RESEARCH ARTICLE

Management and cost of snakebite injuries at a teaching and referral hospital in Western Kenya [version 1; peer review: 2 approved, 2 approved with reservations]

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Abstract

Background: Data on the cost of snakebite injuries may inform key pillars of universal health coverage including proper planning, allocation, and utility of resources. This study evaluated the injuries, management, and costs resulting from snakebites at Jaramogi Oginga Odinga Teaching and Referral Hospital (JOOTRH) in Kenya.
Methods: In total, medical records of 127 snakebite victims attending JOOTRH between January 2011 and December 2016 were purposely selected and data on the age, gender, type of residence (urban or rural), part of the body bitten, time of bite, injuries, pre-hospital first aid, time to hospital, length of stay, treatment, and costs were collected. Regression analysis was used to predict the total indirect cost of snakebite injuries and $p \leq 0.05$ was considered significant. Mortality and loss of income of hospitalized victims were considered as direct costs.
Results: It was found that 43 victims were 13-24 years of age, 64 were female, 94 were from rural areas, 92 were bitten on the lower limbs, 49 were bitten between 6.00 pm and midnight, 43 attempted pre-hospital first aid, and the median time to hospital was 4.5 hours. Antivenom, supportive therapy, antibiotics, antihistamines, corticosteroids, analgesics, and non-steroidal anti-inflammatory drugs were used. Cellulitis, compartment syndrome, gangrenous foot, psychiatric disorder, and death were the main complications. Most victims spent 1-5 days in hospital and the median cost of treating a snakebite was 2652 KES (~$26). Drugs, ward charges, and nursing procedures were the highest contributors to the total indirect cost. Victims hospitalized for 6-10 days and >10 days incurred 32% and 62% more costs, respectively, compared to those hospitalized for 1-5 days.
Conclusions: The longer snakebite victims are hospitalized, the higher the

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cost incurred. Continuous medical education on the correct management of snakebites should be encouraged to minimize complications that may increase hospital stays and costs incurred.

Keywords
snakebite, snakebite envenoming, costs of snakebite, universal health coverage, neglected tropical disease, snakebite burden, sub-Saharan Africa, management of snakebite

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Introduction

Snakebite envenoming is a topic perhaps too little discussed on the global stage. The disease has only recently been formally re-instated to the WHO list of neglected tropical diseases after a four-year hiatus[1]. The additional focus is welcome and has been widely anticipated by many people that deal with and understand the devastating impact of snakebite envenoming on individuals, their families, and communities in general. It is widely hoped that the reinstatement will significantly boost efforts to reduce the burden of snakebite in Asia, Africa, and Latin America where the burden is highest[1,2].

Specifying the requirements for antivenom at the local level, educating at-risk groups, improving accessibility to antivenoms, and training of healthcare personnel are the major challenges in addressing snakebites[1]. Most of the mitigative strategies focus on ways and means of addressing these challenges[1]. However, evaluating the cost associated with managing snakebites at the local hospital level has often been overlooked. To date, there are no studies that provide estimates for how much it may cost to treat a victim of a snakebite at the local hospital setting.

Kenya is a country with a population of about 40 million people[3]. Access to affordable healthcare in the country has often been fraught with controversy[4]. In a bid to provide quality healthcare to its citizens, the government of Kenya has recently adopted the big four agenda[5], which seeks to deliver healthcare, food security, manufacturing growth, and affordable housing[5]. To deliver on healthcare, the government has embraced the Kenyan Health Policy, which borrows heavily from the WHO model on Universal Healthcare Coverage (UHC)[6]. The aim is to ensure that every Kenyan receives quality healthcare (promotive, preventive, curative and rehabilitative) without suffering financial strain[7].

There has been a huge clamor for UHC in Kenya. However, only four counties/administrative units, namely Kisumu, Isiolo, Nyeri, and Machakos, have been selected to pilot the rollout of the program[7]. Data on the cost of treating various diseases may inform key pillars of UHC, including proper health planning, resource allocation and utility of resources. Snakebite injuries are probably one of the most hidden public health crises globally. However, in a country that is grappling with HIV/AIDS, malaria, tuberculosis and other non-communicable diseases[8], there is a real risk that snakebites may be further neglected in terms of policy and resource allocation. Estimating the cost of managing snakebite injuries at the local hospital level may go a long way in highlighting the gaps that require the attention of the government and other relevant stakeholders.

In a previous study on acute poisoning at Jaramogi Oginga Odinga Teaching and Referral Hospital (JOOTRH), we established that snakebites were the leading cause of poisoning between the years 2011 and 2016[9]. Therefore, the objective of the present study was to evaluate the injuries, management, and costs associated with snakebites at the hospital between the years 2011 and 2016. The information may be important for guiding policy on proper health planning, resource allocation and utility of the limited resources available to the counties.

Methods

Ethical considerations

Permission to conduct the study was obtained from the hospital administration; ethical clearance was obtained from the Ethical Review Committee (ERC) of JOOTRH (Ref no: ERC. IB/VOL1/412). The ethical approval document is provided as *Extended data* (Figure S1)[10].

Study design

This was a descriptive cross-sectional study that was carried out between July and November 2017 using data from a retrospective audit on records of acute poisoning at JOOTRH[9]. All patients with acute poisoning due to snakebite envenoming presenting to and managed in the emergency department of JOOTRH between January 2011 and December 2016 were reviewed for inclusion. Victims transferred from health centers, dispensaries, and sub-county hospitals to JOOTRH were counted once after thorough scrutiny of the medical records to ensure there was no double reporting. The medical records had to have all the study variables of interest; age, gender, type of residence (urban or rural), part of the body bitten, time of bite, injuries, pre-hospital first aid, time to hospital, length of stay, treatment, and costs. Any medical records that had incomplete information or did not have any of these parameters of interest were excluded from the analysis. In total, 127 medical records of snakebite victims attending the hospital between January 2011 and December 2016 were purposely selected for the study. The digital archiving of medical records at JOOTRH based on the international classification of diseases begun in January 2011 and this made it easier for us to access/trace the physical medical records, as opposed to periods before the digital archiving was in place. We therefore selected a five-year time frame from the period of inception of the digital archiving as our study period. Data on the age, gender, type of residence (urban or rural) of the victim, part of the body bitten, and the time of the bite was retrieved. Other data retrieved included the type of injuries, pre-hospital management measures, time taken to reach the hospital, length of stay at the hospital, type of treatment, and associated costs. Indirect costs included those related to registration, admission, file fees, laboratory, laundry, physiotherapy, nursing procedures, antivenom, other drugs, daily ward charges, caretaker costs, cost of non-pharmaceuticals, surgical operations on victims, and miscellaneous. The direct costs considered in this analysis were those incurred due to mortalities and loss of income by patients who were hospitalized.

