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REVIEW

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Unraveling the binational outbreak of anthrax in Ghana and Nigeria: an in-depth investigation of epidemiology, clinical presentations, diagnosis, and plausible recommendations toward its eradication in Africa

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Abstract

Background Anthrax is a zoonotic disease that is still regarded as a public health issue in developing nations. This paper aims to discuss the epidemiology of anthrax in Africa, the current outbreaks in Ghana and Nigeria, clinical presentations, diagnosis, and treatment of anthrax, challenges associated with the transmission of the disease to both countries and recommendations to reduce this current outbreak and curb future outbreaks in Africa.

Main body of the abstract Online databases (PubMed, and Google Scholar) and Nigeria Ministry of Agriculture report were used to provide detailed information on the paper. On June 1, 2023, two suspected human cases of anthrax were reported, via a letter sent to all stakeholders in the country, with one death in Binduri District, Upper East region of Ghana. The cases were due to the consumption of dead cattle. Four cattle were reported dead at the time, and eleven suspected human cases were identified through contact tracing. Afterward, on July 17, 2023, the Federal Ministry of Agriculture and Rural Development of Nigeria announced the first case of anthrax disease in Nigeria. The National Veterinary Research Institute confirmed the case from samples collected from a suspected livestock farm in Niger State, Nigeria. No human case has been reported.

Short conclusion Anthrax poses significant challenges to public health and requires cooperation between nations, especially in regions like Ghana and Nigeria, where animal movement and ecological changes can impact disease transmission. Challenges attributed to the spread of anthrax in both countries were discussed, focusing on the role of government and the general public in addressing this public health concern. Given the endemicity of certain transboundary animal diseases such as anthrax in sub-Saharan Africa, the control of animal movement across intra- and international borders in the region needs to be tightened. Regulations governing the transboundary movement of animals should be based on the World Organisation of Animal Health Terrestrial Code and should be strictly enforced to prevent ongoing and future outbreaks in Africa.

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Keywords Anthrax, Nigeria, Ghana, Africa, Outbreaks

Background

Anthrax is a zoonotic disease caused by *Bacillus anthracis*, a Gram-positive, spore-forming, rod-shaped bacterium (Kummerfeldt 2014). Each year, between 2000 and 20,000 human cases of anthrax are reported worldwide (Amiri et al. 2021). Humans usually contract anthrax by contact with infected meat from wild animals and livestock (CDC 2022). In humans, cutaneous anthrax accounts for 95–99% of all recorded cases, while gastrointestinal and inhalation forms of anthrax are less common (Kisaakye et al. 2020).

The majority of African nations, where anthrax is endemic, report at least one human epidemic annually (Makurumidze et al. 2021). Despite having successful control programs in Botswana, Zimbabwe, and Zambia, a study from 2018 found that the disease was still endemic in at least those two nations (Asante et al. 2019). According to Yamtitina and Makarov (2019), anthrax is a disease that affects domestic animals and wildlife in several nations throughout sub-Saharan Africa. In savanna environments, where significant livestock grazing and animal husbandry are practiced, outbreaks are most common (Dudley et al. 2016).

Recently, the Federal Ministry of Agriculture and Rural Development confirmed one case of the anthrax disease in a mixed livestock farm in Niger State, Nigeria. Since the West Africa outbreak started in Ghana in June 2023, this is the first case involving an animal that has been reported in Nigeria. There were eight abrupt livestock deaths recorded at the farm on July 13, 2023. The deceased animals also appeared to be bleeding from external orifices without blood clotting. This paper aims to discuss the epidemiology of anthrax in Africa, the current outbreaks in Ghana and Nigeria, clinical presentations, diagnosis, and treatment of anthrax, challenges associated with the transmission of the disease to both countries and recommendations to reduce this current outbreak and curb future outbreaks in Africa.

Main text

Recent Anthrax outbreaks in Ghana and Nigeria

On June 1, 2023, two suspected human cases of anthrax were reported, via a letter sent to all stakeholders in the country, with one death in Binduri District, Upper East region of Ghana (NCDC 2023a). The cases were due to the consumption of dead cattle (NCDC 2023a). Four cattle were reported dead at the time (Weekly Bulletin on Outbreaks and Other Emergencies 2023). Eleven suspected human cases were identified through contact tracing (Weekly Bulletin on Outbreaks and Other Emergencies 2023).

