REVIEW ARTICLE
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Anthrax disease burden: Impact on animal and human health

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Abstract

Anthrax is a zoonotic infectious disease caused by *Bacillus anthracis*. According to current knowledge, the disease originates in sub-Saharan Africa, especially Egypt and Mesopotamia. Laboratory tests involving direct staining or culture of samples taken from malignant pustules, sputum, blood, or patient discharge must be performed to establish a diagnosis. *B. anthracis* infection can enter the body through the skin, mouth, or nose. Human infection is usually caused by contact with infected animals or animal products. Anthrax causes a reduction in resource efficiency and decreases livestock productivity. *B. anthracis* spores are resistant to extreme temperatures, pressure, pH, drying, solvents, and ultraviolet light. The biological weapon of this disease may be fatal if it is designed to spread *B. anthracis* spores by aerosols. In the past, the treatment of human anthrax with penicillin at a high dose was the preferred method. The public can take several measures to prevent anthrax infection, such as purchasing and consuming meat that has been legally certified to have been slaughtered in a slaughterhouse, consuming healthy and properly cooked animal meat, and washing hands with antiseptic soap after handling, processing, and cooking animal products. This review aimed to describe the etiology, pathogenesis, mechanism of infection, epidemiology, diagnosis, clinical symptoms, transmission, risk factors, public health importance, economic impact, potential as a bio-warfare agent, treatment, and control of anthrax.

Keywords: animal health, anthrax, human health, infectious disease.

Introduction

Anthrax is a zoonotic infectious disease caused by *Bacillus anthracis* [1]. Mammals, particularly herbivores, and several bird species are the main species affected by this disease [2]. Animals such as cattle, buffalo, goats, sheep, and pigs are frequently affected [3]. There are several other names for anthrax, such as malignant edema, malignant pustule, wool-sorter's disease, lymph inflammation, charbon, and rag pickers' disease [4]. Anthrax can be transmitted from animals to humans by contact with lesions, using tainted animal products, and inhaling *B. anthracis* spores [5]. Although anthrax is present all over the world, incidents of anthrax often affect only a small

geographic region [6]. Areas with alkaline, calcareous soils, warm climates, and intermittent flooding are the areas where outbreaks occur most frequently [7].

This microbe is capsule-shaped and facultatively anaerobic and aerobic [8]. When exposed to the environment through the bodily fluids of an infected cadaver, it may develop spores that allow it to survive for a long time [1]. This disease is extremely communicable, highly contagious, and potentially fatal on infection [9]. These bacterial vegetative cells cannot survive outside the host's body for an extended period without sporulation [10]. The life cycle of vegetative cells is terminated when a corpse remains unopened for more than 72 h [11]. When these bacteria succeed in sporulating, they are resistant to various harsh environmental conditions, including heat, dryness, cold, chemical disinfection, pH, salting, and irradiation [12].

Although anthrax has been documented in the United States, Australia, Sweden, Italy, and several other European countries, Asia and Africa are thought to be the most affected [13]. Human anthrax deaths have also been reported in a number of Indonesian Provinces, particularly in endemic regions [14]. The high fatality rate associated with anthrax in humans is usually caused by undetected and inadequate treatment [15]. Anthrax is an enzootic illness that involves re-emerging or repeated disease [16]. The disease can manifest in peracute, acute, subacute, and chronic forms in animals [1]. In cases of severe infection, animals may die within 48–72 h, and blood may fail to clot and seep from the nose, mouth, and anus [17].

In the best ancient tales written by the Roman poet Virgil, descriptions of anthrax first appear [18]. During the 19th century, due to anthrax infection, several significant medical advancements occurred, such as attenuated anthrax vaccine development, new medical equipment inventions, and the establishment of rapid and more effective control strategies [19]. It is based on Robert Koch's prototype postulate of an infectious disease-causing creature from 1877, which Louis Pasteur confirmed later [20]. Anthrax has become a major contributor to global human disease in most regions of the world due to greater case rates in Africa, the Middle East, Central Asia, and South Asia [21]. Although effective management efforts have made this disease, a minor source of human or livestock infection in developed countries [22].