Study setting

The study was carried out at JOOTRH, a referral hospital in Kisumu County. In December of 2018, the county was selected as the first of four counties to pilot UHC in Kenya[7]. The hospital has a wide catchment area encompassing up to 10 counties (Kisumu, Siaya, Homa Bay, Migori, Kisii, Kakamega, Vihiga, Bungoma, Busia, and Nandi) within the Western Kenya region. Based on estimates from the most recent census (2009), these

counties are estimated to have a population of around 970, 000, 840,000, 750,000, 260,000, 1,150,000, 1,660,000, 550, 000, 1,600,000, 490, 000, and 750,000 people, respectively[9]. Curative, preventive, promotive and rehabilitative health services are provided at JOOTRH[9].

Data handling and statistical analysis

Sociodemographic data from the pre-structured proforma were collated in MS Excel spreadsheets and analyzed using descriptive statistics. Categorical variables were presented in frequencies and percentages and qualitative variables were handled through thematic analysis. Quantitative data including additional costs of treatment were analyzed using descriptive statistical measures including measures of central tendency; mean, median and measures of dispersion: minimum, and maximum. Multiple linear regression was used to determine the predictors of the total indirect cost of treating snakebite (SPSS version 20.0). The total indirect cost (dependent variable) was transformed to $\log_{10}$ and regressed against independent variables including the age, gender, and type of residence (urban or rural) of victims, location of the victims at the time of the bite, season and time of the bite, and the time taken to get to the hospital. Other independent variables were the length of hospital stay, first aid measures initiated, and part of the body bitten. $p<0.05$ was considered significant. The direct costs considered in this analysis were those incurred due to mortalities and loss of income by patients who were hospitalized.

Results

The year of the bite, the type of residence (urban or rural) of victims and the seasonal distribution of snakebite in the catchment area of the hospital is summarized in Table 1[11]. Most bites occurred in the year 2012, with Kisumu County recording the highest number of bites. Moreover, most bites took place during the rainy season.

Table 1. Year of bite, county of origin, and seasonal distribution of the snakebite victims who presented to Jaramogi Oginga Odinga Teaching and Referral Hospital during the study period.

Variable	Frequency (*n*=127)
Year	
2011	19 (14.9%)
2012	30 (23.6%)
2013	24 (18.9%)
2014	27 (21.3%)
2015	18 (14.2%)
2016	9 (7.1%)
County	
Kisumu	101 (79.5%)
Siaya	13 (10.2%)
Vihiga	5 (3.9%)
Homabay	3 (2.4%)
Nandi	3 (2.4%)
Kakamega	1 (0.8%)
Migori	1 (0.8%)
Season	
Long rains 1 (March-May)	26 (20.5%)
Long rains 2 (Oct-Nov)	25 (19.7%)
Short rains (Aug-Sep)	31 (24.4%)
Cool dry season (Jun-July)	25 (19.7%)
Hot dry season (Dec-Feb)	20 (15.7%)

The majority of the victims (110/127, 86.6%) presented to hospitals within Kisumu County, 8/127 (6.3%) cases presented to hospitals in Siaya County, 4/127 (3.1%) cases presented to hospitals in Vihiga County, 2/127 (1.6%) cases presented to hospitals in Homabay County, one (0.8%) case presented to a hospital in Busia County and another one (0.8%) case presented to a hospital in Migori County. Of the 127 cases, 84 (66.1%) presented to JOOTRH as the first port of call. This was followed by nine cases (7.1%) who presented to Ahero Sub-County hospital, four cases (3.1%) who presented to the Kombewa Sub-County hospital, and another four cases (3.1%) who presented to the Nyakach Sub-County hospital (Table S1, *Extended data*)[10]. The gender, type of residence, marital status, and age of the victims who presented to JOOTRH during the study period are summarized in Table 2. About 94/127 (74.0%) of all snakebite cases were from the rural areas and most victims were between 13 and 24 years of age.

The occupation of snakebite victims is summarized in Table 3.

The site of the bite, location of the victim at the time of the bite, and the circumstance/activity during which the snakebite occurred are shown in Table 4. Most bites were on the lower limbs, occurred outdoors, and took place while the victims were walking.

Most bites occurred between 1800 and 2359 and a majority of the victims did not attempt any form of pre-hospital measure after being bitten (Table 5).

Most of the victims took less than six hours to present to the hospital (median time was 4.5 hours). A majority reported having been bitten by what they described as a black snake and cellulitis was the most common complication (Table 6).

The symptoms of victims of snakebite who presented to JOOTRH during the study period are summarized in Table 7. The symptoms were local and systemic (neurological, hematological).

The treatment received by the victims of snakebite included the use of antivenom, supportive therapy, antimicrobial agents, antihistamines, corticosteroids, non-steroidal anti-inflammatory agents, opioid and non-opioid analgesics and general anesthetics (Table 8).

Table 2. Gender, type of residence, marital status, and age of snakebite victims who presented to Jaramogi Oginga Odinga Teaching and Referral Hospital during the study period.

