomation, Ghana, Sub-Saharan Africa, Neglected Tropical Diseases

Author summary

Healthcare workers are the primary users of snake antivenoms rather than the patients who receive them. Therefore, their antivenom prioritization can help policymakers to make better decisions to improve the procurement and supply of quality antivenoms, enhance the effectiveness of snakebite treatment, and improve patient care quality in health facilities in Ghana and other low- and middle-income countries where snakebite envenoming is prevalent. To this end, we conducted a study to assess healthcare workers' antivenom prioritization and provide policymakers with quantitative evidence to guide decision-making. Using an interview-based questionnaire, we surveyed 203 healthcare workers in the Kwahu Afram Plains North and South districts in Ghana's Eastern Region in August 2023. The best-worst scaling experimental design method was used to assess participants' prioritization of different snake antivenom products available in sub-Saharan Africa. Most participants were female, aged 18 to 30 years old with 1-5 years of work experience. Many participants had received snakebite training and mostly lived in rural areas. The majority reported that farmers were the most commonly bitten population during the rainy season, in their farms or bush, between 9 am to 12 noon. Among the snake antivenom products in sub-Saharan Africa, polyvalent antivenoms were highly prioritized over monovalent ones. Inoserp Pan-Africa was the most frequently prioritized, followed by Snake Venom Antiserum -PanAfrica (Premium-A) and EchiTabPlus. Our findings provide valuable insights to guide policy discussions on available antivenoms in treating snakebite envenoming. We urge policymakers to implement regulations on antivenom products, improve quality antivenom procurement and supply, provide ongoing education, and offer training to healthcare workers to combat the burden of snakebite envenoming.

1. Introduction

Snakebite envenoming (SBE) is a severe and widespread condition primarily affecting marginalized communities in low- and middle-income countries (LMICs), such as rural villagers, agricultural workers, nomadic farmers, pregnant women, young males, and working children, who often have limited access to education and healthcare [1, 2, 3]. SBE is a medical emergency when snake venom is injected into the body through a bite or sprayed onto mucosal surfaces or eyes, causing severe bleeding, paralysis, kidney injury, muscle damage, and other local tissue damage [4, 2]. Depending on the venom's toxicity, SBE can lead to permanent disability and death if left untreated [5].

Since 2017, SBE has been classified as a Category A Neglected Tropical Disease (NTD) by the World Health Organization (WHO) [1], and has launched a global strategy to prevent and control SBE, aiming to reduce deaths and disabilities by 50% and deliver three million effective treatments annually by 2030 [6]. According to estimates, 5.4 million people worldwide are bitten by snakes yearly, with 2.7 million experiencing envenoming [2]. SBE is responsible for approximately 83,000-138,000 deaths per annum, and approximately 400,000 people per annum suffer from disabilities such as amputations, scarring leading to

impaired limb function, and post-traumatic stress disorder. In sub-Saharan Africa (SSA) alone, SBE is estimated to affect 435,000-500,000 people annually, with 20,000–32,000 deaths [7]. The hospital visit rate of snakebite victims in rural SSA alone was estimated at 56.4/100,000, and mortality was at 1.35/100,000 inhabitants [3]. In Ghana, rural health facility data put the incidence of snakebite at 35/100,000 inhabitants per annum, with up to 11% case fatalities [8, 9].

Among, the approximately 110 Africa venomous snake species, WHO considers 24 species from four genera (*Bitis*, *Dendroaspis*, *Echis*, and *Naja*) as having the highest (Category 1) medical importance (i.e., venomous snakes that are most encountered and pose the greatest potential threat to human life and wellbeing) in SSA. A further 24 species are of secondary (Category 2) medical importance (i.e., either because they are known to be highly venomous, but are either less frequently associated with serious snakebites, or have little epidemiological data available) [2]. Bites from these categories of snake species are often treated using heterologous animal plasma-derived immunoglobulin preparations, also known as antivenoms (here defined as purified antibodies against snakebite envenoming). Although antivenom products exist and are currently available with active pharmaceutical ingredient (API) (here defined as the specific antibody component that is produced through their production process) as either intact (whole) immunoglobulins (IgG), or as divalent fragment antibodies (F(ab')₂) or, more rarely, monovalent fragment antibodies (Fab) [1, 2], they are mainly classified as ineffective, untested, and weakly regulated in SSA [1]. This broadly negative narrative has given rise to substantial scepticism and concern over the usefulness of antivenoms [2]. Recent studies have investigated the immunomodulatory effects of traditional medicinal compounds [10, 11], suggesting potential complementary therapies that may influence antivenom prioritization.

However, efficient antivenom treatment is crucial in the first hours after a snakebite [4]. Unfortunately, antivenom availability and accessibility remain distant possibilities for most regions where SBE is endemic [12]. Instead of being available at rural health facilities, antivenoms are often only accessible in large referral hospitals [13]. In Ghana, it was reported that antivenoms supplied to designated health facilities were insufficient to meet the demand [14]. Only about 20% of healthcare workers in Uganda, Zambia, and Kenya reported available antivenom stock in 0–34% of facilities across the sectors and countries [15]. Antivenom was available in 45% of public and less than 20% of private facilities in Kenya [16].

Currently, most antivenoms available in SSA are broad-spectrum, Pan-African polyvalent products designed for WHO Category 1 *Bitis*, *Dendroaspis*, *Echis*, and *Naja* species. While some West African countries have monovalent antivenoms for bites by the Category 1 carpet vipers *Echis romani*/*Echis ocellatus*, there are limited quantities available for less common bites by the Category 2 colubrid *Dispholidus typus* [2]. In Ghana, the Food and Drug Authority (FDA) provides guidelines for antivenom registration [17]. All the three registered antivenoms (i.e., Anti Snake Venom Serum Pan Africa – 10, Snake Venom Antiserum -PanAfrica (Premium-A), Snake Venom Antiserum African - 10 (Afriven 10)) [18] are polyvalent and of equine origin.

Although the availability of antivenoms at health facilities involves various processes, including development, manufacture, registration, pricing, procurement, supply, prescribing, and dispensing [4], early diagnosis of symptoms and signs of snakebite envenoming by healthcare workers is crucial for appropriate antivenom administration [2]. Therefore, understanding healthcare workers' antivenom prioritization is essential to provide strategies to improve patient safety and treatment efficacy in Ghana and other LMICs

where SBE is common. The available research primarily focuses on the burden of snakebite, control, and management, estimated cost to meet, projected antivenom need, availability, accessibility, management, and use of antivenoms [3, 19, 20, 21, 4, 22, 23, 14, 24], but there is lack of data on healthcare workers' antivenom prioritization. In light of WHO's strategy for the prevention and control of SBE, it is necessary to improve the information on snake antivenoms available for use in sub-Saharan Africa to have a more robust platform to build strategies to combat this NTD. The present study aims to address this gap by assessing healthcare workers' antivenom prioritization. The study was conducted in the Eastern Region of Ghana and focused on two districts, namely Kwahu Afram Plains North District and Kwahu Afram Plains South District. Using the best-worst scaling (BWS) methodology, we provide a detailed quantification of healthcare workers' antivenom prioritization. Policymakers and healthcare providers can leverage this information to enhance the procurement and supply of antivenoms, improve the efficacy of snakebite treatment, and elevate patient safety and care quality in health facilities in Ghana and SSA, where snakebite envenoming is a significant concern.

2. Methods

2.1. Ethical approval and consent to participate

The study followed ethical guidelines and regulations. Ethical clearance was obtained from the Ethics Committee of the College of Basic and Applied Sciences, University of Ghana (Reference No: ECBAS 065/22-23). Before collecting data, written informed consent was obtained from all respondents after explaining the purpose of the study. It was emphasized that participation in the study was voluntary, and respondents had the choice to decline. Respondents' confidentiality and anonymity were safeguarded using unique identifiers.

2.2. Study site

The study was conducted in the Eastern Region (representing 9.5% of Ghana's population [25]) of Ghana and focused on two districts, namely Kwahu Afram Plains North District (KAPND) and Kwahu Afram Plains South District (KAPSD). These districts were selected based on reported cases of snake bites [26] and consultation with primary healthcare personnel. The KAPND is bordered to the south by KAPSD, the Volta River to the east, and two districts in the Ashanti Region (Sekyer East and Asante-Akim) to the west. KAPND, which covers an area of 2,570 square kilometers, has a population density of 25.9 persons per square kilometer and a population of 66,555, representing 2.3% of the regional population. The male population is 53.4%, the female population is 46.6%, and the average household size is 3.7 [27, 25]. KAPSD is bordered north by KAPND, Kwahu South to the south, the Volta River to the east, and two districts in the Ashanti region (Sekyer East and Ashanti-Akim) to the west. KAPSD covers an area of 3,051 square kilometers, has a population density of 24.3 persons per square kilometer, and a population of 74,002, representing 2.5% of the regional population. The male population is 53.3%, the female population is 46.7%, and the average household size is 3.8 [27, 25].

Both districts are in the savannah vegetation zone, with short deciduous fire-resistant trees and varying grass heights. The rainfall occurs in June and October (the first rainy season starts from May to June and the second from September to October), with the mean annual rainfall ranging from 1,150mm to 1,650mm.

The dry seasons start between November and late February, with high temperatures ranging from 36.6°C to 36.8°C in February and March, respectively, and low temperatures between 19.1°C and 20.1°C in December and January. The Afram and Volta rivers are the primary drainage sources in both districts and are utilized throughout the year for farming, fishing, and household activities [28, 27].

2.3. Sample size and data collection

To conduct this study, we surveyed healthcare workers in the KAPND and KAPSD districts of the Eastern Region of Ghana in August 2023. Data was collected from a simple random sample of 203 out of 698 healthcare workers, including community health nurses, physician assistants/medical doctors, and certificate/enrolled/general nurses in twelve healthcare facilities. The workers were contacted during working hours in the various health facilities. It is worth noting that some of the healthcare workers contacted may not administer antivenoms but involved in the management of snakebites. A prior study in Ghana indicated that medical doctors, registered nurses, physician assistants, community health nurses, and pharmacy technicians were the primary healthcare professionals involved in managing snakebites [29]. The minimum number of required respondents (N) is 81, based on a sample size calculation [30] and the available scenarios ($l=19$) using the formula $N=n/l$. Here, $n \geq r^2 s / v a^2$, where $r = \Phi^{-1}(1 - \alpha/2)$ represents the inverse cumulative distribution function of a standard normal distribution reported at $(1 - \alpha/2)$, v is the true choice proportion of the study population obtained under the assumption of equal choice probabilities, a is the allowable deviation as a percentage between the estimate $\hat{v}$ and v , $s = 1 - v$, α is the level of 95% confidence in the estimations such that $\Pr(|\hat{v} - v| \leq av) \geq \alpha$ for any given sample n under the standard normal distribution. The anticipated sample size of 203 respondents was enough, and all 203 distributed questionnaires were included in the final analysis because of no missing data. This was made possible because enumerators were available to assist and guide respondents in completing the survey instrument.