In the first half of the 20th century, the World Health Organization reported 20,000–100,000 cases of anthrax in humans and livestock annually worldwide. In the second half of the 20th century, the anthrax incidence subsequently declined to approximately 2000 cases/year [23]. The incidence of anthrax is much lower today than it was in the 20th century because many countries have not reported any recent cases. There is a possibility that the disease infection will spread throughout the body and result in serious illness [19]. Anyone who comes into contact with anthrax spores has a chance of getting sick, although the risk is higher for those who frequently work with animals, such as those who raise cattle, work as veterinarians, or handle animal products [24]. The risk of exposure to humans, cattle, and wildlife remains considerable even though the infection rate has decreased in the 21st century [25]. Worldwide, 1.83 billion people and 1.1 billion animals live in anthrax-prone areas, primarily in rural parts of Asia, Africa, and Europe [26]. In addition, *B. anthracis* may be utilized as a potent biological weapon due to its high soil persistence and ease of transmission [20]. Antibiotic-resistant bacteria can grow over time despite being the recommended course of action for anthrax [27, 28].

Agricultural communities in tropical environments with underdeveloped socioeconomic conditions are primarily affected by this disease [29]. The presence of anthrax in a region can cause problems for the local population because it affects not only people's health but also their economic well-being, especially those who depend on cattle [30]. Anthrax decreases the effectiveness of the inputs (resources) that will be transformed into outputs (products), which has a substantial economic impact [31]. Anthrax is a particular type of strategically infectious animal illness that causes significant animal mortality, monetary losses, and societal instability [1].

This review article aims to describe the etiology, pathogenesis, mechanism of infection, epidemiology, diagnosis, clinical symptoms, transmission, risk factors, public health importance, economic impact, potential as a bio-warfare agent, treatment, and control of anthrax. This review may provide important information on the dangers of anthrax disease to human and animal health.

Etiology

B. anthracis is a sizable rod-shaped bacterium with square ends and pointed corners that is 3–5 μm in length and 1–2 μm in width [32]. This Gram-positive bacterium looks blue or purple when stained with Gram's solution under a microscope [33]. Examination of smear preparations made from blood or animal tissue samples with patients under a microscope reveals that these bacteria are grouped in pairs, chains, or alone with a distinctive morphology similar to a bamboo tree segment [34]. Endospores produced by *B. anthracis* have an oval shape, are positioned in the center, and are no larger in diameter than their vegetative form [35]. These endospores develop only if the bacteria are located outside the host body or inside the host's body [2]. Endospores can be discovered in dead animal tissue or blood, culture, soil, and the environment [36]. When *B. anthracis* enters the host, it has a capsule. However, this capsule cannot be cultivated *in vitro* unless sodium bicarbonate is added at a concentration of 5% CO_2 [37].

B. anthracis can grow on nearly all bacterial growth media; however, when grown on blood agar

plates with antibiotic-free blood content, it will grow very well and clearly display its characteristics [38]. Maximum growth can be achieved in an aerobic environment with a pH between 7 and 7.4 [39]. This bacterium can grow at temperatures between 15°C and 40°C. However, 37°C is the ideal temperature for growth [40]. After 24 h of incubation, *B. anthracis* on simple media will grow as large, prominent, gray-white, opaque, and uneven edges with a diameter of about 2–5 mm [41]. The colony's surface appears plumose hairy and fringed like curly hair when viewed under a microscope [42], which is known as hairlike curl, caput medusae, or fringelike edge. Unlike most species of bacteria of the genus *Bacillus*, which are typically motile [43], this bacterium is not motile. *B. anthracis* ferments glucose, maltose, and sucrose into a variety of acids but not mannitol, lactose, or galactose [44]. This bacterium has the ability to dissolve gelatin gently, turn nitrate into nitrite, and produce a positive Voges-Proskauer test result [45].

Pathogenesis

B. anthracis is harmful because of the presence of two virulence factors, namely the capsule and antigen toxin in the form of an exotoxin complex made up of protective antigen (PA), lethal factor, and edema factor (EF) [46]. The exotoxin complex is associated with symptoms, whereas the capsule interferes with phagocytosis [47]. Binding of the PA to the receptor is followed by an admission of lethal and EFs into the cell [48]. Edema and death will result from the interaction of PA and EF, respectively [49].