Variable	Frequency (*n=127*)
Gender	
Male	63 (49.6%)
Female	64 (50.4%)
Type of residence	
Rural	94 (74.0%)
Urban	33 (26.0%)
Marital status	
Single	31 (24.4%)
Married	48 (37.8%)
Divorced	1 (0.8%)
Widowed	3 (2.4%)
Child	35 (27.6%)
Not captured	9 (7.1%)
Age (years)	
0-12	31 (24.4%)
13-24	43 (33.9%)
25-36	25 (19.7%)
37-48	13 (10.2%)
49-60	9 (7.1%)
61-72	4 (3.1%)
73-84	2(1.6%)

Table 3. Occupation of the victims of snakebite who presented to Jaramogi Oginga Odinga Teaching and Referral Hospital during the study period.

Variable	Frequency (*n=127*)
Occupation	
Attending school	47 (37.0%)
Entrepreneur	20 (15.7%)
Farming	18 (14.2%)
Toddler	8 (6.3%)
Not captured	7 (5.5%)
Laborer	5 (3.9%)
Unemployed	5 (3.9%)
Artisan	5 (3.9%)
Homemaking	4 (3.1%)
Security	3 (2.4%)
Hospitality	3 (2.4%)
Teaching	2 (1.6%)

Table 4. Site of the bite, location, and activity of the victim at the time of the bite.

Variable	Frequency (*n=127*)
Site of bite	
Upper limbs	20 (15.7%)
Lower limbs	92 (72.4%)
Other	2 (1.6%)
Not specified	13 (10.2%)
Location of the victim at the time of the bite	
Indoors	15 (11.8%)
Outdoors	71 (55.9%)
Unspecified	41 (32.3%)
Circumstance/activity	
Walking	54 (42.5%)
Unknown	31 (24.4%)
Resting/sleeping	12 (9.4%)
Farming	12 (9.4%)
Working	10 (7.9%)
Playing	6 (4.7%)
Relieving him/herself	2 (1.6%)

Of the 127 victims of snakebite, 53/127 (42%) received antivenom while 74/127 (58%) did not. Of those that received antivenom, 51 survived while two died. Among the victims who received antivenom, 44 received one vial of antivenom, six received two vials of antivenom, one received three vials of antivenom, and another two received five vials of antivenom (Table S2, *Extended data*)[10]. Among those who did not receive antivenom, 72 survived and two died.

Of the 52 victims of snakebite who survived after receiving antivenom, 15 had complications including cellulitis (n=7), compartment syndrome (n=4), gangrenous foot (n=2), a psychiatric episode (n=1), and soft tissue injury (n=1). None of the 74 victims who did not receive antivenom developed any complications.

The majority (107/127, 84%) of all victims of snakebite spent between one and five days in the hospital, 12 (9%) spent between six and 10 days, two (1.6%) spent between 11 and 15 days and another two (1.6%) spent between 16 and 20 days (Figure 1). There was one victim (0.8%) who spent between 21 and 25 days in the hospital, while another two (1.6%) victims spent between 26 and 30 days in the hospital (Figure 1).

When considered in terms of the daily minimum wage in Kenya (KES 452; ~ $4 USD), victims of snakebite who spent at least five, 10 and 20 days in the hospital lost about KES 2260 (~$22), KES 4520 (~$44) and KES 9, 040 (~$88) worth of wages, respectively.

Table 5. Time of bite, and pre-hospital first aid measures taken by victims who presented to Jaramogi Oginga Odinga Teaching and Referral Hospital during the study period.

Variable	Frequency *(n=127)*
Time of bite	
06:00–11:59	22 (17.3%)
12:00–17:59	24 (18.9%)
18:00–23:59	49 (38.6%)
00:00–05:59	9 (7.1%)
No data	23 (18.1%)
Pre-hospital measures	
None	86 (67.7%)
Tourniquet only	14 (11.0%)
Herbal medicine only	10 (7.9%)
Tourniquet, incisions, herbal medicine	9 (7.1%)
Herbal medicine, incisions	3 (2.4%)
Incisions only	2 (1.6%)
Burning matchstick at the site of the bite	1 (0.8%)
Herbal medicine, limb immobilization	1 (0.8%)
Herbal medicine, cleaning wound with cold water	1 (0.8%)
Tourniquet, cloth impregnated with charcoal	1 (0.8%)
Tourniquet, incisions	1 (0.8%)
Tourniquet, application of vaseline at the site of the bite	1 (0.8%)
Cleaning the wound with potassium permanganate	1 (0.8%)
Cleaning the wound with povidone-iodine	1 (0.8%)
Tourniquet, pouring paraffin on the site of the bite	1 (0.8%)

Table 6. The time taken to get to the hospital, description of offending snakes, and the complications of snakebite among victims who presented to Jaramogi Oginga Odinga Teaching and Referral Hospital during the study period.

Variable	Frequency
Time taken to get to the hospital	***(n=127)***
0–6 hours	54 (42.5%)
6–12 hours	14 (11.0%)
>12 hours	10 (7.9%)
No data	49 (38.6%)
Description of offending snakes	***(n=127)***
Black snake	49 (38.6%)
Snake not seen	44 (34.6%)
Green snake	13 (10.2%)
Brown snake	8 (6.3%)
Brown and black snake	7 (5.5%)
Grey snake with white spots	1 (0.8%)
Red and brown spots	1 (0.8%)
White and brown snake	1 (0.8%)
White, brown, and black snake	1 (0.8%)
White-bellied snake	1 (0.8%)
Yellow snake	1 (0.8%)
Complications of snakebite	***(n=30)***
Cellulitis	18 (69.2%)
Death	4 (15.4%)
Compartment syndrome	4 (15.4%)
Gangrene	2 (7.7%)
Cellulitis and gangrene	1 (3.8%)
Psychiatric episode	1 (3.8%)

Table 7. Signs and symptoms of snakebite among victims in the study area during the study period.

