Anthrax

Woolsorters' Disease,
Cumberland Disease,
Maladi Charbon,
Malignant Pustule,
Malignant Carbuncle,
Milzbrand, Splenic Fever

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the Center for
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Importance

Anthrax is a serious zoonotic disease that can affect most mammals and several species of birds, but is particularly important in herbivores. This disease is caused by a spore-forming bacterium, *Bacillus anthracis*. Anthrax spores are extremely resistant to inactivation by heat or chemicals, and can survive in the environment for decades. Susceptibility to clinical disease varies, with domesticated and wild ruminants most susceptible, horses somewhat less susceptible, and omnivores and carnivores relatively resistant. In endemic regions, anthrax can be a serious problem in unvaccinated ruminants. Although antibiotics may be effective if started early, the course of disease is usually rapid in these animals, and symptomatic infections are often fatal. Epizootics in wildlife are also a concern. In 2004, an outbreak in the Malilangwe Wildlife Reserve in Zimbabwe killed almost all of the approximately 500 kudu in the reserve, as well as large numbers of other wild ruminants.

Human cases usually develop after exposure to infected animals and their tissues. In most countries, human anthrax occurs infrequently and sporadically, mainly as an occupational hazard among veterinarians, agricultural workers, and workers who process hides, hair, wool, and bone products. In humans, the three forms of anthrax are cutaneous, gastrointestinal, and inhalational. Cutaneous anthrax accounts for more than 95% of natural infections, and is rarely fatal if treated with antibiotics. The gastrointestinal form is less common but more serious, and can occur in outbreaks associated with contaminated meat. Inhalational anthrax is the most serious form, and has a very high case fatality rate even when treated. Natural cases of inhalational anthrax are rare; however, anthrax has been used as a weapon by bioterrorists, and weaponized anthrax can form aerosols readily. In 2001, weaponized anthrax was delivered in letters through the United States mail, resulting in 11 cases of inhalational anthrax and 11 cases of cutaneous anthrax. Five people with inhalational anthrax died. Because ruminants are particularly sensitive to anthrax, widespread disease in animals might serve as an early warning of a bioterrorist attack under some circumstances.

Etiology

Anthrax results from infection by *Bacillus anthracis*, a spore forming, Gram positive, aerobic rod in the family Bacillaceae. Fully virulent *B. anthracis* isolates have two plasmids: pX01, which codes for a tripartite protein exotoxin complex, and pX02, which encodes the capsule genes. *B. anthracis* is genetically very homogeneous; however, researchers have identified several genetically distinct groups that appear to be derived from clones. Some of these clones are distributed worldwide, while others are found in limited geographic areas.

B. anthracis is a member of the *Bacillus cereus* group, which also contains *B. cereus* and *Bacillus thuringiensis*. These three organisms are very closely related. Based on genetic analysis, some authors consider them to be a single species; however, this idea is controversial. Plasmids closely related to pX01 and/or pX02 have recently been found in a few *B. cereus* isolates that caused anthrax-like diseases in people, chimpanzees or gorillas.

Geographic Distribution

Although *B. anthracis* can be found worldwide, anthrax cases usually occur only in limited geographic regions. Outbreaks are most common in areas characterized by alkaline, calcareous soil, a warm environment, and periodic episodes of flooding. Anthrax is particularly common in parts of Africa, Asia and the Middle East. In the United States, this disease has been reported from most states, but it occurs most often in the Midwest and West. Endemic foci are currently located in the Dakotas, Texas, northwest Minnesota, and Nevada, with smaller areas in other U.S. states.

Transmission

In animals, transmission occurs by ingestion and possibly inhalation of spores, although entry through skin lesions has not been ruled out. Herbivores usually become infected when they ingest sufficient numbers of spores in soil or on plants in pastures. Outbreaks are often associated with heavy rainfall, flooding, or drought. Contaminated bone meal and other feed can also spread this disease. Carnivores

usually become infected after eating contaminated meat. Vultures and flies may disseminate anthrax mechanically after feeding on infected carcasses.