Cattle, goats, sheep, and horses are most commonly affected by anthrax [1]. Animals are likely to consume *B. anthracis* endospores attached to grass or other plants and contaminate the soil [50]. This bacterial endospore typically infects people orally, through skin sores, or through inhalation [51]. As a result of these endospores, the tissue where the bacterial endospores enter will develop into vegetative bacteria after infection [52]. This vegetative bacterium causes congestion and gelatinosa edema [53]. In addition, bacteremia develops until sepsis due to the spread of these bacteria through lymph flow to the bloodstream [54].

Mechanism of Infection

Livestock, particularly herbivores such as cattle and sheep, which serve as the major hosts, become infected with *B. anthrachis* spores when they graze on or consume leaves contaminated with anthrax spores, which starts the infection cycle [50]. Food-borne anthrax bacteria proliferate in the digestive tract after entering the animal's body [2]. Animals with anthrax infection discharge bacteria in their urine, feces, or other wastes [1]. The tissues of dead anthrax-infected animals still contain a significant amount of anthrax bacteria, which will sporulate when the animal carcass is opened and exposed to oxygen or water [51]. When anthrax spores leave the corpses of sick animals, the surrounding soil, vegetation, and water sources become contaminated [24]. *B. anthracis* spores have been discovered in locations or regions that are known as anthrax reservoirs [55]. Anthrax infection in humans can occur in a number of ways, but it typically results from contact with diseased animals, ingesting contaminated animal products, or processing contaminated animal products [15].

Anthrax can infect humans through four main routes: inhalation, gastrointestinal, cutaneous, and intravenous/injection [56]. Anthrax spores enter the cutaneous route due to direct contact between anthrax-infected wounds or lesions on the skin and livestock or livestock products [57]. Anthrax spores in the air enter the respiratory tract through the inhalation route, digestive tract through the gastrointestinal route, and through the skin [4]. Human anthrax can potentially be spread through bug bites [58]. Inhaled anthrax spores immediately germinate and release significant toxins [59]. The toxin subsequently spreads throughout the bloodstream and produces a variety of clinical signs, such as edema, necrosis, sepsis, and blood vessel destruction [60].

Epidemiology

Anthrax has been recognized as a disease since ancient times [4]. According to current knowledge, the disease originates in sub-Saharan Africa, especially Egypt and Mesopotamia [61]. However, anthrax has been documented in ancient Greece and Rome through well-known literature, such as the Iliad written by Homer around 700 BC and the epic written by Virgil (who lived from 70 to 19 BC) and is believed to have had spread globally [62]. Skin-related anthrax was first medically characterized by March in 1752 and Fournier in 1769 [1]. In 1877, Robert Koch experimented with anthrax bacteria and developed Koch postulates, which proposed a causal link between disease and specific microbes [63]. In the late 19th and early 20th centuries, the greatest number of domesticated and wild animal deaths was attributed to anthrax [64]. In South Africa, the outbreak of this disease in 1923 is thought to have killed between 30,000 and 60,000 animals [65].

Anthrax has been intermittently reported in Western Europe, North America, and Australia [1]. It has been reported to occur enzootically in Greece, Spain, Southern Italy, Turkey, and Albania, but not in northern or central Europe [66]. Mexico, Bolivia, and other Latin American countries, as well as Peru, have reported an enzootic outbreak in Haiti [1]. Numerous Asian nations, such as eastern India, the Philippines, South Korea, Mongolia, and the hilly area of western China, are home to endemic cases of this disease [67]. This disease occurs every summer in African countries and wreaks havoc during heavy rain years [68].

Anthrax causes more than 80% of herbivore deaths [2]. Anthrax has been found in almost all nations, particularly in the Mediterranean, Africa, and Asia [20].

Some animal products imported from endemic regions, such as sheep wool and bone meal, may potentially serve as a source of transmission if contaminated with these bacterial endospores [22]. Infrequent anthrax infections occur in a number of American states, including Oklahoma, Texas, Colorado, Louisiana, and California [69]. In Indonesia, 14 provinces have been declared as anthrax endemic areas: Central Java, DKI Jakarta, West Java, West Nusa Tenggara, West Sumatra, DI Yogyakarta, Jambi, Central Sulawesi, South Sulawesi, West Sulawesi, Southeast Sulawesi, East Java, Gorontalo, and East Nusa Tenggara [70].

Anthrax is currently receiving more attention because it can be used as a bioterrorism weapon [71]. In the fall of 2001, 30,000 people in the United States were exposed to anthrax spores distributed through the mail, which resulted in 5 deaths and 17 other infections [72].