Classification of the symptoms	Manifestations
Local	Septicemia, tissue necrosis, gangrene, swelling, edematous swelling, edema, mild tenderness on palpation, tenderness, gradual/progressive swelling, leg ulcer, purulent discharge, pitting edema, cellulitis, shiny appearance of foot, bullae on leg, blistering (ruptured and unruptured), multiple bruising on lower limbs, tense skin with bullous eruptions, bland blistering, cold leg, fang marks with/without pruritus
Systemic (Neurological)	Radiating/pulsating/localized/sudden onset pain, pulse awareness, paresthesia, dysphagia, numbness, blurred vision, headache, frothing at the mouth, cough, unconsciousness, pin-point pupil, dizziness, elevated body temperature, weakness, dyspnea, loss of hearing on left ear, profuse sweating, slurred speech, easy fatiguability, nausea, vomiting
Systemic (hematological)	Slight/mild/minimal bleeding, severe/excessive bleeding, hyperpigmentation at the site of the bite, ecchymosis, erythema

Table 8. An overview of the treatment regimen used for the management of snakebite in the study area.

Treatment	Description
Antivenom	Unspecified brands
Supportive therapy	Normal saline, normal saline and ringer's lactate, glucose infusion
Antimicrobial agents	Floxapen IV, ceftriaxone IV, floxapen PO, metronidazole IV, benzylpenicillin IV, fluconazole PO, ampliclox PO, amoxil PO, augmentin PO, co-trimoxazole PO, gentamycin IV, metronidazole PO, cefuroxime PO, ceftazidime IV, Lincomycin IV
Antihistamines	Piriton IV, piriton PO, cetirizine PO
Corticosteroids	Hydrocortisone IV, hydrocortisone ointment, dexamethasone IV, prednisolone PO
Non-steroidal anti-inflammatory drugs (NSAID's)	Diclofenac IM, ibuprofen PO, diclofenac PO, ketorolac tromethamine PO, aspirin PO, flamchek PO (chlorzoxazone:diclofenac:paracetamol:250mg/50mg/325mg), betapyn PO(paracetamol:codeine phosphate:caffeine: doxylamine succinate:450/10/50/5), aceclofenac PO
Analgesics	Non-opioid (paracetamol PO), opioid (morphine PO, betapyn PO (paracetamol:codeine phosphate:caffeine: doxylamine succinate:450/10/50/5), tramadol IV, tramadol PO, tramadol IM, flamchek(chlorzoxazone:diclofenac:paracetamol:250mg/50mg/325mg)
General anesthetics	Suxamethonium IV, bupivacaine IM, sodium thiopental IV, pancuronium bromide IV, neostigmine IV, atropine IV, halothane IV
Miscellaneous	Lasix IV, Mupirocin ointment (Bactroban), phytomenadione IV, lignocaine IM, Aloha PO, anti-tetanus IM, emanzen forte PO, omeprazole PO, X-tone PO, adrenaline SC, orofer PO, haloperidol PO, artane PO, aldactone PO, nifedipine PO, heavy bupivacaine IM

IV: intravenous, PO: per oral, IM: intramuscular.

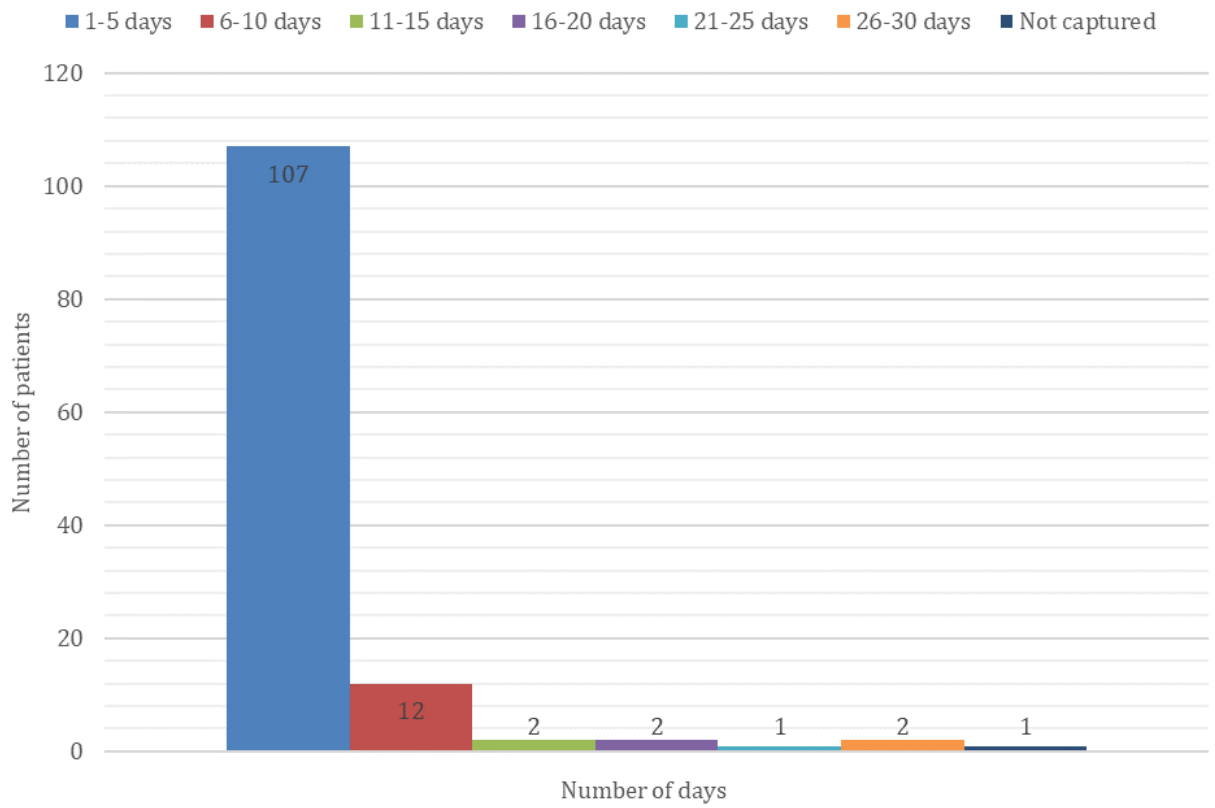

Figure 1. Number of days spent in the hospital by victims of snakebite in the study area.