Subsequently, on July 17, 2023, the Federal Ministry of Agriculture and Rural Development (FMARD) of Nigeria announced the first case of anthrax disease in Nigeria (NCDC 2023). After the report, the samples were collected from multiple species of animal and transported to the National Veterinary Research Institute (NVRI), Plateau State, Nigeria for laboratory confirmation of the disease, and the results were positive for anthrax. No human case has been reported (NCDC 2023). Efforts are being made to reveal the source of the infection and to curb the spread of the disease.

Anthrax status in Ghana and Nigeria

Anthrax was reported in Ghana in 1972, 1997, 2018, and 2019 (FAO 1972; WOAH 1997), before the resurgence of the disease in 2023. Nigeria has not recorded any Anthrax cases in the past. The 2023 outbreak is the first recorded case of Anthrax in Nigeria.

Epidemiology of Anthrax in Africa

Anthrax is endemic to Africa, with numerous outbreaks across several countries, especially in sub-Saharan Africa. Here, we present reported anthrax cases in humans and animals across African countries (Table 1). The reports in the table were extracted from the scientific articles published during the period of the outbreak in each country.

Clinical presentations of Anthrax in humans and animals

There are five conventional clinical manifestations of naturally occurring anthrax: inhalational, gastrointestinal, cutaneous, injectional, and oropharyngeal (Table 2) (Savransky et al. 2020). According to Sweeney et al. (2011), the patient's innate and specific immunity, virulence, and number of infecting bacteria all affect the severity of anthrax infection. With a fatality rate of 9–33%, injectional anthrax is a recently identified clinical form that has been observed in drug users because of injecting spore-contaminated morphine (Sweeney et al. 2011; Mariam 2023). Most Anthrax cases (> 95%) have a cutaneous origin, and the availability of good antibiotics used widely has reduced the fatality rate to 3–5% recently (Savransky et al. 2020). Occasionally occurring side effects include sepsis and meningoencephalitis

Table 1 Number of cases of anthrax reported in humans and animals from 2011 to 2022 in Africa

Country	Year	Human cases	Animal cases	References
Zimbabwe	2022–2023	88 cases	NA	Weekly bulletin on outbreaks and other emergencies (2023)
	2021	212 cases	NA	Weekly bulletin on outbreaks and other emergencies (2021)
	2019–2021	979 cases and 3 deaths	NA	Weekly bulletin on outbreaks and other emergencies (2021)
	2019	NA	8 elephants and 2 buffaloes	
	2018	NA	100 impalas	Mukarati et al. (2020)
	2013–2014	64 cases	180 deaths (cattle)	Makurumidze et al. (2021)
	2012	49 cases	NA	Makurumidze et al. (2021)
	2011	37 cases	NA	Makurumidze et al. (2021)
Namibia	2017	NA	107 hippopotami and 20 buffaloes	Cossaboom et al. (2019)
Kenya	2023	15 cases and 3 deaths	NA	Weekly bulletin on outbreaks and other emergencies (2023)
	2017	9 cases	2 cattle and 2 wildlife	Muturi et al. (2018)
	2015	NA	10 cattle and 766 wildlife	
	2014	6 cases	8 cattle	
Sierra Leone	2022	8 cases	223 deaths (91 cattle, 53 goats, and 79 sheep)	Bangura et al. (2022)
South Africa	2012	NA	30 hippopotami and 45 antelopes	Bekker et al. (2012)
	2010	NA	2000 deaths	Thapa et al. (2014)
Ethiopia	2022	9 cases	NA	Seyoum et al. (2022)
	2016–2019	1188 cases and 15 deaths	NA	Wondmnew and Asrade (2023)
Democratic Republic of the Congo	2022	9 cases and 2 deaths	NA	Muhindo et al. (2023)
Uganda	2022	8 cases and 1 death	NA	Weekly bulletin on outbreaks and other emergencies (2022)
	2018–2021	15 and 10 deaths	NA	Omodo et al. (2023)
South Sudan	2022	8 cases	NA	Weekly bulletin on outbreaks and other emergencies (2022)
Lesotho	2019	50 cases	106 cases and 24 deaths	National Institute for Communicable Disease (2019)
Guinea	2019	5 cases and 1 death	NA	Tournier et al. (2019)
Tanzania	2019	77 cases and 4 deaths	NA	Mwakapeje et al. (2019)
	2017	NA	NA	
Mozambique	2017	NA	2 elephants and 1 kudu	de Garine-Wichatitsky et al. (2017)
Morocco	2015	9 cases	NA	Raza et al. (2022)
Angola	2014	NA	150 cattle and 5 deaths	Chavwanga (2014)

NA: Not available

brought on by the spread of the cutaneous lesion (Elbahr et al. 2022). As for the other types of clinical manifestations, Doganay et al. (2023) reported that the incidence rate of inhalation anthrax, and gastrointestinal anthrax are 12% and 5%, respectively.