2.4. Best-worst scaling

In various fields such as healthcare, conflict resolution, environmental sustainability, and consumer research, the BWS approach is used to elicit preferences for various goods and services [31, 32, 33, 34, 35, 36]. Respondents are asked to choose the best (or most desired/preferred) and worst (or least desired/preferred) options from a list of at least three attributes within a BWS scenario or choice set. BWS method enables evaluation of the relative importance of attributes across multiple scenarios. This method requires more cognitive work and involvement than typical rating scale tasks, which might help respondents complete a decision task [37]. Earlier works have also highlighted that BWS [38, 39] is more appealing than discrete choice experiment design approach [40].

In this study, we utilized BWS Case 1 [41]. We started with an initial list of 28 attributes related to snake antivenoms based on a literature review [20, 1, 4]. Notably, although there was some overlap, 6, 2, and 20 of the antivenoms appeared in [1], [4], and [20], respectively. Through focus group discussions with healthcare professionals, we validated and narrowed this list down to twenty plausible snake antivenoms. Notwithstanding, a literature scrutiny was carried out using ScienceDirect [<https://www.sciencedirect.com/#life-sciences>] PubMed [<https://pubmed.ncbi.nlm.nih.gov>] and Google Scholar [<https://scholar.google.com>] databases to unearth published works on snake antivenoms that have been used or available/recommended for use in the management and treatment of SBE in Ghana. Although may not be exhaustive, the search revealed 11 of such antivenoms, of which only three are registered with

the FDA (Table 1). Table 1 provides information on the snake antivenom products available for treating snakebite envenoming in SSA, including the brand name, the facilities producing them, the country of production, and the snake species against which the antivenom is active.

Table 1

Snake antivenoms available for treating snakebite envenoming

	Antivenoms	Description
1	ASNA antivenom C (ASNA-C)*	Antivenom brand: Name of facility and country: Type of API: Snake species covered: - ASNA antivenom C (ASNA-C) - Bharat Serums and Vaccines, India - F(ab')₂-equine - <i>Bitis arietans</i>, <i>B. gabonica</i>, <i>B. nasicornis</i>, <i>Dendroaspis angusticeps</i>, <i>D. jamesoni</i>, <i>D. polylepis</i>, <i>Echis carinatus</i>, <i>Naja haje</i>, <i>N. melanoleuca</i>, <i>N. nigricollis</i>, <i>N. nivea</i>
2	ASNA antivenom D (ASNA-D)	Antivenom brand: Name of facility and country: Type of API: Snake species covered: - ASNA antivenom D (ASNA-D) - Bharat Serums and Vaccines, India - F(ab')₂-equine - <i>B. arietans</i>, <i>B. gabonica</i>, <i>B. nasicornis</i>, <i>D. angusticeps</i>, <i>D. jamesoni</i>, <i>D. polylepis</i>, <i>E. ocellatus</i>, <i>N. haje</i>, <i>N. melanoleuca</i>, <i>N. nigricollis</i>, <i>N. nivea</i>
3	Fav-Afrique (FAV-A)*	Antivenom Brand: Name of Facility and country: Type of API: Snake species covered: - Fav-Afrique (FAV-A) - MicroPharm Ltd, UK - F(ab')₂-equine - <i>B. arietans</i>, <i>B. gabonica</i>, <i>B. jamesoni</i>, <i>D. polylepis</i>, <i>D. viridis</i>, <i>E. leucogaster</i>, <i>E. ocellatus</i>, <i>N. haje</i>, <i>N. melanoleuca</i>, <i>N. nigricollis</i>
4	EchiTabPlus (ET-Plus)*	Antivenom Brand: Name of facility and country: Type of API: Snake species covered: - EchiTabPlus (ET-Plus) - Instituto Clodomiro Picado, University of Costa Rica, Costa Rica - Immunoglobulin G (IgG) (Intact IgG —ovine) - <i>B. arietans</i>, <i>B. gabonica</i>, <i>B. rhinoceros</i>, <i>B. nasicornis</i>, <i>E. ocellatus</i>, <i>E. leucogaster</i>, <i>E. pyramidum</i>, <i>E. coloratus</i>, <i>N. nigricollis</i>, <i>N. ashei</i>, <i>N. mossambica</i>, <i>N. katiensis</i>
5	Inoserp Pan-Africa (Inoserp-P)*	Antivenom brand: Name of facility and country: Type of API: Snake species covered: - Inoserp Pan-Africa (Inoserp-P) - Inosan Biopharma, S.A., Spain - F(ab')₂-equine - <i>B. arietans</i>, <i>B. gabonic</i>, <i>B. nasicornis</i>, <i>B. rhinoceros</i>, <i>D. angusticeps</i>, <i>D. jamesoni</i>, <i>D. polylepis</i>, <i>D. viridis</i>, <i>E. leucogaster</i>, <i>E.</i>

			<i>ocellatus, E. pyramidum, N. haje, N. katiensis, N. melanoleuca, N. nigricollis, N. nivea, N. pallida</i>
6	Antivipmyn-Africa (Antivip-A)*	Antivenom brand: Name of facility and country: Type of active substance: Snake species covered:	- Antivipmyn-Africa (Antivip-A) - Instituto Bioclon/Silanes, Mexico - F(ab') ₂ -equine - <i>B. arietans, E. ocellatus, E. pyramidum, E. romani</i>
7	SAIMR Echis*	Antivenom brand: Name of facility and country: Type of active substance: Snake species covered:	- SAIMR Echis - South African Vaccine Producers (SAVP), South Africa - F(ab') ₂ -equine - <i>E. carinatus, E. ocellatus, E. coloratus, E. pyramidum, C. cerastes</i>
8	Snake Venom Antiserum - PanAfrica (Premium-A)**	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Antiserum -PanAfrica (Premium-A) - Premium Serums and Vaccines, India - F(ab') ₂ -equine - <i>B. arietans, B. gabonica, B. nasicornis, B. rhinoceros, D. angusticeps, D. jamesoni, D. polylepis, D. viridis, E. carinatus, E. leucogaster, E. ocellatus, N. nigricollis, N. haje, N. melanoleuca</i>
9	Snake Venom Antiserum - Central Africa (Premium-CA)	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Snake Venom Antiserum - Central Africa (Premium-CA) - Premium Serums and Vaccines, India - F(ab') ₂ -equine - <i>B. rhinoceros, E. carinatus, D. polylepis, Daboia russelli</i>
10	Combipack of Snake Venom Antiserum (African- Ten)	Antivenom brand: Name of facility and country: Type of active substance: Snake species covered:	- Combipack of Snake Venom Antiserum (African- Ten) - Premium Serums and Vaccines, India - F(ab') ₂ -equine - <i>B. rhinoceros, E. carinatus, D. russelli, D. polylepis</i>
11	Snake Venom Antiserum African - 10 (Afriven 10)**	Antivenom brand: Name of facility and country: Type of active substance: Snake species covered:	- Snake Venom Antiserum African-10 (Afriven 10) - VINS Bioproducts, India - F(ab') ₂ -equine - <i>B. arietans, B. gabonica, D. jamesoni, D. polylepis, D. viridis, E. leucogaster, E.</i>

			<i>ocellatus, N. haje, Naja melanoleuca, N. nigricollis</i>
12	Menaven, Snake Venom Antitoxin	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Menaven, Snake Venom Antitoxin - VINS Bioproducts, India - F(ab') ₂ -equine - <i>Cerastes cerastes, N. haje, N. nigricollis</i>
13	Snake Venom Antiserum Echiven Plus	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Snake Venom Antiserum Echiven Plus - VINS Bioproducts, India - F(ab') ₂ -equine - <i>N. nigricollis, N. haje, D. polylepis, B. arietans, E. ocellatus</i>
14	Anti-Snake Venom Serum Central Africa (VINS-CA)	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Anti-Snake Venom Serum Central Africa (VINS-CA) - VINS Bioproducts, India - F(ab') ₂ -equine - <i>B. gabonica, E. carinatus, D. russelli, Dendroaspis polylepis</i>
15	Anti Snake Venom Serum Central Africa -6	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Anti Snake Venom Serum Central Africa -6 - Biological E Limited, India - F(ab') ₂ -equine - <i>B. arietans, C. cerastes, D. deserti, E. leucogaster, N. haje, N. nigricollis</i>
16	Anti Snake Venom Serum Pan Africa – 10**	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Anti Snake Venom Serum Pan Africa – 10 - Biological E Limited, India - F(ab') ₂ -equine - <i>B. arietans, B. gabonica, D. jamesoni, D. polylepis, D. viridis, E. leucogaster, E. ocellatus, N. haje, Naja melanoleuca, N. nigricollis</i>
17	EchiTABG*	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- EchiTABG - Monospecific MicroPharm Ltd, UK - Immunoglobulin G (IgG) (Intact IgG —ovine) - <i>E. coloratus, E. ocellatus, E. pyramidum</i>
18	Snake venom antiserum Echis ocellatus (VINS-Echis)	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Snake venom antiserum Echis ocellatus (VINS-Echis) - VINS Bioproducts, India - F(ab') ₂ -equine - <i>E. ocellatus</i>
19	Snake Venom Antiserum (Echiven)	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Snake Venom Antiserum (Echiven) - VINS Bioproducts, India - F(ab') ₂ -equine - <i>E. ocellatus</i>

20	Anti Snake Venom Serum Monovalent Echis ocellatus*	Antivenom brand: Name of facility and country: Type of API: Snake species covered:	- Anti Snake Venom Serum Monovalent Echis ocellatus - Biological E Limited, India - F(ab') ₂ -equine - <i>E. ocellatus</i>
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*Snake antivenom products available for treating SBE in SSA with names of facilities producing them, country of production, and snake species against which antivenom is active according to product insert. API: active pharmaceutical ingredient; (F(ab')₂: dimeric antigen-binding fragments. *= snake antivenoms that have been used or available/recommended for use in Ghana; **=Registered snake antivenoms with the Food and Drug Authority of Ghana.*

A statistical experiment block design [42] was used to randomly assign the snake antivenoms products in the BWS. We created 95 BWS scenarios, each containing four snake antivenoms. To make it easier for participants, we divided the 95 BWS scenarios into five equal blocks of 19 scenarios each [34]. Each participant was randomly assigned to one block with 19 BWS scenarios/questionnaires, each with four antivenoms. Through an interviewer-administered questionnaire, participants were asked to choose which antivenom they prioritize most and the least by writing out their responses using paper and pencil. We calculated the relative importance of each snake antivenom based on the frequency of choices made by participants. We collected demographic data from participants and asked them some questions about their experience or background before starting the survey. We also pilot tested the questionnaire with ten healthcare workers to ensure that respondents understood the definition of the snake antivenom products and could make trade-offs between them. Participants were verbally informed about the snake antivenom profiles and asked to inform the interviewer if any part of the survey needed clarification or was easier to answer. Participants found the survey questionnaire to be transparent and easy to answer. Although some participants believed that some snake antivenoms might not be available in the health facilities, none suggested any other antivenom for inclusion in the study. Fig. 1 shows a completed example BWS scenario.