The total indirect cost of managing snakebite in the study area during the period of study was KES 568,557.72 (~$5530). Seven victims of snakebite received a waiver on the total indirect costs amounting to 91,601 KES (~$890). None of these victims had any hospital insurance cover (Table S3, *Extended data*)[10]. The highest contributors to the total indirect cost of snakebite were drugs (KES 152,964; ~$1485), ward charges (KES 142,300 KES; ~$1380), and nursing procedures (KES 81,500; ~$790) (Figure 2).

The median cost of treating snakebite was KES 2652 (~$26; range: KES 1100-41399 or ~11-400$). The predictors of the total indirect cost of treating snakebite are summarized in Table 9. Generally, victims who spent 6–10 days and >10 days incurred 32% and 62% more costs, respectively, compared to those who spent 1–5 days.

Discussion

To the best of our knowledge, this is the first study that has reported on the cost of snakebites in any hospital setting. Our findings suggest that drugs (excluding antivenom), ward charges, and nursing procedures are the highest contributors to the total indirect cost of managing snakebite. When antivenom is added to the valuation, the problem of managing snakebite in a local hospital setting suddenly becomes more complex. We also report that the median cost of treating snakebite was 2652 KES (~$26). According to a recently published survey, nearly half of Kenyan households earn less than 10,000 KES (~$97) per month, while 2% have no income at all[12]. What this means is that, in the event of a snakebite, around 50% of all Kenyan households would need to spend approximately 25% of their monthly income treating the condition, and another 2% would have no means of paying for the treatment. Moreover, the minimum wage in Kenya is currently KES 13,572 (~$134) per month, which translates to about KES 452 (~$4) per day[13]. Hence, for a person who misses work for 10 days due to hospitalization, the lost revenue would be about KES 4,520 (~$44). In essence, this person becomes poorer as they may not be able to buy food for their family, pay rent, or pay school fees for their children. Their productivity is therefore dented, which is bound to affect their socioeconomic standing. Moreover, the four individuals in this study who died from their injuries may also have an impact on cost, as these individuals will no longer be financially available for their families who are most likely to slide into poverty.

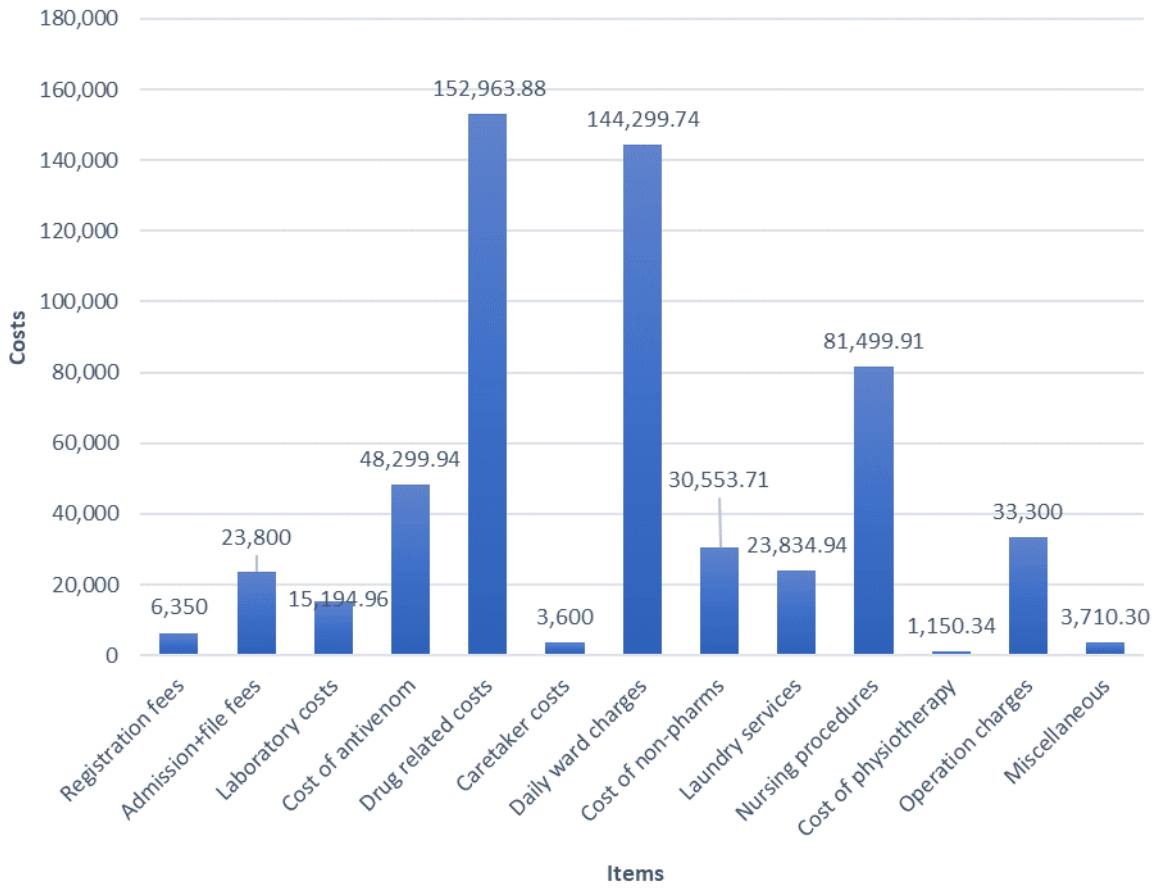

Figure 2. Summary of the cost of snakebite injuries in the study area.

Table 9. Overview of snakebite related factors influencing the total indirect cost of snakebite at Jaramogi Oginga Odinga Teaching and Referral Hospital.