Diagnosis of Anthrax in humans and animals

The following steps are taken in order to diagnose anthrax: patient history taking, clinical examination, and laboratory testing.

The WHO Guidance states that probable cases should be verified by taking appropriate samples from the patient's lesions and then having a laboratory evaluation (Forbes et al. 2018). In cases where inhalational anthrax is suspected, these samples may comprise swabs from skin lesions, blood, sputum, pulmonary effusion, or bronchial biopsy specimens. Samples from oropharyngeal lesions, ascites fluid, feces, and vomit in probable intestinal anthrax cases, as well as cerebral fluid in suspected meningitis cases, are also included.

Table 2 Various forms of clinical presentation of Anthrax

Clinical forms	Explanation
Injectional anthrax	Injectional anthrax is a new clinical form of anthrax wherein the injection site infects soft tissue, resulting in septicemia and cytotoxicity. Abnormal symptoms include gas gangrene, necrotizing soft tissue infections, and severe cellulitis
Cutaneous anthrax	Most of the lesions appear on exposed body parts such as the arms, hands, neck, and face during the 2–7-day (range 1–19 days) incubation period. A lesion generally begins as a painful papule and, in 2–4 days, develops into a ring of vesicles encircled by erythema and edema. Certain lesions have the potential to be severe and chronic. When the lesions are on the face and neck, there may be significant edema and toxemia. Regardless of the course of treatment, the eschar's creation and remission may take two to six weeks
Inhalation anthrax	This clinical manifestation is uncommon but typically associated with industrial exposure. Despite the medical care available, more than 80% fatality rate is being recorded. Initial symptoms are nonspecific and include lethargy, mild fever, myalgia, malaise, nonproductive cough, and minor abdomen or chest pain after an incubation period of one to seven days. As the illness worsens, cyanosis, dyspnea, toxemia, and a high temperature are common symptoms. One common finding of anthrax inhalation is described as the widening of the mediastinum. Up to 50% of people experience meningitis as a side effect. Inhalation anthrax could mimic community-acquired pneumonia as well as several lung disorders
Gastrointestinal anthrax	After consuming contaminated food or beverages containing *B. anthracis*, the illness develops 3–7 days later. The bacteria can affect any part of the gastrointestinal tract. The wall of the cecum or terminal ileum is where the lesions most frequently appear. Gastrointestinal anthrax manifests as fever, vomiting, nausea, diarrhea, and anorexia. Acute abdominal pain, hematemesis, bloody diarrhea, and immense ascites are among the symptoms that worsen as the infection progresses. Toxemia and shock follow, which ultimately causes death
Oropharyngeal anthrax	Oropharyngeal anthrax is characterized by dysphagia, fever, hoarseness, sore throat, soft tissue edema, painful regional lymphadenopathy, and neck swelling

According to biochemical and blood characteristics, cutaneous anthrax cases often have a leukocyte count of less than 10×10^3 cells/μL (CDC 2015). Elevations of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) may be observed in cases of chronic cutaneous infections, toxic shock, systemic anthrax, leukocytosis with neutrophilia, hypoalbuminemia, and hyponatremia (Doganay et al. 2010). Disseminated intravascular coagulation (DIC), thrombocytopenia, and leukopenia may arise if severe sepsis progresses (Stearns-Kurosawa et al. et al. 2006).

According to Pillai et al. (2019), a number of easy first-line laboratory tests can be used to distinguish *B. anthracis* from other Bacillus species. These tests include susceptibility to penicillin, lack of motility, hemolytic activity when cultured on blood agar, and gamma phage susceptibility. The best method to detect the bacteria is using microbiological techniques, although often these methods produce confounding findings, especially when trying to distinguish the pathogen from closely related strains of Bacillus cereus. Certain *B. cereus* strains may also exhibit certain *B. anthracis* phenotypic traits. For instance, reports of hemolytic *B. anthracis* strains resistant to the gamma phage and penicillin have also been documented.