<i>MOST prioritized antivenom</i>	<i>Antivenom products</i>		<i>LEAST prioritized antivenom</i>
	<u>Antivenom brand:</u> <u>Name of facility and country:</u> <u>Type of API:</u> <u>Snake species covered:</u>	- ASNA antivenom D (ASNA-D) - Bharat Serums and Vaccines, India - F(ab') ₂ -equine - <i>B. arietans</i> , <i>B. gabonica</i> , <i>B. nasicornis</i> , <i>D. angusticeps</i> , <i>D. jamesoni</i> , <i>D. polylepis</i> , <i>E. ocellatus</i> , <i>N. haje</i> , <i>N. melanoleuca</i> , <i>N. nigricollis</i> , <i>N. nivea</i>	
	<u>Antivenom brand:</u> <u>Name of facility and country:</u> <u>Type of API:</u> <u>Snake species covered:</u>	- Anti Snake Venom Serum Monovalent Echis ocellatus - Biological E Limited, India - F(ab') ₂ -equine - <i>E. ocellatus</i>	✓
✓	<u>Antivenom brand:</u>	- Inoserp Pan-Africa (Inoserp-P)	

	<u>Name of facility and country:</u> <u>Type of API:</u> <u>Snake species covered:</u>	- Inosan Biopharma, S.A., Spain - F(ab')₂-equine - <i>B. arietans</i>, <i>B. gabonic</i>, <i>B. nasicornis</i>, <i>B. rhinoceros</i>, <i>D. angusticeps</i>, <i>D. jamesoni</i>, <i>D. polylepis</i>, <i>D. viridis</i>, <i>E. leucogaster</i>, <i>E. ocellatus</i>, <i>E. pyramidum</i>, <i>N. haje</i>, <i>N. katiensis</i>, <i>N. melanoleuca</i>, <i>N. nigricollis</i>, <i>N. nivea</i>, <i>N. pallida</i>	
	<u>Antivenom brand:</u> <u>Name of facility and country:</u> <u>Type of API:</u> <u>Snake species covered:</u>	- Fav-Afrique (FAV-A) - MicroPharm Ltd, UK - F(ab')₂-equine - <i>B. arietans</i>, <i>B. gabonica</i>, <i>B. jamesoni</i>, <i>D. polylepis</i>, <i>D. viridis</i>, <i>E. leucogaster</i>, <i>E. ocellatus</i>, <i>N. haje</i>, <i>N. melanoleuca</i>, <i>N. nigricollis</i>	

Fig. 1. A sample completed BWS scenario presented to respondents. The set of BWS scenarios generated for this study contain four antivenoms each, and the sample completed scenario represents BWS scenario number 1 in the first block and contains antivenoms labelled as 2, 20, 5, and 3.

3. Statistical analysis

3.1. Maximum difference model

In this study, healthcare workers were asked to prioritize different antivenoms based on several criteria, including the brand name, the facilities producing them, the country of origin, and the specific snake species for which the antivenom is effective. Participants were instructed to identify which antivenom they would prioritize the most and which they would prioritize the least from a provided set of scenarios (Figure 1, for example). Repeated choices by participants from the sets of unordered BWS scenarios reveal the trade-offs healthcare workers are willing to make between the antivenoms. This choice is modeled as a function of the antivenoms using random utility theory (RUT) [43, 44, 45]. RUT is based on the idea that people (healthcare professionals) will make their decisions on the attributes of a product (antivenom) as well as a certain amount of chance (a random component). The random component results from either the respondent's antivenom prioritization being somewhat random or the researcher does not have the complete set of information available to the respondent [46]. By using a model with a random component, we can estimate how often one snake antivenom might be chosen or prioritized over another. Here, the frequency of choices made by participants are used as a metric to compare the relative importance of different snake antivenoms. We assume that each choice has an underlying value or utility to respondents. To estimate these utilities, we use the maximum difference model [35, 45] to analyze the data. Statistical significance was observed with a 95% confidence interval (CI) greater or less than zero. A parameter estimate is considered significant if the 95% CI is greater or less than zero. If the 95% CI overlaps, the parameter estimate is not significantly different. A significant positive/negative parameter estimate indicates a prioritization/trade-off for a particular snake antivenom product. In the absence of CIs, statistical significance is considered if the significant probability (*p*-value) is either less than or equal to 0.001, 0.01, and 0.05. All statistical analysis was conducted using JMP Pro (Version 16.0). It is worth noting that the

utility estimates (UE) quantify the perceived importance of the matching level of the effect. Higher values indicate that the effect's level is deemed more important. The standard errors (SE) measure the uncertainty surrounding the parameter estimate for each antivenom. The better the model fits the data, the smaller the SE of the parameter estimate. The greatest utility difference (GUD) is the maximum change in utility that can be achieved from a specific antivenom based on the plausible antivenoms in the BWS study.

4. Results

4.1. Demographic description

In this study, 203 healthcare workers participated, including community health nurses, physician assistants/medical doctors, and certificate/enrolled/general nurses. The analysis of variance revealed 2 degrees of freedom, a sum of squares of 0.620, a mean square of 0.310, an F-ratio of 0.465, and a p-value of 0.628, indicating no significant difference in mean responses by professional qualifications. Table 2 offers an overview of these healthcare workers. Out of the participants, 78 (38.4%) worked in community-based health planning and services (CHPS) compounds, 100 (49.3%) worked in health centres/clinics, and 25 (12.3%) worked in hospitals (Table 2). Of the 203 respondents, 141 (69.5%) were female and aged between 18 and 30 years old, while 62 (30.5%) were male. Most respondents had 1-5 years of working experience 126 (62.1%). Additionally, 110 (54.2%) respondents had received snakebite training, and 116 (57.1%) mostly lived in rural areas. The healthcare workers reported that farmers 130 (64.0%) were mainly bitten during the rainy season 114 (56.2%), in their farms or bush 129 (63.5%), and between 9 am to 12 noon 119 (58.6%).

Table 2

Demographic description of the study population

Variable	Category	Respondents (<i>n</i> = 203)
Age (years) median (IQR)		30 (28-34)
Age (years)	18-30	108 (53.2%)
	> 30	95 (46.8%)
Gender	Male	62 (30.5%)
	Female	141 (69.5%)
Professional qualification	Certificate/enrolled/general nurses	129 (63.5%)
	Community health nurses	57 (28.1%)
	Physician assistants /medical doctors	17 (8.4%)
	Rural	116 (57.1%)

Place you spent most of your childhood	Urban	87 (42.9%)
Place of practice	Health centre/Clinic	100 (49.3%)
	CHPS compound	78 (38.4%)
	Hospital	25 (12.3%)
Number of years of practice	1-5	126 (62.1%)
	6-10	62 (30.5%)
	>10	15 (7.4%)
Ever trained in snakebite management	Yes	110 (54.2%)
	No	93 (45.8%)
Season often bitten	Rainy	114 (56.2%)
	Dry	89 (43.8%)
Place of bitten	Farm/bush	129 (63.5%)
	Outdoors	61 (30.1%)
	Indoors	4 (2.0%)
	Don't know	9 (4.4%)
Time often bitten	5 am – 8 am	13 (6.4%)
	9 am – 12 noon	119 (58.6%)
	1 pm – 4 pm	70 (34.5%)
	5 pm – 8 pm	1 (0.5%)
Perceived occupation of common snakebite victims	Farmers	130 (64.0%)
	Herdsmen	44 (21.7%)
	Student/pupil	17 (8.4%)
	Other	9 (4.4%)
	Unemployed	2 (1.0%)
	Housewife	1 (0.5%)
Pattern of envenomation	Local swelling/ulceration (cytotoxic) only	156 (76.8%)

	Coagulopathy only	28 (13.8%)
	Cytotoxic+coagulopathy	15 (7.4%)
	No signs of envenoming	4 (2.0%)

**Most of the healthcare workers surveyed were females between the ages of 18 and 30. A significant portion of participants had 1-5 years of experience and had been trained in snakebite treatment. Participants reported that farmers were the most common victims of snakebites during the rainy season, while working in the fields or in the bush, typically between 9 am and 12 noon.*

Table 3 presents the model results of the snake antivenom products available for use in SSA. The results include utility estimates (UE), standard errors (SE), and confidence intervals (CIs). Figure 2 shows the relative importance healthcare workers attach to the snake antivenom products, represented by the UE and length of bars indicating the marginal probability (MP) values. All UE had the expected sign and significance at 95% CIs except for the Snake Venom Antiserum - Central Africa (Premium-CA) antivenom, which was insignificant. Among the antivenoms available for use in sub-Saharan Africa, participants highly prioritize Inoserp Pan-Africa (UE: 2.510; MP: 0.339; 95% C.I: 2.344, 2.681) and Snake Venom Antiserum -PanAfrica (UE: 1.548; MP: 0.129; 95%C.I: 1.419, 1.680). Other snake antivenoms with higher prioritization are EchiTabPlus (UE: 0.960; MP: 0.072; 95%C.I: 0.839, 1.082), followed by ASNA antivenom D (UE: 0.872; MP: 0.066; 95%C.I: 0.753, 0.992), ASNA antivenom C (UE: 0.799; MP: 0.061; 95%C.I: 0.682, 0.917), Snake Venom Antiserum African – 10 (UE: 0.668; MP: 0.053; 95%C.I: 0.552, 0.785), Anti Snake Venom Serum Pan Africa – 10 (UE: 0.658; MP: 0.053; 95%C.I: 0.542, 0.774), and Fav-Afrique (UE: 0.522; MP: 0.046; 95%C.I: 0.407, 0.637). These results suggest that some of the highly prioritized antivenom products may not necessarily be effective/quality but most commonly available, used, or familiar to the workers.

Although significant, healthcare workers tend to trade-off or least prioritize some snake antivenoms, including SAIMR Echis, Combipack of Snake Venom Antiserum, Anti Snake Venom Serum Central Africa -6, Anti-Snake Venom Serum Central Africa, Snake Venom Antiserum Echiven Plus, Antivipmyn-Africa, Menaven, Snake Venom Antitoxin, Snake Venom Antiserum, Anti Snake Venom Serum Monovalent Echis ocellatus, EchiTabG, as well as Snake venom antiserum Echis ocellatus (VINS-Echis) (UE: -0.214 to -1.375; MP: 0.022 to 0.007; 95%C.I: -0.324, -0.102 to -1.497, -1.253).

Our results indicate that healthcare workers prioritize polyvalent and monovalent snake antivenom products differently. Some of the least prioritized antivenom products may not be commonly available, used, or familiar to these workers.