Parameter	Estimate	Std. error	t(106)	t pr.	Odds
Type of residence					
Rural	-0.04	0.06	-0.64	0.52	0.96
First aid measure					
Did not attempt	-0.07	0.05	-1.21	0.23	0.94
Gender					
Female	0.03	0.05	0.54	0.59	1.03
Location of victim					
Outdoors	-0.09	0.09	-0.95	0.35	0.92
Unspecified	-0.19	1.00	-1.88	0.06	0.83
Length of stay					
6–10 days	0.28	0.09	3.24	0.002	1.32
>10 days	0.48	0.11	4.42	<0.01	1.00
Part bitten					
Upper limbs	0.00	0.07	0.05	0.96	1.00
Other	-0.19	0.20	-0.95	0.35	0.83
Unspecified	0.04	0.09	0.45	0.66	1.04
Season					
Wet	-0.10	0.06	-1.73	0.09	0.91
Time of bite					
1200–1759	-0.07	0.08	-0.91	0.37	0.93
1800–2359	0.05	0.07	0.73	0.47	1.05
0000–0559	0.16	0.13	1.26	0.21	1.17
No data	0.02	0.10	0.26	0.80	1.03
Time to hospital					
60–239 minutes	-0.01	0.21	-0.02	0.98	1.00
240–480 minutes	0.13	0.21	0.61	0.54	1.14
>480 minutes	-0.06	0.22	-0.28	0.78	0.94
Not captured	0.02	0.21	0.09	0.93	1.02

From our findings, the longer a snakebite victim was in the hospital, the more likely they were to incur higher costs. Additionally, we established that spending more than 10 days in the hospital was associated with a 62% increase in the total cost, relative to spending between one and five days in hospital. A length of stay of between six and 10 days was associated with a 32% increase in the total cost of treating the snakebite at the hospital.

The first guidelines for the prevention, diagnosis, and management of snakebite envenoming in Kenya were published in April 2019[6]. These guidelines provide details of how snakebite envenoming should be managed at the different levels of care in Kenya, including at the rural dispensary/health center, sub-county/district hospital, and at the referral hospital level[6]. Based on our findings, there was no evidence that the 20-minute whole blood clotting test or any urine exam, considered as standard diagnostic tests in snakebite guidelines, were done in any of these facilities. Moreover, non-steroidal anti-inflammatory drugs (NSAIDs) such as diclofenac, ketorolac, aceclofenac, and ibuprofen were routinely given to victims of snakebite, despite their use being contraindicated in managing the disease. It was also evident that some of the bites had hematological effects, including slight/mild/minimal bleeding, severe/excessive bleeding, hyper-pigmentation at the site of the bite, ecchymosis, and erythema. NSAIDs interfere with the blood coagulation cascade

and may potentiate hematological disturbances in the event of a snakebite, particularly those from snakes with hemotoxic venom[6]. It is interesting to note that all the victims who died had received an NSAID (intramuscular diclofenac in particular) for snakebite-associated pain.

According to the clinical notes (particularly those that had something to do with the referral chain), the unavailability of antivenom was the main reason for referring victims from the smaller facilities to either the sub-county/district hospital or to the referral hospital. At the sub-county/district hospital level, conservative management of snakebite by use of blood transfusion or fresh frozen plasma (FFP) was often not possible as the blood/FFP was seldom available at the facilities. Furthermore, sub-county/district hospitals had to refer patients to JOOTRH for an array of reasons, including the unavailability of antivenom, the lack of the pre-requisite reagents to perform clinical and laboratory examinations, and the lack of ECG/radiography services, as well as a lack of snakebite management skills.

At JOOTRH, antivenom was also not always available, and there were many cases of victims being asked to buy the antivenom from private pharmacies in the town of Kisumu. This was a challenge, especially for cases that occurred at night. Many of the private pharmacies in the area do not operate at night and most did not stock antivenom, further delaying treatment. Furthermore, based on our findings, there was no evidence that bacterial cultures were used to inform the choice of antibiotics for managing snakebite-associated infections. This observation is troubling considering the current state of antimicrobial resistance in developing countries including Kenya. The fact that very few victims were subjected to laboratory evaluation is also quite alarming. The reasons for this observation need to be elaborated.

Despite all the shortcomings in managing snakebite at JOOTRH, there were a few positives. First, based on the two cases of gangrene that were resolved successfully (after fasciotomy), it seems that the surgical team at the facility is well equipped to manage venomous snakebite-induced necrosis. Second, it was good to see that rehabilitative services were offered to some victims by the department of physiotherapy and occupational therapy. Third, the availability of psychological services to snakebite victims was also commendable. This was exemplified by the case of a 16-year-old female victim of snakebite who had a psychiatric episode secondary to the bite, who was discharged three days after presenting to JOOTRH having received antivenom, supportive care (IV fluids) and psychological counseling.

Kisumu East sub-county contributed at least four in every ten cases of snakebite at JOOTRH during the study period. The area has several wards including Central Kolwa, East Kajulu, West Kajulu, East Kolwa, and Manyatta wards[14]. JOOTRH is also located in Kisumu East. We therefore posit that the numbers of patients presenting to the hospital from this region may be related to the proximity of the victims to the hospital.

There were more bites during the rainy season than the dry season, in agreement with other similar studies[15,16]. This observation may have something to do with the fact that snakes seek dry and safe shelter whenever heavy rains disrupt their habitats[17].

Our findings of more bites occurring in the rural areas, predominantly affecting the young people, mostly being inflicted on the lower limbs and occurring in the late evenings are consistent with the reports of other similar studies[18–22].

The demographic that was most affected by snakebite included students and individuals partaking in outdoor activities. Moreover, most bites occurred while the victims were walking. In rural Africa, more often than not, students have to travel long distances to have access to education. We posit that these students may have been bitten in the evening hours as they walked back home from school.

The symptoms of snakebite envenoming and the description of the offending snakes are largely consistent with the type of snakes known to be in the area. These snakes are mostly of the Viperidae and Elapidae families[6] and include the puff adder (*Bitis arietans*), gaboon viper (*Bitis gabonica*), rhinoceros viper (*Bitis nasicornis*), black mamba (*Dendroaspis polylepis*), Jameson's mamba (*Dendroaspis jamesoni*), the eastern forest cobra (*Naja subfulva*), and the gold tree cobra (*Pseudohaje goldi*)[6].