B. anthracis can be definitively and quickly diagnosed in clinical and environmental specimens using Real-time PCR testing and DNA amplification-based PCR (Polymerase Chain Reaction) (Zasada 2020). In the study by Wang et al. (2021), certain DNA regions of the genes pagA (pXO1), capB (pXO2), capC (pXO2), and Ba813 (chromosomal) are diagnostic targets. More recently, reports have indicated that more advanced isothermal DNA amplification methods, including HDA (helicase-dependent amplification), LAMP (loop-mediated isothermal amplification), and RPA (recombinase polymerase amplification), can be applied. Apart from DNA-based techniques, immunological methods can also be utilized to anthrax pathogens. Luminex test, MPFIA (magnetic particle fluorogenic immunoassay), FRET (Förster resonance energy transfer), ELISA (enzyme-linked immunosorbent assay), ABICAP (antibody immuno column for analytical processes) immunofiltration, and flow cytometry analysis using fluorescently labeled antibodies are a few of these.

The creation of biosensors that can identify *B. anthracis* quickly and precisely has received attention in recent years (Kim and Yoon 2010; Wang et al. 2021). Genosensors (nucleic acid probes), immunosensors (antibody probes), aptasensors (aptamers), and peptide-nucleic acid chimera probes (PNAs) are the four different types of biosensor systems that are currently available. They use a variety of signal production techniques, including as optical, piezoelectric, and electrochemical (amperometric, conductometric, and potentiometric). Genosensors operate on the basis that a signal is produced when pathogen-specific DNA binds to a probe. Thus far, pagA, lef, and BA813 have been the targets of developed genosensors (Yordanov and Dimitrova 2023). Additionally, *B. anthracis* spore simulants have been identified in a single step using impedimetric aptasensors (Mazzaracchio et al. 2019). A magnesium niobate-lead titanate/tin (PMN-PT/

Sn) piezoelectric microcantilever sensor (PEMS) and an ultrasensitive portable capillary biosensor (UPAC) have both been equipped with antibody probes that identify the antigenic structure unique to *B. anthracis* (Zasada 2020). The pathogen has also been found in clinical and environmental specimens using matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF) mass spectrometry (MS) (Seng et al. 2013; Tsuchida et al. 2020).

Treatment of Anthrax in humans and animals

In Africa, all forms of anthrax are treated by antibiotics and antitoxin after proper conduction of antibiotic sensitivity testing. Antibiotics can also be used a prophylaxis to prevent anthrax manifestation in people who have been exposed but have not shown clinical symptoms. The major two antibiotics that are being used are ciprofloxacin and doxycycline to prevent anthrax.

Challenges associated with the spread of anthrax in Ghana and Nigeria

Anthrax is a zoonotic disease and its spread poses significant challenges to public health and requires cooperation between nations, especially in regions like Ghana and Nigeria, where animal movement and ecological changes can impact disease transmission. The following points discuss the challenges attributed to the spread of anthrax in both countries, focusing on the role of government and the general public in addressing this public health concern.

1. ***Animal/wildlife movement:*** Animal migration plays a crucial role in the spread of anthrax, as infected animals can carry the bacterium to new locations. Especially in the case of Ghana and Nigeria, where the outbreak of anthrax was first reported in Ghana and the porosity of the two countries' border. The movement of infected animals across borders poses a significant challenge in containing the spread of anthrax. Lack of coordinated surveillance and tracking mechanisms can make it difficult to identify and quarantine potentially infected animals.
2. ***Trade of livestock and animal products:*** The trade of livestock that is not being regulated can facilitate the introduction of infected animals into new areas, increasing the risk of anthrax outbreaks. In these countries, the importation of animal products is large because of what the products are being used for locally such as food (Pomo), leather (for bags, belts, shoes, etc.), and other decorative house materials.
3. ***Human travel:*** Human travel can contribute to the spread of anthrax, especially if infected individuals unknowingly carry the bacterium. Frequent travel between Ghana and Nigeria, whether for trade, tourism, or work, can possibly lead to the transmission of anthrax between the two countries.
4. ***Environmental changes***: Environmental changes, such as deforestation or climatic shifts can alter the distribution of anthrax in the environment, making it more challenging to predict and control outbreaks (Hugh-Jones and Blackburn 2009; Steenkamp et al. 2018). One of the transmissions of Anthrax is through spores, there is a possibility of the spores being transmitted to Nigeria through the Niger River coupled with the recent flood breakout that has been occurring in some southern and western parts of Nigeria.
5. ***Public health:*** Swift and effective containment measures are essential to prevent further spread of anthrax. Limited resources and infrastructure in some regions of Ghana and Nigeria can hinder the implementation of robust containment measures. Quick identification of anthrax cases, timely reporting, and adequate isolation of infected individuals and animals are critical but may be impeded by limited healthcare facilities and reduced trained health personnel.
6. ***International Cooperation:*** Collaborative efforts between Ghana and Nigeria are crucial to effectively combat the spread of anthrax. Disparities in healthcare systems and priorities between the two countries can make cooperation challenging. Effective communication and sharing of vital information between health authorities are important for early detection and coordinated responses to outbreaks. Building trust and fostering a spirit of collaboration can be hindered by political or economic factors.