Marginal Utility	Marginal Probability		Snake antivenom products
2.510	0.339		Inoserp Pan-Africa (Inoserp-P)
1.548	0.129		Snake Venom Antiserum -PanAfrica (Premium-A)
0.960	0.072		EchiTabPlus (ET-Plus)
0.872	0.066		ASNA antivenom D (ASNA-D)
0.799	0.061		ASNA antivenom C (ASNA-C)

Marginal Utility	Marginal Probability	Snake antivenom products
0.668	0.053	Snake Venom Antiserum African - 10 (Afriven 10)
0.658	0.053	Anti Snake Venom Serum Pan Africa - 10
0.522	0.046	Fav-Afrique (FAV-A)
-0.111	0.024	Snake Venom Antiserum - Central Africa (Premium-CA)
-0.214	0.022	SAIMR Echis
-0.234	0.021	Combipack of Snake Venom Antiserum (African- Ten)
-0.239	0.021	Anti Snake Venom Serum Central Africa -6
-0.498	0.016	Anti-Snake Venom Serum Central Africa (VINS-CA)
-0.654	0.014	Snake Venom Antiserum Echiven Plus
-0.698	0.013	Antivipmyn-Africa (Antivip-A)
-0.986	0.010	Menaven, Snake Venom Antitoxin
-1.097	0.009	Snake Venom Antiserum (Echiven)
-1.101	0.009	Anti Snake Venom Serum Monovalent Echis ocellatus
-1.330	0.007	EchiTABG
-1.375	0.007	Snake venom antiserum Echis ocellatus (VINS-Echis)

Fig. 2. Marginal utility estimates and marginal probability of snake antivenoms available for treating snakebite envenoming. The corresponding marginal utility and probability values determine the importance attached to each snake antivenom.

Table 3

Maximum difference model results of snake antivenoms available for treating snakebite envenoming

Snake antivenoms	Parameter estimates	SE	Lower 95%	Upper 95%
Anti Snake Venom Serum Central Africa -6	-0.239	0.057	-0.351	-0.127
Anti Snake Venom Serum Monovalent Echis ocellatus	-1.101	0.059	-1.219	-0.984
Anti Snake Venom Serum Pan Africa - 10	0.658	0.059	0.542	0.774
Antiserum -PanAfrica (Premium-A)	1.548	0.066	1.419	1.680
Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.498	0.056	-0.609	-0.388
Antivipmyn-Africa (Antivip-A)	-0.698	0.058	-0.813	-0.583
ASNA antivenom C (ASNA-C)	0.799	0.059	0.682	0.917
ASNA antivenom D (ASNA-D)	0.872	0.060	0.753	0.992
Combipack of Snake Venom Antiserum (African-Ten)	-0.234	0.056	-0.345	-0.122
EchiTABG	-1.330	0.061	-1.452	-1.209
EchiTabPlus (ET-Plus)	0.960	0.061	0.839	1.082
Fav-Afrique (FAV-A)	0.522	0.058	0.407	0.637

Inoserp Pan-Africa (Inoserp-P)	2.510	0.085	2.344	2.681
Menaven, Snake Venom Antitoxin	-0.986	0.059	-1.102	-0.870
SAIMR Echis	-0.213	0.056	-0.324	-0.102
Snake Venom Antiserum - Central Africa (Premium-CA)	-0.111	0.057	-0.223	0.001
Snake Venom Antiserum (Echiven)	-1.097	0.060	-1.215	-0.979
Snake Venom Antiserum African - 10 (Afriven 10)	0.668	0.059	0.552	0.785
Snake venom antiserum Echis ocellatus (VINS-Echis)	-1.374	0.062	-1.497	-1.253
L-R Tests				
L-R Chi-Square	4506.541			
DF	19			
<i>P-Value</i>	<0.0001			

*SE, standard error; L-R, likelihood ratio; DF, degree of freedom.

In Table 4 (in Appendix), we compare different snake antivenoms available for use in SSA with their associated marginal probabilities (MP), odds, and the greatest utility difference (GUD) between the antivenom products. Our findings revealed that there is a higher likelihood for healthcare workers to prioritize Inoserp-P antivenom (Odds: 48.66; MP: 0.979; GUD: 3.884; $p=9e-227$) compared to Snake Venom Antiserum Echis ocellatus (Odds: 0.020; MP: 0.020). Additionally, healthcare workers are more likely to prioritize Inoserp-P antivenom (Odds: 36.856 to 6.306; MP: 0.973 to 0.863; GUD: 3.607 to 1.841; $p=2e-204$ to $1.7e-65$) compared to other snake antivenom products such as Snake Venom Antiserum African - 10 (Afriven 10) and Snake Venom Antitoxin (Odds: 0.027 to 0.158; MP: 0.026 to 0.136). On the other hand, the likelihood of healthcare workers prioritizing Snake Venom Antiserum -PanAfrica (Premium-A) (Odds: 0.382; MP: 0.276; GUD: -0.961; $p=9.9e-20$) is lower compared to Inoserp-P antivenom (Odds: 2.615; MP: 0.723).

However, participants are more likely to prioritize Snake Venom Antiserum -PanAfrica (Odds: 18.603 to 1.800; MP: 0.948 to 0.642; GUD: 2.923 to 0.588; $p=7e-180$ to $6.9e-11$) compared to other snake antivenom products such as EchiTabPlus and Anti-Snake Venom Serum Central Africa (Odds: 0.053 to 0.555; MP: 0.051 to 0.357). Finally, there is a higher likelihood for healthcare workers to prioritize EchiTabPlus (Odds: 10.330; MP: 0.911; GUD: 2.335; $p=5e-133$) compared to other antivenom products such as Anti Snake Venom Serum Pan Africa – 10 and Fav-Afrique (Odds: 9.458 to 6.666; MP: 0.904 to 0.869; GUD: 2.246 to 1.897; $p=6e-124$ to $3.4e-95$).

5. Discussion

Antivenom is a vital emergency medication used to treat snakebites, including pregnant women and people of all ages. Although patients receive antivenom treatment, healthcare workers are the primary end-users. As such, their antivenom prioritization is crucial to the research agenda and efforts to reduce the global burden of SBE. This study aimed to determine healthcare workers' antivenom prioritization using the best-

worst scaling methodology. The study provides quantitative evidence which could guide policy discussions on available snake antivenom products to enhance the procurement and supply of quality antivenoms, improve the efficacy of snakebite treatment, and elevate patient safety and care quality in health facilities in Ghana and SSA, where snakebite envenoming is a significant concern.

This study involved 203 healthcare workers, including community health nurses, physician assistants, medical doctors, and certificate/enrolled/general nurses. A prior study in Ghana indicated that medical doctors, registered nurses, physician assistants, community health nurses, and pharmacy technicians were the primary healthcare professionals involved in managing snakebites. In contrast, registered midwives and pharmacists were found to be the least engaged in snakebite management [29]. The study revealed that most participating healthcare workers were women aged between 18 and 30. Additionally, most respondents had received training in snakebite treatment. The healthcare workers reported that farmers were the most frequent victims of snakebites during the rainy season, often while working in their fields or the bush, typically between 9 AM and 12 noon. These findings are consistent with previous studies [47, 48, 49, 15, 14].

A key finding of this study was that healthcare workers' highly prioritized Inoserp-P polyvalent snake antivenom. The other antivenoms that healthcare workers prioritized were Snake Venom Antiserum - PanAfrica, followed by ASNA-D, ASNA-C, Snake Venom Antiserum African - 10, Anti Snake Venom Serum Pan Africa – 10, and Fav-Afrique. However, some antivenoms were less commonly prioritized, such as SAIMR Echis, Combipack of Snake Venom Antiserum, Anti Snake Venom Serum Central Africa -6, Anti-Snake Venom Serum Central Africa, Snake Venom Antiserum Echiven Plus, Antivipmyn-Africa, Menaven, Snake Venom Antitoxin, Snake Venom Antiserum (Echiven), Anti Snake Venom Serum Monovalent Echis ocellatus, EchiTabG, and Snake venom antiserum Echis ocellatus (VINS-Echis). It is worth noting that some of the highly prioritized antivenom products may not necessarily be effective/quality in treating SBE but most commonly available, used, or familiar to the workers.

Our results revealed that healthcare workers' highly prioritized Inoserp Pan-Africa (Inoserp-P) antivenom. Earlier research reported that antivenom products with high market penetration [50, 21] were marketed without data on safety and clinical effectiveness from well-designed, pragmatic clinical trials [23], nor prior independent preclinical efficacy testing as well as poor preclinical efficacy [51, 52]. Therefore, multifaceted interventions are required, including but not limited to developing regional hubs for developing, evaluating, and regulating antivenoms alongside other recommendations by the WHO Strategy for Prevention and Control of Snakebite Envenoming [6]. An excellent strategy is WHO's recent report on Target Product Profiles [2], which describes the characteristics needed to produce good antivenoms for Africa, thereby supporting the efforts towards designing and producing new antivenoms that respond to the African countries' needs [20]. To reshape the market and improve compliance, national regulatory authorities should only register or authorize the marketing of antivenoms in the presence of independent preclinical neutralization tests and well-designed, pragmatic clinical dose-finding and safety studies [22, 53].

This study further revealed that healthcare workers prioritize Snake Venom Antiserum -PanAfrica, ASNA-D, ASNA-C, Snake Venom Antiserum African - 10 (Afriven 10), Anti Snake Venom Serum Pan Africa – 10, and FAV-Afrique. A study [54] similarly reported that ASNA Antivenom C and FAV-Afrique antivenom [55] are the most commonly used treatments for snakebites in Ghana. It is important to note that

most of these antivenoms are polyvalent and are recommended for patients in areas where the venoms of different snake species produce similar clinical effects and where the dead snake is not available for identification. Further, although monospecific antivenoms are recommended for treating SBE caused by a known species of snake, they were least prioritized or traded off in this study. This suggests that monospecific antivenoms may be less commonly used for snakebite treatment, scarcer and more expensive. Efforts are needed to maintain a sustainable supply of appropriate antivenoms at a reasonable price [4, 2]. It is also important to implement regulations for available antivenoms, provide ongoing education and training to healthcare workers. Our study found that healthcare workers were more likely to prioritize certain antivenoms, such as Inoserp Pan-Africa and EchiTabPlus, than others. This finding highlights the need for the Ministry of Health to provide antivenoms following the recommendation of WHO, improve the availability and accessibility of antivenoms [56] in health facilities, as well as to ensure the quality and regulation of the product in the open market. Investigating alternative treatments, including immunomodulatory therapies from traditional medicines [10, 11], may offer complementary strategies alongside antivenom administration, potentially influencing healthcare workers' priorities.

According to our findings, healthcare workers were more likely to prioritize Inoserp Pan-Africa (Inoserp-P) antivenom than snake venom antiserum *Echis ocellatus* (VINS-Echis). There is a lower chance of prioritizing Snake Venom Antiserum -PanAfrica (Premium-A) compared to Inoserp-P, but it is still more likely than other antivenom options. EchiTabPlus (ET-Plus) is more likely to be prioritized than some other antivenom options. Studies indicated that the choice of antivenom significantly influences certain treatment outcomes [57, 58, 59]. In contrast, other studies reported no significant impact [60, 61, 62]. Our results provide insight into the need to implement regulations for available antivenoms to improve patient safety and effective treatment. The application of computational models and bioinformatics tools [63, 64] has the potential to improve our understanding of venom components and antivenom efficacy. This may, in turn, influence healthcare workers' preferences by informing them of the most effective treatments.