Diagnosis

To establish the diagnosis, laboratory tests involving direct staining or culture of samples taken from malignant pustules, sputum, blood, or patient discharge must be performed [73]. It depends on the clinical signs and symptoms that these patients experience. Several contaminating bacteria from the non-pathogenic *Bacillus* genus, such as *Bacillus cereus*, make it challenging to isolate *B. anthracis* from this culture [74]. *B. anthracis* can be distinguished from *B. cereus* by a number of characteristics, such as the capacity to form capsules, sensitivity to penicillin, non-motility, and the capacity to lyse bacteriophages, which are not shared by *B. cereus* [75]. It is important to understand that only specific laboratories with BSL2/Biological Safety Level 2 criteria can diagnose suspected anthrax in the laboratory [76].

Rapid screening techniques, such as polymerase chain reaction and enzyme-linked immunosorbent assay, have been developed for direct use in clinical and environmental settings, but these techniques are only available in reference and research laboratories, particularly in developed nations [77]. Initial identification can be made in the hospital laboratory by direct Gram staining of skin lesions (vesicular fluid or eschar), cerebrospinal or pleural fluid, unspun peripheral blood exhibiting encapsulated, widespread Gram-positive bacilli [78]. The clinical samples were coated on blood agar for initial identification to observe the characteristic cell and colony morphology [79]. In addition, blood samples taken from individuals suspected of having anthrax can be used in blood culture systems (blood bottles), which can improve the probability of isolating the pathogen [80]. Analytical profile index (API) 50 CH test strips (bioMérieux, United Kingdom) can be used to identify *B. anthracis* [77]. However, if the laboratory is not informed of the possibility of anthrax, *B. anthracis* may not be properly identified [81]. Confirmatory tests may be performed in regional reference laboratories or abroad, provided that these facilities are available.

Clinical Symptoms

In animal

The obligatory pathogen *B. anthracis* incubation period is either 1–14 days or 3–7 days [6]. The clinical course in herbivores ranges from acute to chronic. The acute form may affect cattle, sheep, or goats without prior signs of the disease and is characterized by a fast and rapid start, staggering, dyspnea, shaking, collapse, and many convulsive movements [1]. Other signs include a lack of or partial rigor mortis, dark blood in the mouth, nostrils, and vulva that resembles tar [82].

In the acute type, there is a sudden increase in body temperature and brief periods of excitement, followed by depression, cardiac or respiratory problems, shakiness, convulsions, and death [1]. Body temperature may rise to 41.5°C, animals may abort, and rumination may cease [22]. Blood is released from a naturally occurring bodily orifice, typically lasting 48 h [83]. In pigs and horses, fever, anorexia, lethargy, edema of the throat, face, neck, and belly, and petechial hemorrhages on the skin are common [84]. The symptoms of dysentery may include bloody froth in the nostrils [85]. Localized subcutaneous edema in the chronic type is most prevalent in the ventral neck region, shoulders, and chest [54].

In human

Approximately 95% of anthrax cases are cutaneous [86]. These lesions frequently begin with itching and typically develop on the exposed skin [73]. Clinical symptoms progress through a number of stages, including the papular stage, the vesicular stage with blisters that frequently erupt into hemorrhagic lesions, and the eschar stage, which appears 2–6 days after the hemorrhagic vesicles dry out into a depressed black scab (malignant pustule) and may be surrounded by significant redness and edema (swelling) [54]. Although anthrax lesions are typically harmless, the edema that surrounds them can cause pain [24]. Untreated lesions may also develop and involve local lymph nodes [9]. Severe cases may lead to exceptional septicemia [87]. A timely initial therapy reduces the risk of death due to cutaneous anthrax, which has a mortality rate of 5%–20% when left untreated [88].

Pulmonary (inhalation) type of anthrax is extremely uncommon and frequently manifests as mild, nonspecific symptoms such as fever, lethargy, a moderate cough, or chest pain (upper respiratory tract symptoms are extremely uncommon) [51]. The early signs of sickness may be mistaken for flu [22]. In 3–6 days, hypoxia, dyspnea, high body temperature, and radiographic indications of mediastinal expansion are rapidly followed [61]. Meningitis is frequently fatal, and the death rate without treatment or delay is almost 100% [89]. Antibiotics administered appropriately throughout the prodromal period resulted in considerably lower mortality [90].