More than half of all the victims did not attempt any pre-hospital first aid measures. A similar number reported to the hospital within six hours of having been bitten. When taken collectively, this may suggest that the locals recognize that snakebite is a medical emergency requiring urgent medical intervention. On the other hand, the lack of initiative by the victims or their proxies in attempting any pre-hospital measure may suggest that the population is not knowledgeable on the appropriate steps to take in the event of snakebite. Where some form of pre-hospital measure was used, the measure adopted cannot be considered as beneficial. Some of the measures are contraindicated and have been shown to do more harm than good[23]. The use of tourniquets, incisions, suction, heat, ice, alcohol, and electric shock have all been reported to be counterproductive in snakebites[23]. The jury may still be out on the role of herbal medicine in snakebites. Those that oppose the practice argue that seeking treatment from traditional herbal medicine practitioners often delays access to proper medical intervention and may result in complications[24,25]. In contrast, proponents of herbal medicine argue that the purpose of herbal medicine is not to replace antivenom, but serve an adjunctive role, particularly in managing local effects of envenomation such as necrosis, as has been reported by several authors[26–28]. The latter seems to be buoyed by the fact that some phytochemicals isolated from medicinal plants have shown some promising *in vitro* and *in vivo* neutralization capacity against phospholipase A_2 and metalloproteases, which are enzymes associated with local tissue damage[26–29].

It is difficult to see how other practices such as burning matchsticks at the site of the bite, the use of a cloth impregnated with charcoal, the application of petroleum jelly at the site of the bite, the use of potassium permanganate and povidone-iodine, and pouring paraffin at the site of the bite could mitigate against snakebite envenoming. There is a need for public health

awareness programs aimed at dissuading such harmful practices from being advanced in the management of snakebite among this population.

Limitations

The cost of medicines and health services in Kenya are yet to be standardized and as such the indirect costs we have provided are mere estimates and may be higher or lower in other hospital settings. Moreover, this study did not capture information on the victims of snakebite who may have died on their way to the hospital or those who sought treatment outside the hospital's catchment area. Furthermore, owing to the retrospective nature of this study, it was not possible to capture information on other costs incurred by victims, such as the costs incurred in transporting the victims to the hospital.

Conclusions

Snakebite injuries contribute significantly to medical costs in the hospital setting. The longer snakebite victims stay in hospital, the higher the cost. Continuous medical education on the correct management of snakebites should be encouraged to minimize snakebite-related complications that may increase hospital stay and, consequently, the cost incurred by victims. Prospective work is needed to provide better estimates of the direct and indirect costs of snakebite injuries in the hospital setting.

Data availability

Underlying data

Figshare: Raw data on the study titled 'management and cost of snakebite injuries at a teaching and referral hospital in Western Kenya. https://doi.org/10.6084/m9.figshare.9642005.v2[11]

This project contains the following underlying data:

- Snake bite injuries-working data -modified.xlsx (raw demographic, medical and cost data for each participant)

Extended data

Figshare: Extended data on the study titled 'management and cost of snakebite injuries at a teaching and referral hospital in Western Kenya'. https://doi.org/10.6084/m9.figshare.9204773.v5[10]

This project contains the following extended data:

- Figure S1: Ethical approval document from the ethical review committee of Jaramogi Oginga Odinga Teaching and Referral Hospital
- Table S1: A summary of the hospitals that referred victims of snakebite to JOOTRH during the study period
- Table S2: A summary of the utility of antivenom among victims of snakebite presenting to JOOTRH during the study period
- Table S3: A summary of the waivers received by some victims of snakebite at JOOTRH during the study period

Acknowledgments

The authors acknowledge the assistance of officers at the medical records department (Jaramogi Oginga Odinga Teaching and Referral Hospital) notably the chairman Mr. Tom Kayago Morike, and others including Mr. Shem Kojo Odero, Mr. Michael Onyango Muhoma, and Ms. Miriam Akoth Okuta. We also wish to thank the administration of the Jaramogi Oginga Odinga Teaching and Referral Hospital for all the help accorded to us in collecting the data.

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Open Peer Review

Current Peer Review Status: ? ✓ ? ✓

Version 1

Reviewer Report 05 December 2019

https://doi.org/10.5256/f1000research.22270.r55941

✓ **Oommen Oommen**
Department of Computational Biology and Bioinformatics, University of Kerala, Thiruvananthapuram, Kerala, 695581, India

I have read the above manuscript with interest and found it to be a good survey followed by their conclusions. The manuscript is well written with the data available and help understand the lacunae in snake bite management in Kenya. The study included authentic data collected for 5 years from JOOTRH between 2011-2016. They have screened 127 medical records having full desired data and made the analysis.They followed international classification from medical archives to arrive at their conclusions. The snake bite still remains a neglected tropical disease in Kenya as is similar in other tropical countries. The fact that snake bite victims have to travel a long distance to avail antivenom is certainly a big draw back. Even in some cases, the antivenom is still not available in place like JOOTRH. The results of the present study should be made available to Health officials to take adequate measures for future snake bit management. Ideally local county hospitals should be empowered to reduce travel time and cost of treatment. Antivenom may be made available in referral hospitals to reduce, mortality and cost of treatment especially when the average monthly income of citizen is $44. The quality of antivenom also to be improved, probably with support from UN. It is welcome to take initial traditional and dependable herbal medicines and avail anitvenom from nearest county hospitals.The authors deserve credit for their commitment and concern for snake bite cases in Kenya.
The manuscript is well written and the language is good. I recommend the manuscript for indexing in your journal and also with a request to implement the important findings of this study to reduce the snake bite deaths and sufferings of the survivors.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Working on herbal products for snake bite treatment and to improve the antivenom quality.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 03 December 2019

https://doi.org/10.5256/f1000research.22270.r56985

?

Godpower Chinedu Michael
Department of Family Medicine, Aminu Kano Teaching Hospital, Kano, Nigeria

Comments

General comment:

- Thank you inviting me to review this manuscript. The title of this manuscript is apt and is of relevance in many resource-limited settings.