The authors acknowledge several limitations. Since the research was conducted solely in two districts of the Eastern Region, the findings may not accurately represent antivenom product prioritization by healthcare workers in other areas of Ghana and SSA. Although most respondents reported having received training on snakebite management, and the WHO recommends antivenom products that meet safety standards for deployment in primary healthcare facilities that have health workers who have been trained in the diagnosis and emergency treatment of snakebite envenoming [2], some healthcare workers interviewed may not regularly administer antivenoms. Additionally, even though they are experienced and had ever been involved in the management of snakebite victims in their facilities, some might have never administered antivenoms or possess varying levels of knowledge on the subject based on their professional backgrounds (such as community health nurses, physician assistants, medical doctors, and enrolled or general nurses). This variation in experience and knowledge may skew the findings toward the perspectives of the dominant cadre. Nevertheless, a prior study in Ghana indicated that medical doctors, registered nurses, physician assistants, community health nurses, and pharmacy technicians were the primary healthcare professionals involved in managing snakebites. In contrast, registered midwives and pharmacists were found to be the least engaged in snakebite management [29]. The antivenoms included in this study might not cover all available options, which could influence prioritization. Again, although the study investigated snake antivenom products available for treating SBE in SSA, some of the antivenoms may not be in the open market (Fav-Afrique, for example) or available for use in Ghana, including the Regional

Medical Stores and health facilities. This may lead to biased utility estimates. Ultimately, further study is needed to confirm prioritization of actual antivenom products available for use in the Regional Medical Stores as well as in the various health facilities in Ghana, likely to be safe and efficacious, that its quality, safety, and efficacy are acceptable by WHO. There is also the need to assess whether these antivenoms are effective in local envenoming. Additionally, the study relied on provider reports or subjective judgments, and their integrity could not be verified. Therefore, detailed information from studies combining field and hospital data is needed to validate these results by reviewing hospital admission and discharge case report forms for administered antivenom products. There is an urgent need to assess antivenom availability and management in Ghana, including the public health system and medicine sales outlets such as pharmacies and licensed drug stores. Further study is needed to expand the classic health research toolkit by adapting existing robust methodologies like BWS and incorporating new tools such as artificial intelligence (AI), including machine learning (ML) and deep learning, to gather better snakebite information [65].

To conclude, this study presents crucial information to facilitate conversations on the antivenoms available in SSA for treating SBE. There is a pressing necessity to enforce regulations on snake antivenom products, improve procurement and supply of quality antivenoms, provide ongoing education, and offer training to healthcare workers to tackle the issue of SBE.

Consent for publication

Not applicable

Data availability statement

The datasets used and/analyzed in this study are available from the corresponding author upon reasonable request.

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Ethical considerations

The study followed ethical guidelines and regulations. Ethical clearance was obtained from the Ethics Committee of the College of Basic and Applied Sciences, University of Ghana (Reference No: ECBAS 065/22-23). Before collecting data, written informed consent was obtained from all respondents after explaining the purpose of the study. It was emphasized that participation in the study was voluntary, and respondents had the choice to decline. Respondents' confidentiality and anonymity were safeguarded using unique identifiers.

CRedit authorship contribution statement

Eric Nyarko: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Writing – original draft, Writing – review & editing, Visualization. **Ebenezer Kwesi Ameh:** Formal analysis, Resources, Investigation, Data curation, Project administration, Writing – review & editing.

Declaration of competing interests

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

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Appendix A. Supplementary material

Table 4

All levels comparison of snake antivenoms available for treating snakebite envenoming.

Compared1	Compared2	Utility 1	Utility 2	Probability1	Probability2	Odds 1	Odds 2
Anti Snake Venom Serum Central Africa - 6	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.239	-1.101	0.703	0.296	2.367	0.422
	Anti Snake Venom Serum Pan Africa - 10	-0.239	0.658	0.289	0.710	0.407	2.453
	Antiserum -PanAfrica (Premium-A)	-0.239	1.548	0.143	0.856	0.167	5.975
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.239	-0.498	0.564	0.435	1.295	0.771
	Antivipmyn-Africa (Antivip-A)	-0.239	-0.698	0.612	0.387	1.582	0.631
	ASNA antivenom C (ASNA-C)	-0.239	0.799	0.261	0.738	0.354	2.824
	ASNA antivenom D (ASNA-D)	-0.239	0.872	0.247	0.752	0.329	3.038
	Combipack of Snake Venom Antiserum (African- Ten)	-0.239	-0.234	0.498	0.501	0.995	1.005
	EchiTabG	-0.239	-1.330	0.748	0.251	2.976	0.335
	EchiTabPlus (ET-Plus)	-0.239	0.960	0.231	0.768	0.301	3.318
	Fav-Afrique (FAV-A)	-0.239	0.522	0.318	0.681	0.466	2.141
	Inoserp Pan-Africa (Inoserp-P)	-0.239	2.510	0.060	0.939	0.063	15.630

	Menaven, Snake Venom Antitoxin	-0.239	-0.986	0.678	0.321	2.110	0.473
	SAIMR Echis	-0.239	-0.213	0.493	0.506	0.974	1.025
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.239	-0.111	0.468	0.531	0.879	1.136
	Snake Venom Antiserum (Echiven)	-0.239	-1.097	0.702	0.297	2.357	0.424
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.239	0.668	0.287	0.712	0.403	2.478
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.239	-1.374	0.756	0.243	3.113	0.321
	Snake Venom Antiserum Echiven Plus	-0.239	-0.654	0.602	0.397	1.514	0.660
Anti Snake Venom Serum Monovalent Echis ocellatus	Anti Snake Venom Serum Central Africa -6	-1.101	-0.239	0.296	0.703	0.422	2.367
	Anti Snake Venom Serum Pan Africa - 10	-1.101	0.658	0.146	0.853	0.172	5.808
	Antiserum -PanAfrica (Premium-A)	-1.101	1.548	0.066	0.933	0.070	14.148
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-1.101	-0.498	0.353	0.646	0.547	1.827
	Antivipmyn-Africa (Antivip-A)	-1.101	-0.698	0.400	0.599	0.668	1.495
	ASNA antivenom C (ASNA-C)	-1.101	0.799	0.130	0.869	0.149	6.687
	ASNA antivenom D (ASNA-D)	-1.101	0.872	0.122	0.877	0.139	7.193
	Combipack of Snake Venom Antiserum (African- Ten)	-1.101	-0.234	0.295	0.704	0.420	2.379
	EchiTabG	-1.101	-1.330	0.556	0.443	1.257	0.795
	EchiTabPlus (ET-Plus)	-1.101	0.960	0.112	0.887	0.127	7.857
	Fav-Afrique (FAV-A)	-1.101	0.522	0.164	0.835	0.197	5.070
	Inoserp Pan-Africa (Inoserp-P)	-1.101	2.510	0.026	0.973	0.027	37.008
	Menaven, Snake Venom Antitoxin	-1.101	-0.986	0.471	0.528	0.891	1.121
	SAIMR Echis	-1.101	-0.213	0.291	0.708	0.411	2.429

	Snake Venom Antiserum - Central Africa (Premium-CA)	-1.101	-0.111	0.270	0.729	0.371	2.691
	Snake Venom Antiserum (Echiven)	-1.101	-1.097	0.498	0.501	0.995	1.004
	Snake Venom Antiserum African - 10 (Afriven 10)	-1.101	0.668	0.145	0.854	0.170	5.867
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-1.101	-1.374	0.568	0.431	1.314	0.760
	Snake Venom Antiserum Echiven Plus	-1.101	-0.654	0.390	0.609	0.639	1.563
Anti Snake Venom Serum Pan Africa - 10	Anti Snake Venom Serum Central Africa -6	0.658	-0.239	0.710	0.289	2.453	0.407
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.658	-1.101	0.853	0.146	5.808	0.172
	Antiserum -PanAfrica (Premium-A)	0.658	1.548	0.291	0.708	0.410	2.436
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.658	-0.498	0.760	0.239	3.178	0.314
	Antivipmyn-Africa (Antivip-A)	0.658	-0.698	0.795	0.204	3.882	0.257
	ASNA antivenom C (ASNA-C)	0.658	0.799	0.464	0.535	0.868	1.151
	ASNA antivenom D (ASNA-D)	0.658	0.872	0.446	0.553	0.807	1.238
	Combipack of Snake Venom Antiserum (African- Ten)	0.658	-0.234	0.709	0.290	2.440	0.409
	EchiTabG	0.658	-1.330	0.879	0.120	7.302	0.136
	EchiTabPlus (ET-Plus)	0.658	0.960	0.425	0.574	0.739	1.352
	Fav-Afrique (FAV-A)	0.658	0.522	0.533	0.466	1.145	0.872
	Inoserp Pan-Africa (Inoserp-P)	0.658	2.510	0.135	0.864	0.156	6.371
	Menaven, Snake Venom Antitoxin	0.658	-0.986	0.838	0.161	5.177	0.193
	Snake Venom	0.658	-0.213	0.705	0.294	2.39	0.418
	Snake Venom Antiserum - Central Africa (Premium-CA)	0.658	-0.111	0.683	0.316	2.158	0.463

	Snake Venom Antiserum (Echiven)	0.658	-1.097	0.852	0.147	5.784	0.172
	Snake Venom Antiserum African - 10 (Afriven 10)	0.658	0.668	0.497	0.502	0.989	1.010
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.658	-1.374	0.884	0.115	7.636	0.130
	Snake Venom Antiserum Echiven Plus	0.658	-0.654	0.787	0.212	3.715	0.269
Antiserum - PanAfrica (Premium-A)	Anti Snake Venom Serum Central Africa -6	1.548	-0.239	0.856	0.143	5.975	0.167
	Anti Snake Venom Serum Monovalent Echis ocellatus	1.548	-1.101	0.933	0.066	14.148	0.070
	Anti Snake Venom Serum Pan Africa - 10	1.548	0.658	0.708	0.291	2.436	0.410
	Anti-Snake Venom Serum Central Africa (VINS-CA)	1.548	-0.498	0.885	0.114	7.743	0.129
	Antivipmyn-Africa (Antivip-A)	1.548	-0.698	0.904	0.095	9.458	0.105
	ASNA antivenom C (ASNA-C)	1.548	0.799	0.679	0.320	2.115	0.472
	ASNA antivenom D (ASNA-D)	1.548	0.872	0.662	0.337	1.966	0.508
	Combipack of Snake Venom Antiserum (African- Ten)	1.548	-0.234	0.856	0.143	5.945	0.168
	EchiTabG	1.548	-1.330	0.946	0.053	17.788	0.056
	EchiTabPlus (ET-Plus)	1.548	0.960	0.642	0.357	1.800	0.555
	Fav-Afrique (FAV-A)	1.548	0.522	0.736	0.263	2.790	0.358
	Inoserp Pan-Africa (Inoserp-P)	1.548	2.510	0.276	0.723	0.382	2.615
	Menaven, Snake Venom Antitoxin	1.548	-0.986	0.926	0.073	12.612	0.079
	SAIMR Echis	1.548	-0.213	0.853	0.146	5.824	0.171
	Snake Venom Antiserum - Central Africa (Premium-CA)	1.548	-0.111	0.840	0.159	5.256	0.190
	Snake Venom Antiserum (Echiven)	1.548	-1.097	0.933	0.066	14.090	0.070