In infected animals, large numbers of bacteria are present in hemorrhagic exudates from the mouth, nose, and anus. When they are exposed to oxygen, these bacteria form endospores and contaminate the soil. Sporulation also occurs if a carcass is opened; however, this process requires oxygen and does not occur inside a closed carcass. Anthrax spores can remain viable for decades in the soil or animal products, such as dried or processed hides and wool. Spores can also survive for two years in water, 10 years in milk, and up to 71 years on silk threads. Vegetative organisms are thought to be destroyed within a few days during the decomposition of unopened carcasses.

Humans usually develop the cutaneous form of anthrax after skin contact with infected animal tissues, such as hides, wool, bone meal, and blood. Experiments in mice suggest that anthrax spores may germinate and enter the skin in abraded, but not intact, skin. Biting flies that feed on infected animals or carcasses may be able to transmit this form mechanically. Inhalational anthrax occurs after inhaling spores from animal products, laboratory cultures, or other sources. Gastrointestinal anthrax results from the ingestion of raw or undercooked meat containing viable spores.

Anthrax has been weaponized by a number of countries. This agent has been used by terrorists. Weaponized anthrax forms aerosols readily and is often inhaled, but cutaneous exposure or ingestion can also occur.

Ecology

The ecology of anthrax is controversial. *B. anthracis* has long been considered an "obligate pathogen." Unlike other members of the genus *Bacillus*, which are saprophytes, *B. anthracis* is thought to multiply almost exclusively inside the body. In the environment, it may exist only as dormant spores. If this idea is correct, spores originally derived from carcasses are the only source of exposure for animals, although carnivores, rain, and other agents can disperse the spores to other locations. Heavy rains, alternating with dry periods, may concentrate the spores and result in outbreaks among grazing animals. Alternatively, the "incubator hypothesis" suggests that anthrax spores can germinate and divide to a limited extent in the environment, if certain conditions are met. This is thought to increase the concentration of *B. anthracis* in "incubator areas" where outbreaks then occur. Although the incubator hypothesis is controversial, *B. anthracis* spores were recently shown to germinate on and around the roots of grass in a simple plant/ soil system. Plasmid transfer between *B. anthracis* isolates was also described in this system. As of March 2007, spore germination on plant roots had not been described outside the laboratory.

Disinfection

Anthrax spores are resistant to heat, sunlight, drying, and many disinfectants. They can be killed with formaldehyde or 2% glutaraldehyde; overnight soaking is recommended. A 10% NaOH or 5% formaldehyde solution can be used for stockyards, pens, and other equipment. Sodium hypochlorite has also been recommended for some purposes. The sporicidal effectiveness of hypochlorite solutions varies with the pH and the concentration of free available chlorine. To become an effective sporicidal agent, household bleach must be diluted with water to increase the free available chlorine, and adjusted to pH 7. Prolonged contact is recommended. Gaseous sterilization can be accomplished with chlorine dioxide, formaldehyde gas, and other methods, under specific conditions of humidity and temperature. Sterilization is also possible by heating to 121°C (250°F) for at least 30 min. Gamma radiation has been used to decontaminate animal products, as well as mail from contaminated postal facilities. Exposed arms and hands can be washed with soap and hot water then immersed for one minute in a disinfectant such as an organic iodine solution or 1 ppm solution of mercuric perchloride. Clothing should be cleaned and boiled.

There is little information on the time and temperatures needed to destroy *B. anthracis* spores in food; however, these spores are less resistant to heat inactivation than *Clostridium botulinum* spores, and methods to kill botulism spores are probably sufficient to destroy anthrax spores.

Comprehensive information regarding the efficacy of specific sterilization methods for *B. anthracis* and other *Bacillus* species is available at http://www.cdc.gov/ncidod/eid/vol9no6/02-0377.htm. Disinfectant sensitivity information for *B. anthracis* is limited; however, a recent study suggests that decontamination data for solid surfaces can be extrapolated from closely- related *Bacillus* species.