The intestinal or oropharyngeal type of anthrax can cause significant outbreaks in underdeveloped

nations following the consumption of infected animal meat [21]. Intestinal anthrax has a case fatality rate of 25%–75%; gastrointestinal symptoms may be followed by fever, septicemia, and death [91]. The symptoms of oropharyngeal anthrax include fever, sore throat, mouth sores, lymphadenopathy-induced enlargement of the neck, dysphagia, severe local swelling and ulceration, septicemia, and death, with a case fatality rate comparable to that of intestinal anthrax [9].

Transmission

B. anthracis infection can enter the body through the skin, mouth, or nose [71]. These bacteria are spread by rivers, insects, dogs, other carnivores, wild birds, and feces from sick animals [1]. Infected animal products, such as bone meal, fertilizers, hides, wool, concentrates, or infected forages, frequently spread the infection to other locations [22]. Animals rarely suffer from respiratory illnesses but may become infected by polluted dust [92]. Human anthrax infection caused by wool sorters is caused by the inhalation of anthrax spores by workers in the wool and hair industries; however, cutaneous anthrax is significantly more prevalent in these industries [93].

Humans may contract anthrax from non-occupational exposure (accidental or daily) as well as occupational exposure (agricultural or industrial) [24]. Animal cemeteries, burial grounds, biothermal vents, and other locations where deceased animals are disposed of may be sources of anthrax spore infection [84]. The term "stationary anthrax-affected areas" is used in Russia and some former Soviet republics to describe inhabited areas where epizootic anthrax spores can be found, such as farms, meadows, or natural areas [94].

Direct contact with bloody feces or the bodies and organs of anthrax-suspected animals may result in the transmission of *B. anthracis* during the vegetative phase [9]. Indirect transmission of *B. anthracis* spore form is more significant [95]. Humans are susceptible to infection when they are in contact with infected carcasses and raw, undercooked, or fully cooked foods and when exposed to spore-contaminated materials [96]. Anthrax outbreaks can also be caused by laboratory mishaps, unintentional release of anthrax spores from labs and production facilities (such as the Sverdlovsk incident in 1979), or the spread of anthrax aerosols that can enter the lungs deeply (such as the 2001 letter attacks in the United States) [97].

There are very few cases where people are indirectly exposed to *B. anthracis*, such as through the use of spore-containing medications or everyday items made from raw animal products from endemic regions (such as goat skin, horse hair, fur, or ivory), leather goods and toys, bongo drums, rugs, toy animals, or shaving brushes [24].

Risk Factors

Workers handling animal products (wool, meat, hair, skin, bone, or bone products), animal health officers, veterinarians, livestock workers, particularly in anthrax endemic areas, households or breeders who have discovered their livestock died and consumed meat contaminated with anthrax spores, military personnel, laboratory workers handling anthrax samples, and emergency response workers handling bioterrorism are among those at high risk of contracting anthrax [98]. In addition, not wearing footwear when engaging in outdoor activities, especially playing and walking through fields, increases the risk of contracting anthrax spore [99].

Public Health Importance

Anthrax primarily attacks herbivorous animals [31]. Typically, human infection is caused by contact with infected animals or animal products [22]. Handling processed leather, goat hair, bone products, wool, and diseased wildlife is a particularly risky task for anthrax patients [71]. The disease may also spread through contact with infected meat, such as between abattoir workers [100]. The addition of bone meal-containing feed may result in the emergence of new infection sites in animals [36]. There have been cases of cutaneous anthrax in tradespeople and persons who are close to animals [101]. Anthrax may also be used in bioterrorism or bio-warfare, most likely by aerosols [20].