	Snake Venom Antiserum African - 10 (Afriven 10)	1.548	0.668	0.706	0.293	2.411	0.414
	Snake venom antiserum Echis ocellatus (VINS-Echis)	1.548	-1.374	0.948	0.051	18.603	0.053
	Snake Venom Antiserum Echiven Plus	1.548	-0.654	0.900	0.099	9.051	0.110
Anti-Snake Venom Serum Central Africa (VINS-CA)	Anti Snake Venom Serum Central Africa -6	-0.498	-0.239	0.435	0.564	0.771	1.295
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.498	-1.101	0.646	0.353	1.827	0.547
	Anti Snake Venom Serum Pan Africa - 10	-0.498	0.658	0.239	0.760	0.314	3.178
	Antiserum -PanAfrica (Premium-A)	-0.498	1.548	0.114	0.885	0.129	7.743
	Antivipmyn-Africa (Antivip-A)	-0.498	-0.698	0.549	0.450	1.221	0.818
	ASNA antivenom C (ASNA-C)	-0.498	0.799	0.214	0.785	0.273	3.659
	ASNA antivenom D (ASNA-D)	-0.498	0.872	0.202	0.797	0.253	3.937
	Combipack of Snake Venom Antiserum (African- Ten)	-0.498	-0.234	0.434	0.565	0.767	1.302
	EchiTabG	-0.498	-1.330	0.696	0.303	2.297	0.435
	EchiTabPlus (ET-Plus)	-0.498	0.960	0.188	0.811	0.232	4.300
	Fav-Afrique (FAV-A)	-0.498	0.522	0.264	0.735	0.360	2.774
	Inoserp Pan-Africa (Inoserp-P)	-0.498	2.510	0.047	0.952	0.049	20.254
	Menaven, Snake Venom Antitoxin	-0.498	-0.986	0.619	0.380	1.628	0.613
	Snake Venom	-0.498	-0.213	0.429	0.570	0.752	1.329
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.498	-0.111	0.404	0.595	0.678	1.472
	Snake Venom Antiserum (Echiven)	-0.498	-1.097	0.645	0.354	1.819	0.549
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.498	0.668	0.237	0.762	0.311	3.211

	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.498	-1.374	0.706	0.293	2.402	0.416
	Snake Venom Antiserum Echiven Plus	-0.498	-0.654	0.538	0.461	1.168	0.855
Antivipmyn-Africa (Antivip-A)	Anti Snake Venom Serum Central Africa -6	-0.698	-0.239	0.387	0.612	0.631	1.582
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.698	-1.101	0.599	0.400	1.495	0.668
	Anti Snake Venom Serum Pan Africa - 10	-0.698	0.658	0.204	0.795	0.257	3.882
	Antiserum -PanAfrica (Premium-A)	-0.698	1.548	0.095	0.904	0.105	9.458
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.698	-0.498	0.450	0.549	0.818	1.221
	ASNA antivenom C (ASNA-C)	-0.698	0.799	0.182	0.817	0.223	4.470
	ASNA antivenom D (ASNA-D)	-0.698	0.872	0.172	0.827	0.207	4.809
	Combipack of Snake Venom Antiserum (African- Ten)	-0.698	-0.234	0.385	0.614	0.628	1.590
	EchiTabG	-0.698	-1.330	0.652	0.347	1.880	0.531
	EchiTabPlus (ET-Plus)	-0.698	0.960	0.159	0.840	0.190	5.252
	Fav-Afrique (FAV-A)	-0.698	0.522	0.227	0.772	0.295	3.389
	Inoserp Pan-Africa (Inoserp-P)	-0.698	2.510	0.038	0.961	0.040	24.741
	Menaven, Snake Venom Antitoxin	-0.698	-0.986	0.571	0.428	1.333	0.749
	Snake Venom	-0.698	-0.213	0.381	0.618	0.615	1.624
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.698	-0.111	0.357	0.642	0.555	1.799
	Snake Venom Antiserum (Echiven)	-0.698	-1.097	0.598	0.401	1.489	0.671
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.698	0.668	0.203	0.796	0.254	3.922
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.698	-1.374	0.662	0.337	1.966	0.508

	Snake Venom Antiserum Echiven Plus	-0.698	-0.654	0.488	0.511	0.956	1.045
ASNA antivenom C (ASNA-C)	Anti Snake Venom Serum Central Africa -6	0.799	-0.239	0.738	0.261	2.824	0.354
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.799	-1.101	0.869	0.130	6.687	0.149
	Anti Snake Venom Serum Pan Africa - 10	0.799	0.658	0.535	0.464	1.151	0.868
	Antiserum -PanAfrica (Premium-A)	0.799	1.548	0.320	0.679	0.472	2.115
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.799	-0.498	0.785	0.214	3.659	0.273
	Antivipmyn-Africa (Antivip-A)	0.799	-0.698	0.817	0.182	4.470	0.223
	ASNA antivenom D (ASNA-D)	0.799	0.872	0.481	0.518	0.929	1.075
	Combipack of Snake Venom Antiserum (African- Ten)	0.799	-0.234	0.737	0.262	2.810	0.355
	EchiTabG	0.799	-1.330	0.893	0.106	8.407	0.118
	EchiTabPlus (ET-Plus)	0.799	0.960	0.459	0.540	0.851	1.174
	Fav-Afrique (FAV-A)	0.799	0.522	0.568	0.431	1.318	0.758 1
	Inoserp Pan-Africa (Inoserp-P)	0.799	2.510	0.153	0.846	0.180	5.534
	Menaven, Snake Venom Antitoxin	0.799	-0.986	0.856	0.143	5.961	0.167
	SAIMR Echis	0.799	-0.213	0.733	0.266	2.752	0.363
	Snake Venom Antiserum - Central Africa (Premium-CA)	0.799	-0.111	0.713	0.286	2.484	0.402
	Snake Venom Antiserum (Echiven)	0.799	-1.097	0.869	0.130	6.659	0.150
	Snake Venom Antiserum African - 10 (Afriven 10)	0.799	0.668	0.532	0.467	1.139	0.877
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.799	-1.374	0.897	0.102	8.792	0.113
	Snake Venom Antiserum Echiven Plus	0.799	-0.654	0.810	0.189	4.277	0.233

ASNA antivenom D (ASNA-D)	Anti Snake Venom Serum Central Africa -6	0.872	-0.239	0.752	0.247	3.038	0.329
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.872	-1.101	0.877	0.122	7.193	0.139
	Anti Snake Venom Serum Pan Africa - 10	0.872	0.658	0.553	0.446	1.238	0.807
	Antiserum -PanAfrica (Premium-A)	0.872	1.548	0.337	0.662	0.508	1.966
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.872	-0.498	0.797	0.202	3.937	0.253
	Antivipmyn-Africa (Antivip-A)	0.872	-0.698	0.827	0.172	4.809	0.207
	ASNA antivenom C (ASNA-C)	0.872	0.799	0.518	0.481	1.075	0.929
	Combipack of Snake Venom Antiserum (African- Ten)	0.872	-0.234	0.751	0.248	3.023	0.330
	EchiTabG	0.872	-1.330	0.900	0.099	9.044	0.110
	EchiTabPlus (ET-Plus)	0.872	0.960	0.477	0.522	0.915	1.092
	Fav-Afrique (FAV-A)	0.872	0.522	0.586	0.413	1.418	0.704
	Inoserp Pan-Africa (Inoserp-P)	0.872	2.510	0.162	0.837	0.194	5.144
	Menaven, Snake Venom Antitoxin	0.872	-0.986	0.865	0.134	6.413	0.155
	SAIMR Echis	0.872	-0.213	0.747	0.252	2.961	0.337
	Snake Venom Antiserum - Central Africa (Premium-CA)	0.872	-0.111	0.727	0.272	2.672	0.374
	Snake Venom Antiserum (Echiven)	0.872	-1.097	0.877	0.122	7.164	0.139
	Snake Venom Antiserum African - 10 (Afriven 10)	0.872	0.668	0.550	0.449	1.225	0.815
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.872	-1.379	0.904	0.095	9.458	0.105
	Snake Venom Antiserum Echiven Plus	0.872	-0.654	0.821	0.178	4.602	0.217
Combipack of Snake Venom Antiserum (African- Ten)	Anti Snake Venom Serum Central Africa -6	-0.234	-0.239	0.501	0.498	1.005	0.995

	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.234	-1.101	0.704	0.295	2.379	0.420
	Anti Snake Venom Serum Pan Africa - 10	-0.234	0.658	0.290	0.709	0.409	2.440
	Antiserum -PanAfrica (Premium-A)	-0.234	1.548	0.143	0.856	0.168	5.945
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.234	-0.498	0.565	0.434	1.302	0.767
	Antivipmyn-Africa (Antivip-A)	-0.234	-0.698	0.614	0.385	1.590	0.628
	ASNA antivenom C (ASNA-C)	-0.234	0.799	0.262	0.737	0.355	2.810
	ASNA antivenom D (ASNA-D)	-0.234	0.872	0.248	0.751	0.330	3.023
	EchiTABG	-0.234	-1.330	0.749	0.250	2.991	0.334
	EchiTabPlus (ET-Plus)	-0.234	0.960	0.232	0.767	0.302	3.301
	Fav-Afrique (FAV-A)	-0.234	0.522	0.319	0.680	0.469	2.130
	Inoserp Pan-Africa (Inoserp-P)	-0.234	2.510	0.060	0.939	0.064	15.552
	Menaven, Snake Venom Antitoxin	-0.234	-0.986	0.679	0.320	2.121	0.471
	SAIMR Echis	-0.234	-0.213	0.494	0.505	0.979	1.020
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.234	-0.111	0.469	0.530	0.884	1.131
	Snake Venom Antiserum (Echiven)	-0.234	-1.097	0.703	0.296	2.369	0.421
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.234	0.668	0.288	0.711	0.405	2.465
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.234	-1.374	0.757	0.242	3.128	0.319
	Snake Venom Antiserum Echiven Plus	-0.234	-0.654	0.603	0.396	1.522	0.656
EchiTABG	Anti Snake Venom Serum Central Africa -6	-1.330	-0.239	0.251	0.748	0.335	2.976
	Anti Snake Venom Serum Monovalent Echis ocellatus	-1.330	-1.101	0.443	0.556	0.795	1.257
	Anti Snake Venom Serum Pan Africa - 10	-1.330	0.658	0.120	0.879	0.136	7.302