Infections in Humans

Incubation Period

The incubation period in humans is usually 1 to 7 days, but varies with the form of the disease. Typically, symptoms of cutaneous anthrax appear after 2 to 3 days. The incubation period for the gastrointestinal form is usually 2- to 5 days, but may be as short as 15 hours. In one outbreak, the mean incubation period for the oropharyngeal form of gastrointestinal anthrax was 42 hours (range 2-144 hours). The incubation period for inhalational anthrax is highly variable. This disease can appear after two days, but spores may remain viable in the lungs for several weeks, and they can germinate and cause inhalational anthrax during that time. After accidental aerosol release in the Soviet Union, cases continued to appear for up to six weeks.

Clinical Signs

Three forms of disease are seen in humans: cutaneous anthrax, gastrointestinal anthrax, and inhalational anthrax.

Cutaneous anthrax is characterized by a papular skin lesion, which becomes surrounded by a ring of fluid-filled vesicles. The central papule ulcerates, dries, and develops a firmly adherent, depressed, black scab. The skin lesion is usually painless, but it is often surrounded by significant edema. There may be regional lymphadenopathy. Swelling on the face or neck may occlude the airways. Lesions on the face or neck can also develop into meningitis. Fever, pus, and pain are seen only if secondary infections occur. Cutaneous lesions often resolve spontaneously, but disseminated, fatal infections occur in approximately 20% of cases. Small anthrax lesions usually heal with minimal scarring.

Gastrointestinal anthrax develops after eating contaminated meat. When spores germinate in the intestinal tract, they cause ulcerative lesions. These lesions can occur anywhere and may, in severe cases, result in hemorrhages, obstruction, or perforation. There is limited information on this form of anthrax, but reported cases range from asymptomatic infections to fatal disease. Gastrointestinal anthrax has been divided into two syndromes: abdominal and oropharyngeal anthrax. The initial symptoms of the abdominal form may be mild and can include malaise, a low fever, and mild gastrointestinal symptoms such as nausea, vomiting, diarrhea, and anorexia. This may be followed by the acute onset of severe gastrointestinal symptoms , such as severe abdominal pain, hematemesis, and bloody diarrhea. Massive ascites can also occur. In addition, there may be high fever, dyspnea, cyanosis, disorientation, and other signs of septicemia. Severe gastrointestinal anthrax rapidly progresses to shock, coma, and death. Abdominal anthrax may not always be severe. In an outbreak in Thailand, seven of 74 people with gastrointestinal anthrax had severe symptoms; acute diarrhea was the only symptom in the others.

The oropharyngeal form is little known. The initial symptoms may include a sore throat, dysphagia, fever, hoarseness, and swelling of the neck. The neck swelling is caused by edema and cervical lymphadenopathy, and can result in airway compromise. Mouth lesions have been reported on the tonsils, pharynx, and hard palate. In one report, these lesions were initially edematous and congested. A central whitish area, caused by necrosis and ulceration, developed by the end of the first week,. During the second week, a pseudomembrane developed over the ulcer.

Inhalational anthrax occurs after inhaling spores. The clinical signs develop gradually and are nonspecific. Early symptoms may include fever, chills, tiredness, and malaise; a nonproductive cough and mild chest pain may be present. The symptoms sometimes improve for several hours to three days. The prodromal period ends with the acute onset of severe respiratory distress, tachycardia, diaphoresis, stridor, and cyanosis, followed by fatal septicemia and shock within one to two days. Hematogenous spread of *B. anthracis* can also cause gastrointestinal lesions and symptoms.

Anthrax meningitis can be a complication of any of the other three forms of disease. After a prodromal period of 1-6 days, typical signs of meningoencephalitis develop rapidly. Patients quickly lose consciousness and die, many within 24 hours. Blood is often found in the cerebrospinal fluid.

Communicability

Person to person transmission of anthrax is extremely rare and has been reported only in cases of cutaneous anthrax.