In some countries, there is still a high risk of anthrax epidemics, which occasionally affect people [102]. According to estimates, each anthrax-infected cow in Africa could result in up to 10 human cases [21]. However, developed countries have seen a significant decline in anthrax cases [4]. In the early 1900s, there were approximately 130 human cases/year in the U.S., but today there are often only one or two cases of cutaneous anthrax per year [6]. Anthrax is an uncommon and occasional disease that mostly affects veterinarians, agricultural workers, and people who produce leather, hair, wool, and bone products because of occupational hazards [9]. Cutaneous anthrax accounts for 90%–95% of all anthrax infections [103]. Although it appears rare, outbreaks related to tainted meat may involve gastrointestinal anthrax [91]. Aerosol bioweapons are expected to produce a high percentage of inhaled anthrax, notwithstanding the rarity of such occurrences [104]. In 2001, anthrax-contaminated mail was used in 11 cases of inhalation anthrax, and 11 cases of cutaneous anthrax were linked to bioterrorist activities [105]. The mortality rate varies depending on the type of disease; skin anthrax is lethal in 5%–20% of untreated cases and less than 1% of individuals receiving antibiotic treatment [51]. In contrast, inhalational anthrax has a high fatality rate, even with proper care [88]. According to earlier estimations, the case fatality rate for this type is more likely to be between 90% and 100%**;** however, newer and more intensive treatment plans may help to reduce the mortality rate [6]. Six out of eleven individuals with inhalational anthrax

recovered with treatment in the bioterrorist incident related to the 2001 letter (45% case fatality rate) [105]. However, one study found that the fatality rate was 97% once patients reached the fulminant stage regardless of treatment [106]. Anthrax meningoencephalitis is also lethal, with an estimated case fatality rate of 95%–100% [107]. Information regarding gastrointestinal anthrax is scarce [108]. Although the fatality rate for abdominal anthrax is unknown, it has been predicted to range from 25% to 60%–75% [89]. In some outbreaks, asymptomatic or mild illness has been reported in adults and children have a higher mortality rate [6].

Economic Impact

Anthrax causes a decrease in resource efficiency and a decrease in livestock productivity [3]. In the majority of developing countries, vaccination of susceptible animals in enzootic areas has decreased the occurrence of the disease to a negligible proportion on a national level; however, significant losses can still occur in certain groups [1]. Economic losses are due to the mortality of infected animals and animals in the post-vaccination period, the reduction of animal products, the complete destruction of carcasses and by-products, and the closure of slaughterhouses [109]. The anthrax death rate varies among animal species [17]. Pigs often recover from this disease, but clinical infection in ruminants and horses usually causes death [22]. Although the mortality rate in carnivores is also quite low, little information is available on infection rates in wild animals [110].

Potency as a Bio-warfare Agent

Anthrax had long been associated with soil contamination before *B. anthracis* was identified as the causative agent [34]. Bacterial spores are resistant to severe temperatures, pressure, pH, drying, solvents, and ultraviolet light [71]. *Bacillus* spores have been reported to last in soil for approximately 100 years [111]. Following germination, bacteria inactive in the spore form will revert to a vegetative state [112]. Highly resistant spores can be used as a potential bioterror weapon against anthrax [20]. *B. anthracis* spores spread by aerosol can be a deadly biological weapon of this disease [64]. Anthrax spores can be manufactured**,** purified, and dried out for long-term storage [113]. Spores can persist for years in water and on the surface of soil [55]. Inhaling anthrax spores is the most harmful infection [54]. The obvious reason why inhaling anthrax spores is so hazardous is that when it manifests, the initial symptoms are thought to be similar to those of the common cold, making early identification challenging, but by the time the disease is correctly detected, treatment would be too late [24].

The possibility of using these germs as weapons of war or as bioterrorist agents is increasing all over the world [20]. Any biological agent from a wide range of diseases that cause human infections may be considered as a biological weapon [114]. However, few of these agents meet the necessary requirements, such as simplicity in isolation and deployment, to be identified as biological weapons [115]. Anthrax spores, which are simpler to produce and store [116], pose the greatest bioterrorism threat. Anthrax spores were utilized in a terrorist anthrax letter atttack during 2001 in the United States as a bioweapon due to their high case fatality rate, fast aerosol transmission, and environmental stability and are anticipated to continue to be the biothreat agent of choice in the future [9]. The release of these bacterial spore bio-warfare agents by militants or criminals is unlikely to be traced and detected [117]. Therefore, *B. anthracis* is considered the most lethal biological weapon.