	Antiserum -PanAfrica (Premium-A)	-1.330	1.548	0.053	0.946	0.056	17.788
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-1.330	-0.498	0.303	0.696	0.435	2.297
	Antivipmyn-Africa (Antivip-A)	-1.330	-0.698	0.347	0.652	0.531	1.880
	ASNA antivenom C (ASNA-C)	-1.330	0.799	0.106	0.893	0.118	8.407
	ASNA antivenom D (ASNA-D)	-1.330	0.872	0.099	0.900	0.110	9.044
	Combipack of Snake Venom Antiserum (African- Ten)	-1.330	-0.234	0.250	0.749	0.334	2.991
	EchiTabPlus (ET-Plus)	-1.330	0.960	0.091	0.908	0.101	9.878
	Fav-Afrique (FAV-A)	-1.330	0.522	0.135	0.864	0.156	6.374
	Inoserp Pan-Africa (Inoserp-P)	-1.330	2.510	0.021	0.978	0.021	46.528
	Menaven, Snake Venom Antitoxin	-1.330	-0.986	0.414	0.585	0.709	1.410
	Snake Venom	-1.330	-0.213	0.246	0.753	0.327	3.054
	Snake Venom Antiserum - Central Africa (Premium-CA)	-1.330	-0.111	0.228	0.771	0.295	3.383
	Snake Venom Antiserum (Echiven)	-1.330	-1.097	0.442	0.557	0.792	1.262
	Snake Venom Antiserum African - 10 (Afriven 10)	-1.330	0.668	0.119	0.880	0.135	7.377
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-1.330	-1.374	0.511	0.488	1.045	0.956
	Snake Venom Antiserum Echiven Plus	-1.330	-0.654	0.337	0.662	0.508	1.965
EchiTabPlus (ET-Plus)	Anti Snake Venom Serum Central Africa -6	0.960	-0.239	0.768	0.231	3.318	0.301
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.960	-1.101	0.887	0.112	7.857	0.127
	Anti Snake Venom Serum Pan Africa - 10	0.960	0.658	0.574	0.425	1.352	0.739
	Antiserum -PanAfrica (Premium-A)	0.960	1.548	0.357	0.642	0.555	1.800
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.960	-0.498	0.811	0.188	4.300	0.232

	Antivipmyn-Africa (Antivip-A)	0.960	-0.698	0.840	0.159	5.252	0.190
	ASNA antivenom C (ASNA-C)	0.960	0.799	0.540	0.459	1.174	0.851
	ASNA antivenom D (ASNA-D)	0.960	0.872	0.522	0.477	1.092	0.915
	Combipack of Snake Venom Antiserum (African- Ten)	0.960	-0.234	0.767	0.232	3.301	0.302
	EchiTabG	0.960	-1.330	0.908	0.091	9.878	0.101
	Fav-Afrique (FAV-A)	0.960	0.522	0.607	0.392	1.549	0.645
	Inoserp Pan-Africa (Inoserp-P)	0.960	2.510	0.175	0.824	0.212	4.710
	Menaven, Snake Venom Antitoxin	0.960	-0.986	0.875	0.124	7.004	0.142
	Snake Venom	0.960	-0.213	0.763	0.236	3.234	0.309
	Snake Venom Antiserum - Central Africa (Premium-CA)	0.960	-0.111	0.744	0.255	2.919	0.342
	Snake Venom Antiserum (Echiven)	0.960	-1.097	0.886	0.113	7.824	0.127
	Snake Venom Antiserum African - 10 (Afriven 10)	0.960	0.668	0.572	0.427	1.339	0.746
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.960	-1.374	0.911	0.088	10.330	0.096
	Snake Venom Antiserum Echiven Plus	0.960	-0.654	0.834	0.165	5.026	0.198
Fav-Afrique (FAV-A)	Anti Snake Venom Serum Central Africa -6	0.522	-0.239	0.681	0.318	2.141	0.466
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.522	-1.101	0.835	0.164	5.070	0.197
	Anti Snake Venom Serum Pan Africa - 10	0.522	0.658	0.466	0.533	0.872	1.145
	Antiserum -PanAfrica (Premium-A)	0.522	1.548	0.263	0.736	0.358	2.790
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.522	-0.498	0.735	0.264	2.774	0.360
	Antivipmyn-Africa (Antivip-A)	0.522	-0.698	0.772	0.227	3.389	0.295
	ASNA antivenom C (ASNA-C)	0.522	0.799	0.431	0.568	0.758	1.318

	ASNA antivenom D (ASNA-D)	0.522	0.872	0.413	0.586	0.704	1.418
	Combipack of Snake Venom Antiserum (African- Ten)	0.522	-0.234	0.680	0.319	2.130	0.469
	EchiTabG	0.522	-1.330	0.864	0.135	6.374	0.156
	EchiTabPlus (ET-Plus)	0.522	0.960	0.392	0.607	0.645	1.549
	Inoserp Pan-Africa (Inoserp-P)	0.522	2.510	0.120	0.879	0.137	7.299
	Menaven, Snake Venom Antitoxin	0.522	-0.986	0.818	0.181	4.519	0.221
	SAIMR Echis	0.522	-0.213	0.676	0.323	2.087	0.479
	Snake Venom Antiserum - Central Africa (Premium-CA)	0.522	-0.111	0.653	0.346	1.883	0.530
	Snake Venom Antiserum (Echiven)	0.522	-1.097	0.834	0.165	5.049	0.198
	Snake Venom Antiserum African - 10 (Afriven 10)	0.522	0.668	0.463	0.536	0.864	1.157
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.522	-1.374	0.869	0.130	6.666	0.150
	Snake Venom Antiserum Echiven Plus	0.522	-0.654	0.764	0.235	3.243	0.308
Inoserp Pan-Africa (Inoserp-P)	Anti Snake Venom Serum Central Africa -6	2.510	-0.239	0.939	0.060	15.630	0.063
	Anti Snake Venom Serum Monovalent Echis ocellatus	2.510	-1.101	0.973	0.026	37.008	0.027
	Anti Snake Venom Serum Pan Africa - 10	2.510	0.658	0.864	0.135	6.371	0.156
	Antiserum -PanAfrica (Premium-A)	2.510	1.548	0.723	0.276	2.615	0.382
	Anti-Snake Venom Serum Central Africa (VINS-CA)	2.510	-0.498	0.952	0.047	20.254	0.049
	Antivipmyn-Africa (Antivip-A)	2.510	-0.698	0.961	0.038	24.741	0.040
	ASNA antivenom C (ASNA-C)	2.510	0.799	0.846	0.153	5.534	0.180
	ASNA antivenom D (ASNA-D)	2.510	0.872	0.837	0.162	5.144	0.194

	Combipack of Snake Venom Antiserum (African- Ten)	2.510	-0.234	0.939	0.060	15.552	0.064
	EchiTabG	2.510	-1.330	0.978	0.021	46.528	0.021
	EchiTabPlus (ET-Plus)	2.510	0.960	0.824	0.175	4.710	0.212
	Fav-Afrique (FAV-A)	2.510	0.522	0.879	0.120	7.299	0.137
	Menaven, Snake Venom Antitoxin	2.510	-0.986	0.970	0.029	32.991	0.030
	SAIMR Echis	2.510	-0.213	0.938	0.061	15.234	0.065
	Snake Venom Antiserum - Central Africa (Premium-CA)	2.510	-0.111	0.932	0.067	13.750	0.072
	Snake Venom Antiserum (Echiven)	2.510	-1.097	0.973	0.026	36.856	0.027
	Snake Venom Antiserum African - 10 (Afriven 10)	2.510	0.668	0.863	0.136	6.306	0.158
	Snake venom antiserum Echis ocellatus (VINS-Echis)	2.510	-1.374	0.979	0.020	48.660	0.020
	Snake Venom Antiserum Echiven Plus	2.510	-0.654	0.959	0.040	23.675	0.042
Menaven, Snake Venom Antitoxin	Anti Snake Venom Serum Central Africa -6	-0.986	-0.239	0.321	0.678	0.473	2.110
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.986	-1.101	0.528	0.471	1.121	0.891
	Anti Snake Venom Serum Pan Africa - 10	-0.986	0.658	0.161	0.838	0.193	5.177
	Antiserum -PanAfrica (Premium-A)	-0.986	1.548	0.073	0.926	0.079	12.612
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.986	-0.498	0.380	0.619	0.613	1.628
	Antivipmyn-Africa (Antivip-A)	-0.986	-0.698	0.428	0.571	0.749	1.333
	ASNA antivenom C (ASNA-C)	-0.986	0.799	0.143	0.856	0.167	5.961
	ASNA antivenom D (ASNA-D)	-0.986	0.872	0.134	0.865	0.155	6.413

	Combipack of Snake Venom Antiserum (African- Ten)	-0.986	-0.234	0.320	0.679	0.471	2.121
	EchiTabG	-0.986	-1.330	0.585	0.414	1.410	0.709
	EchiTabPlus (ET-Plus)	-0.986	0.960	0.124	0.875	0.142	7.004
	Fav-Afrique (FAV-A)	-0.986	0.522	0.181	0.818	0.221	4.519
	Inoserp Pan-Africa (Inoserp-P)	-0.986	2.510	0.029	0.970	0.030	32.991
	SAIMR Echis	-0.986	-0.213	0.315	0.684	0.461	2.165
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.986	-0.111	0.294	0.705	0.416	2.399
	Snake Venom Antiserum (Echiven)	-0.986	-1.097	0.527	0.472	1.117	0.895
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.986	0.668	0.160	0.839	0.191	5.231
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.986	-1.374	0.595	0.404	1.474	0.678
	Snake Venom Antiserum Echiven Plus	-0.986	-0.654	0.417	0.582	0.717	1.393
SAIMR Echis	Anti Snake Venom Serum Central Africa -6	-0.213	-0.239	0.506	0.493	1.025	0.974
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.213	-1.101	0.708	0.291	2.429	0.411
	Anti Snake Venom Serum Pan Africa - 10	-0.213	0.658	0.294	0.705	0.418	2.390
	Antiserum -PanAfrica (Premium-A)	-0.213	1.548	0.146	0.853	0.171	5.824
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.213	-0.498	0.570	0.429	1.329	0.752
	Antivipmyn-Africa (Antivip-A)	-0.213	-0.698	0.618	0.381	1.624	0.615
	ASNA antivenom C (ASNA-C)	-0.213	0.799	0.266	0.733	0.363	2.752
	ASNA antivenom D (ASNA-D)	-0.213	0.872	0.252	0.747	0.337	2.961
	Combipack of Snake Venom Antiserum (African- Ten)	-0.213	-0.234	0.505	0.494	1.020	0.979
	EchiTabG	-0.213	-1.330	0.753	0.246	3.054	0.327
	EchiTabPlus (ET-Plus)	-0.213	0.960	0.236	0.763	0.309	3.234