Recommendation to curb the future outbreak in Ghana and Nigeria

Because of their porous land borders, Nigeria and Ghana enable unrestricted inflow of livestock, occasionally wild animals, and/or wildlife items (Bouslikhane 2015). Due to this, there is a high risk of zoonotic disease epidemics affecting both humans and animals in the two countries. Given the endemicity of certain transboundary animal diseases (TADs) such as anthrax in sub-Saharan Africa, the control of animal movement across intra- and international borders in the region needs to be tightened. Regulations governing the transboundary movement of animals should be based on the WOAH Terrestrial Code and should be strictly enforced. In order to increase surveillance and monitoring capability for TADs, veterinary quarantine services at borders should be upgraded on all fronts.

Additionally, given that zoonotic diseases make up around 75% of emerging infectious diseases (Rahman et al. 2020), Nigeria and Ghana need to take a multidisciplinary approach to cross-border animal disease surveillance and monitoring. According to the One Health framework, all institutions, disciplines, and sectors with a stake in protecting public health should work together and pool their resources to combat the threat posed by zoonoses (Markotter et al. 2023). If the One Health concept is not utilized in addressing the core causes of zoonotic spillovers at the human–animal interface, individual sectors and disciplines will simply continue in cycles (Willcox and Steele 2021).

We have reached a point where vaccination against anthrax and other vaccine-preventable TADs should be made absolutely mandatory for livestock farmers in Ghana and Nigeria. Animals that are entering the country need also receive vaccinations under the supervision of a professional. A partnership between the public and private sectors would go a long way toward assisting in the establishment of a sustainable vaccination program in both countries in order to achieve this.

Finally, it is crucial to emphasize the role that technology plays in the implementation of successful disease surveillance and monitoring programs. Real-time communication and activity tracking prompted by personnel should be done using modern technologies. This would support the accountability process and aid in reducing corruption of any form in the system.

Limitations of the study

The data provided in this write-up represent the past and current distribution of anthrax in Africa. These data were sourced from online databases. Some of the regions where the anthrax outbreaks occurred but were not reported online were excluded. However, due to the poor documentation system available in Africa, the link between the human and animal cases of anthrax was not available.

Conclusions

Based on the presence of introduction and exposure pathways that aid the transmission of TADs in Nigeria and Ghana, there is a potential link between the recent outbreaks of anthrax in both countries. These recent anthrax epidemics in Ghana and Nigeria might be a sign that the government is unable to adequately restrict the movement of animals across international borders. While livestock mobility is essential for regional trade and sustainable livelihood for the rural populace, there is a need to use a multidisciplinary approach to mitigate the health hazards that it brings to both animals and people. Government parastatals that work to protect public health should work together to create policies on transboundary animal movement and firmly enforce them.

Abbreviations

NVRI	National Veterinary Research Institute
WOAH	World Organizations for Animal Health
TADs	Transboundary Animal Diseases
PEMS	Piezoelectric Microcantilever Sensor
UPAC	Ultrasensitive Portable Capillary Biosensor
MALDI-TOF	Matrix-assisted Laser Desorption Ionization Time-of-flight
MS	Mass Spectrometry
WHO	World Health Organization
CDC	Centers for Disease Control and Prevention
AST	Aspartate Aminotransferase
ALT	Alanine Aminotransferase
PCR	Polymerase Chain Reaction
MPFIA	Magnetic Particle Fluorogenic Immunoassay
FRET	Förster Resonance Energy Transfer
ELISA	Enzyme Linked Immunosorbent Assay
ABICAP	Antibody Immuno Column for Analytical Processes

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