Specific comments:

- Introduction: this beautifully written.

- Methods: Here, I appreciate the description of the study setting and reason for the choice of the period to which medical charts were reviewed (in this case, 5 years). However, I will suggest a review of your definition of costs in the economic evaluation of snakebite injuries. Generally and broadly there are two types of costs:

    1. Direct cost: Refers to the resource consumed in providing health care interventions. It consist of:

        Direct medical cost: cost of hospital stay, outpatient visits, card/consultation fees, drugs, labs, surgery, physiotherapy, etc

        Direct non-medical cost: these resources supporting medical services such as

transportation cost, caregiver costs, etc.

2. Indirect cost: this refers to cost from production losses. These include cost due to incapacity to work, disability or premature death.

- If “complications including death” from snakebite were your outcome measures, then the nomenclature should be reworded to reflect these, instead of “direct cost” as it is presently.
- Data handling and statistical analysis: I struggled to understand what qualitative variables were analyzed through thematic analysis. Your study was of quantitative design; for instance, no focused group discussions were held. This area needs clarification or else the statement I am referring to should be deleted.
- The results may need to reflect the queries above.
- Conclusion: reasonably written.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: snakebite, health economics, primary care, malaria, family medicine training

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 21 November 2019

https://doi.org/10.5256/f1000research.22270.r55940

Charles F.B. Nhachi
Department of Clinical Pharmacology, College of Health Science, University of Zimbabwe, Harare, Zimbabwe

This is a very interesting and important subject to interrogate especially in the Sub Saharan region where snake bite is a significant public health concern even though it is a neglected one. The financial burden of snake bite injuries on the health sector is even more neglected despite the fact that it is significant. So this study is indeed a welcoming breath of fresh air so to speak.

This work is acceptable for indexing with some minor corrections/revisions. While most of the current citations were referred to the paper can be enriched by citing work which has been carried out in the region, e.g. South Africa and Zimbabwe, to emphasise the commonality of the problem in the region.

The authors could also add references from the WHO "Guidelines for the Prevention and Clinical Management of Snakebites in Africa". Although the guidelines are not very recent, they are still the prevailing ones.

What is the age group of "child" according to the authors?

What is the relevance of marital status to snakebite injuries?

Circumstances of injury, "walking", can this be explained further…walking where?

What is "homemaking"?

Perhaps the length of hospitalisation, the site of injury and the kind of snake can be associated to give a more vivid picture. Also the association of cause of death, snake type and injury can be elaborated.

Snake identification can be confusing and difficult. A black snake is not necessarily a black mamba. A black mamba is in fact not black! It's black inside the mouth.

What was the cause of death of the two who died after receiving antivenom? Was it due to reaction to the antivenom or late medical attention and what was the kind of injury?

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Toxicology(including snake bite toxiclogy, Pharmacogenetics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 12 November 2019

https://doi.org/10.5256/f1000research.22270.r55305

?

Benjamin Wachira
Accident and Emergency Department, Aga Khan University Hospital (AKUH), Nairobi, Kenya

The article is well written and easy to follow.

There is a need to classify all the 127 bite victims into the 3 categories Cytotoxic, Haematotoxic and Neurotoxic and any combinations of the same seen so it's clear how many patients had what symptoms.

Subsequently, the patients should be followed down along these pathways so it's clear for each category. It's hard to tell if the 74 who did not get antivenom, did they have any symptoms? They may not have had toxic snake bites or were these excluded from the study...not clear.

As all the data is available, we should be able to track the different patient categories through their hospital stays and also determine the outcomes for each of the categories.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Emergency Care in Kenya

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Comments on this article

Version 1

Reader Comment 19 Sep 2019

Stephen Otieno, Maseno University, Maseno Kisumu, Kenya

This is a good article that is easy to read. As the two comments above indicate it would have helped if the authors gave an explicit definition of direct and indirect costs. The study period under consideration precedes the introduction of UHC and health seeking behaviour of the population may vary depending on the availabilty of free services. The authors are well versed on the treatment of snakebites as per the current guidelines, it would help put things in perspective if the reccomended treatment protocol was costed for comparison. Not all snakes are venomous, one cannot help but wonder what is the cost of unnecessary treatment of the harmless bites.
This is a thought provoking and revelatory paper

Competing Interests: None declared

Reader Comment 16 Sep 2019

Kevin WW Rombosia, Makerere University, Uganda

Great read that is relevant to the current discussion on UHC agenda's tennet on affordability of healthcare services.

My comments:

1. Under which UHC package does snake bite management fall? This would best come out in the introduction.

2. Help the reader by defining direct vs indirect costs as related to the study topic.

3. A brief mention of the conceptual framework would be helpful in helping determine any possible confounders of the costs related to snake bite management that are incurred by a patient.

4. There is no mention of the sample size determination considerations.

5. The wage loss is considered against a blanket daily minimum wage loss. Would it be more prudent to stratify the patients into socio - economic strata and consider the wage loss in these? Would this help in getting a more accurate estimate of the wage loss? What have other similar studies done?

6. You mention qualitative thematic assessment in your methods. I did not see how these were applied.

7. The study title is on the costs of snake bite management. However, I think, your discussion is bent more on the clinical management of snake bites.

Again, this was a good read.

Best regards

Competing Interests: None declared.

Reader Comment 11 Sep 2019

Linda Achieng', JARAMOGI OGINGA ODINGA TEACHING AND REFERRAL HOSPITAL, KISUMU, Kenya

1.Presenting the results in the abstract section in form of percentages rather than numerics would make it easier to comprehend the findings e.g. giving the percentage of females instead of saying 64 females.
2. In my opinion, direct costs are those incurred as a direct result of the injury such as hospitalisation, ward charges, cost of pharmaceauticals and non-pharmaceuticals and laboratory charges whilst indirect costs are those that result in loss of productivity rather than viceversa.
Otherwise a very well researched and easy to read article. A very interesting read.

Competing Interests: No competing interests were disclosed.