	Fav-Afrique (FAV-A)	-0.213	0.522	0.323	0.676	0.479	2.087
	Inoserp Pan-Africa (Inoserp-P)	-0.213	2.510	0.061	0.938	0.065	15.23 4
	Menaven, Snake Venom Antitoxin	-0.213	-0.986	0.684	0.315	2.165	0.461
	Snake Venom Antiserum - Central Africa (Premium- CA)	-0.213	-0.111	0.474	0.525	0.902	1.107
	Snake Venom Antiserum (Echiven)	-0.213	-1.097	0.707	0.292	2.419	0.413
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.213	0.668	0.292	0.707	0.413	2.415
	Snake venom antiserum Echis ocellatus (VINS- Echis)	-0.213	-1.374	0.761	0.238	3.194	0.313
	Snake Venom Antiserum Echiven Plus	-0.213	-0.654	0.608	0.391	1.554	0.643
Snake Venom Antiserum - Central Africa (Premium-CA)	Anti Snake Venom Serum Central Africa -6	-0.111	-0.239	0.531	0.468	1.136	0.879
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.111	-1.101	0.729	0.270	2.691	0.371
	Anti Snake Venom Serum Pan Africa - 10	-0.111	0.658	0.316	0.683	0.463	2.158
	Antiserum -PanAfrica (Premium-A)	-0.111	1.548	0.159	0.840	0.190	5.256
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.111	-0.498	0.595	0.404	1.472	0.678
	Antivipmyn-Africa (Antivip-A)	-0.111	-0.698	0.642	0.357	1.799	0.555
	ASNA antivenom C (ASNA-C)	-0.111	0.799	0.286	0.713	0.402	2.486
	ASNA antivenom D (ASNA-D)	-0.111	0.872	0.272	0.727	0.374	2.672
	Combipack of Snake Venom Antiserum (African- Ten)	-0.111	-0.234	0.530	0.469	1.131	0.884
	EchiTabG	-0.111	-1.330	0.771	0.228	3.383	0.295
	EchiTabPlus (ET-Plus)	-0.111	0.960	0.255	0.744	0.342	2.919
	Fav-Afrique (FAV-A)	-0.111	0.522	0.346	0.653	0.530	1.883

	Inoserp Pan-Africa (Inoserp-P)	-0.111	2.510	0.067	0.932	0.072	13.755
	Menaven, Snake Venom Antitoxin	-0.111	-0.986	0.705	0.294	2.399	0.416
	SAIMR Echis	-0.111	-0.213	0.525	0.474	1.107	0.902
	Snake Venom Antiserum (Echiven)	-0.111	-1.097	0.728	0.271	2.680	0.373
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.111	0.668	0.314	0.685	0.458	2.180
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-0.111	-1.374	0.779	0.220	3.538	0.282
	Snake Venom Antiserum Echiven Plus	-0.111	-0.654	0.632	0.367	1.721	0.580
Snake Venom Antiserum (Echiven)	Anti Snake Venom Serum Central Africa -6	-1.097	-0.239	0.297	0.702	0.424	2.357
	Anti Snake Venom Serum Monovalent Echis ocellatus	-1.097	-1.101	0.501	0.498	1.004	0.995
	Anti Snake Venom Serum Pan Africa - 10	-1.097	0.658	0.147	0.852	0.172	5.784
	Antiserum -PanAfrica (Premium-A)	-1.097	1.548	0.066	0.933	0.070	14.090
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-1.097	-0.498	0.354	0.645	0.549	1.8196
	Antivipmyn-Africa (Antivip-A)	-1.097	-0.698	0.401	0.598	0.671	1.489
	ASNA antivenom C (ASNA-C)	-1.097	0.799	0.130	0.869	0.150	6.659
	ASNA antivenom D (ASNA-D)	-1.097	0.872	0.122	0.877	0.139	7.164
	Combipack of Snake Venom Antiserum (African- Ten)	-1.097	-0.234	0.296	0.703	0.421	2.369
	EchiTabG	-1.097	-1.330	0.557	0.442	1.262	0.792
	EchiTabPlus (ET-Plus)	-1.097	0.960	0.113	0.886	0.127	7.824
	Fav-Afrique (FAV-A)	-1.097	0.522	0.165	0.834	0.198	5.049
	Inoserp Pan-Africa (Inoserp-P)	-1.097	2.510	0.026	0.973	0.027	36.856
	Menaven, Snake Venom Antitoxin	-1.097	-0.986	0.472	0.527	0.895	1.117
	SAIMR Echis	-1.097	-0.213	0.292	0.707	0.413	2.419

	Snake Venom Antiserum - Central Africa (Premium-CA)	-1.097	-0.111	0.271	0.728	0.373	2.680
	Snake Venom Antiserum African - 10 (Afriven 10)	-1.097	0.668	0.146	0.853	0.171	5.843
	Snake venom antiserum Echis ocellatus (VINS-Echis)	-1.097	-1.374	0.569	0.430	1.320	0.757
	Snake Venom Antiserum Echiven Plus	-1.097	-0.654	0.391	0.608	0.642	1.556
Snake Venom Antiserum African - 10 (Afriven 10)	Anti Snake Venom Serum Central Africa -6	0.668	-0.239	0.712	0.287	2.478	0.403
	Anti Snake Venom Serum Monovalent Echis ocellatus	0.668	-1.101	0.854	0.145	5.867	0.170
	Anti Snake Venom Serum Pan Africa - 10	0.668	0.658	0.502	0.497	1.010	0.989
	Antiserum -PanAfrica (Premium-A)	0.668	1.548	0.293	0.706	0.414	2.411
	Anti-Snake Venom Serum Central Africa (VINS-CA)	0.668	-0.498	0.762	0.237	3.211	0.311
	Antivipmyn-Africa (Antivip-A)	0.668	-0.698	0.796	0.203	3.922	0.254
	ASNA antivenom C (ASNA-C)	0.668	0.799	0.467	0.532	0.877	1.139
	ASNA antivenom D (ASNA-D)	0.668	0.872	0.449	0.550	0.815	1.225
	Combipack of Snake Venom Antiserum (African- Ten)	0.668	-0.234	0.711	0.288	2.465	0.405
	EchiTabG	0.668	-1.330	0.880	0.119	7.377	0.135
	EchiTabPlus (ET-Plus)	0.668	0.960	0.427	0.572	0.746	1.3390
	Fav-Afrique (FAV-A)	0.668	0.522	0.536	0.463	1.157	0.864
	Inoserp Pan-Africa (Inoserp-P)	0.668	2.510	0.136	0.863	0.158	6.306
	Menaven, Snake Venom Antitoxin	0.668	-0.986	0.839	0.160	5.231	0.191
	SAIMR Echis	0.668	-0.213	0.707	0.292	2.415	0.413

	Snake Venom Antiserum - Central Africa (Premium-CA)	0.668	-0.111	0.685	0.314	2.180	0.458
	Snake Venom Antiserum (Echiven)	0.668	-1.097	0.853	0.146	5.843	0.171
	Snake venom antiserum Echis ocellatus (VINS-Echis)	0.668	-1.374	0.885	0.114	7.715	0.129
	Snake Venom Antiserum Echiven Plus	0.668	-0.654	0.789	0.210	3.753	0.266
	Anti Snake Venom Serum Central Africa -6	-1.374	-0.239	0.243	0.756	0.321	3.113
	Anti Snake Venom Serum Monovalent Echis ocellatus	-1.374	-1.101	0.431	0.568	0.760	1.314
	Anti Snake Venom Serum Pan Africa - 10	-1.374	0.658	0.115	0.884	0.130	7.636
	Antiserum -PanAfrica (Premium-A)	-1.374	1.548	0.051	0.948	0.053	18.603
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-1.374	-0.498	0.293	0.706	0.416	2.402
	Antivipmyn-Africa (Antivip-A)	-1.374	-0.698	0.337	0.662	0.508	1.966
	ASNA antivenom C (ASNA-C)	-1.374	0.799	0.102	0.897	0.113	8.792
	ASNA antivenom D (ASNA-D)	-1.374	0.872	0.095	0.904	0.105	9.458
	Combipack of Snake Venom Antiserum (African- Ten)	-1.374	-0.234	0.242	0.757	0.319	3.128
	EchiTabG	-1.374	-1.330	0.488	0.511	0.956	1.045
	EchiTabPlus (ET-Plus)	-1.374	0.960	0.088	0.911	0.096	10.330
	Fav-Afrique (FAV-A)	-1.374	0.522	0.130	0.869	0.150	6.666
	Inoserp Pan-Africa (Inoserp-P)	-1.374	2.510	0.020	0.979	0.020	48.660
	Menaven, Snake Venom Antitoxin	-1.374	-0.986	0.404	0.595	0.678	1.474
	SAIMR Echis	-1.374	-0.213	0.238	0.761	0.313	3.194
	Snake Venom Antiserum - Central Africa (Premium-CA)	-1.374	-0.111	0.220	0.779	0.282	3.538

	Snake Venom Antiserum (Echiven)	-1.374	-1.097	0.430	0.569	0.757	1.320
	Snake Venom Antiserum African - 10 (Afriven 10)	-1.374	0.668	0.114	0.885	0.129	7.715
	Snake Venom Antiserum Echiven Plus	-1.374	-0.654	0.327	0.672	0.486	2.055
Snake Venom Antiserum Echiven Plus	Anti Snake Venom Serum Central Africa -6	-0.654	-0.239	0.397	0.602	0.660	1.514
	Anti Snake Venom Serum Monovalent Echis ocellatus	-0.654	-1.101	0.609	0.390	1.563	0.639
	Anti Snake Venom Serum Pan Africa - 10	-0.654	0.658	0.212	0.787	0.269	3.715
	Antiserum -PanAfrica (Premium-A)	-0.654	1.548	0.099	0.900	0.110	9.051
	Anti-Snake Venom Serum Central Africa (VINS-CA)	-0.654	-0.498	0.461	0.538	0.855	1.168
	Antivipmyn-Africa (Antivip-A)	-0.654	-0.698	0.511	0.488	1.045	0.956
	ASNA antivenom C (ASNA-C)	-0.654	0.799	0.189	0.810	0.233	4.277
	ASNA antivenom D (ASNA-D)	-0.654	0.872	0.178	0.821	0.217	4.602
	Combipack of Snake Venom Antiserum (African- Ten)	-0.654	-0.234	0.396	0.603	0.656	1.522
	EchiTabG	-0.654	-1.330	0.662	0.337	1.965	0.508
	EchiTabPlus (ET-Plus)	-0.654	0.960	0.165	0.834	0.198	5.026
	Fav-Afrique (FAV-A)	-0.654	0.522	0.235	0.764	0.308	3.243
	Inoserp Pan-Africa (Inoserp-P)	-0.654	2.510	0.040	0.959	0.042	23.675
	Menaven, Snake Venom Antitoxin	-0.654	-0.986	0.582	0.417	1.393	0.717
	SAIMR Echis	-0.654	-0.213	0.391	0.608	0.643	1.554
	Snake Venom Antiserum - Central Africa (Premium-CA)	-0.654	-0.111	0.367	0.632	0.580	1.721
	Snake Venom Antiserum (Echiven)	-0.654	-1.097	0.608	0.391	1.556	0.642
	Snake Venom Antiserum African - 10 (Afriven 10)	-0.654	0.668	0.210	0.789	0.266	3.753

	Snake venom antiserum Echis ocellatus (VINS- Echis)	-0.654	-1.374	0.672	0.327	2.055	0.486
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*Pairwise comparison of snake antivenom products available for use in SSA. It compares two components: Compared 1 and Compared 2, which represent the snake antivenom products. Utility 1 and Utility 2 are estimated utilities of the antivenoms. Probability 1 predicts the likelihood of participants prioritizing the first snake antivenom over the second, while Probability 2 predicts the likelihood of participants prioritizing the second antivenom over the first with their associated odd values.

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