Treatment

Early diagnosis of anthrax can be challenging due to its rarity and, in rare circumstances, might result in misinterpretation [13]. Therefore, treating anthrax cases will always be difficult, and intervention times are often delayed. In the past, human anthrax has been treated with penicillin in high dosages [9]. Tetracyclines and erythromycin are substitute antibiotics for penicillin allergy [118]. Other antibiotics include clindamycin, imipenem, chloramphenicol, rifampin, aminoglycosides (tobramycin, gentamicin, and amikacin), fluoroquinolones (ciprofloxacin, levofloxacin, and ofloxacin), and vancomycin [119]. *B. anthracis* is resistant to ceftazidime, cefotaxime, sulfamethoxazole, aztreonam, cefuroxime, and trimethoprim [120]. Antibiotic therapy can effectively treat skin-type anthrax with a reduced death rate of <1% [9]. Untreated inhalation anthrax is almost always fatal; even if antibiotic treatment is started early in the course of the disease, a high mortality rate will occur in infected individuals [6]. The key to effectively managing inhalational anthrax appears to be the prompt introduction of antibiotics and vigorous supportive care [121]. Other techniques, such as chest tube drainage for recurrent hemorrhagic pleural effusions, can result in good clinical improvement [122].

One of the antibiotics was administered 24 h after infection to protect the animals throughout treatment; however, many animals succumbed to anthrax after therapy was discontinued, with antibiotic protection rates ranging from 10% to 90% [123]. When antibiotics are used in combination with PA vaccinations, all animals are completely protected even after treatment [124]. Animals receiving therapy for longer than 24 h after infection develop bacteremia and toxemia [9].

Control

Efforts to prevent the spread of anthrax can be carried out, among others, by routinely vaccinating livestock every year or according to the recommendations of the competent authority, reporting to health officials if they find meat that is slimy, smelly, and dull in color, complying with the Standard Operational Procedure and rules from the competent authority if

you are going to add new livestock, separate sick animals from healthy livestock, avoid direct contact with animals suspected of being infected with anthrax, do not perform autopsies or surgeries on the carcasses of animals that have died from anthrax, cook meat until perfectly cooked, and the animals that died must be burned or buried deep [69]. The public can take several precautions to prevent anthrax infection, such as purchasing and eating meat that has been legally certified as having been killed at a slaughterhouse, eating healthy, properly cooked animal meat, and washing hands with antiseptic soap after handling, processing, and cooking animal goods [125].

The public must immediately report to a livestock officer or animal health center if they encounter sick or sudden death of livestock [30]. Cows exhibiting these symptoms should be confined immediately and given large doses of penicillin for 45 days [126]. In addition, people are not allowed to take sick animals outside the area so that the disease does not spread to other areas, and they should clean themselves with soap or disinfectant immediately after contact with sick or dead animals [51]. To reduce the transmission of anthrax germs from the corpses, dead livestock must be cremated promptly (without butchering) or buried at a minimum depth of 2 m with a disinfecting process surrounding the burial location [1]. However, disposing of the corpse does not prevent others from contracting anthrax in the future. Shallow burials (<2 m) will result in long-term contamination and could be a source of future diseases [127]. Anthrax spores can surface as a result of natural calamities such as heavy rains, floods, landslides, and earthquakes, which increase the risk of infection in herbivorous animals [128]. Avoiding areas where anthrax spores could be infected will help prevent infection [24].

Counseling can be used to raise public awareness, and it should be preceded with a knowledge, attitude, and practice survey to gauge public opinion about anthrax [129]. The foundation of anthrax control is vaccinating livestock using part of the bacterial toxin that has been purified or killed [130]. The majority of vaccinations are carried out on susceptible livestock in endemic areas [131]. In addition, early anthrax infection can be treated using antibiotics [56]. In the event of an outbreak, rapid measures are needed to reduce the effects, prevent environmental contamination and human exposure, and prompt and effective diagnosis and treatment of animals and humans infected with anthrax [9]. Furthermore, public health organizations need to be more aware of the monitoring, inspection, and packaging of animal products, as a lack of knowledge may increase the risk of food contamination by pathogens, which can harm consumers [132].

Conclusion

Anthrax is a dangerous infectious disease. *B. anthracis* spores are resistant to extreme environments, making it a potential biological weapon. The transmission of these bacterial spores through aerosols can lead to fatal consequences that are difficult to diagnose and treat. Counseling can be used to raise public awareness of anthrax, and it should be preceded by a knowledge, attitude, and practice survey to gauge public opinion.

Authors' Contributions

ARK, SCK, and DAA: Drafted the manuscript. IBM, ENU, and MHE: Revised and edited the manuscript. SCR, MAG, AW, and KHPR: Collected the literature and checked the text for inclusion. DAK, AH, SMY, and OSMS: Edited the references as per the text part. All authors have read, reviewed, and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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