Diagnostic Tests

Anthrax is often diagnosed by finding the characteristic organisms in clinical samples or by isolating *B. anthracis* in culture. Blood, fluid samples from skin lesions, aspirates of lymph nodes or spleen, ascitic fluid, pleural effusions, or cerebrospinal fluid (in cases of meningitis) are stained with polychrome methylene blue (M'Fadyean's stain). Using this stain, *B. anthracis* organisms are square-ended, blue-black bacilli surrounded by a pink capsule. In a Gram stain, *Bacillus anthracis* is a large, Gram positive rod that may occur singly, in pairs, or in chains. Spores are not found in host tissues unless they have been exposed to air.

B. anthracis colonies on blood agar are white or gray, flat, approximately 3-5 mm in diameter and nonhemolytic, with a rough, ground-glass appearance and a very tacky, butyrous consistency. Tails - wisps of growth trailing back toward the parent colony - may sometimes be seen; this characteristic has been described as a "Medusa head" appearance. Unlike the other members of the *B. cereus* group, *B. anthracis* is non-motile. Capsules are not found when the this organism is grown aerobically *in vitro,* but but may be demonstrated in mucoid colonies from cultures grown on nutrient agar with 0.7% sodium bicarbonate, and incubated overnight under CO_2. *B. anthracis* is also susceptible to specific bacteriophages (the gamma bacteriophage), and exhibits a characteristic 'string–of–pearls' formation when grown with penicillin; however, these latter characteristics may be absent with some isolates. Antibiotic treatment of patients may prevent isolation of the organism.

Polymerase chain reaction (PCR) techniques can also be used to identify *B. anthracis*.

Antibodies develop late in the course of disease, and serology is only useful in retrospective studies. Both acute and convalescent sera must be taken. Serologic tests include enzyme linked immunosorbent assays (ELISAs) and other tests. Approximately 68-92% of patients with cutaneous anthrax develop antibodies to protective antigen or the capsule. A skin hypersensitivity test using AnthraxinT is used in some countries for retrospective diagnosis.

Treatment

Natural strains of *B. anthracis* are usually susceptible to several antibiotics; most but not all natural strains are susceptible to penicillin. Some strains, particularly those used in bioterrorist attacks, may be resistant to penicillin. For this reason, the U.S. Centers for Disease Control and Prevention (CDC) recommends other antibiotics as the initial treatment, particularly for systemic disease, until antibiotic susceptibility has been determined. Antibiotics are effective only against the vegetative stage of *B. anthracis*, and not against spores. Treatment is continued for at least 60 days in inhalational anthrax, as spores may be able to remain dormant in the lungs and germinate during that time. Supportive therapy may also be necessary, particularly for the inhalational and gastrointestinal forms.

Effective treatment depends on early recognition of the symptoms: treatment for cutaneous anthrax is usually effective, but the inhalational and gastrointestinal forms are difficult to recognize early and the mortality rates are higher.

Prevention

Humans can be protected by preventing disease in animals. Veterinary supervision of animal production and slaughter also helps prevent contact with infected livestock or animal products. Trade restrictions may be placed on certain animal products from countries where anthrax is common and uncontrolled. Improvements in industry standards have decreased the occupational risks for people exposed to imported hides, wool, bone meal, and other animal products. In laboratories, good safety practices, including the use of biological safety cabinets, should be employed. Veterinarians should use protective clothing and equipment when examining sick animals. They should also avoid opening the carcasses of suspected cases. Vaccines are available for humans at a high risk of infection. Human anthrax vaccines in the U.S. are based on an inactivated, cell-free extract of cultivated *B. anthracis*. New vaccines are in development.

Postexposure antibiotic prophylaxis is recommended for people who have been exposed to aerosolized anthrax spores. Treatment is continued for at least 60 days in inhalational anthrax, as spores may remain dormant in the lungs and germinate during that time. Simultaneous antibiotics and vaccination can be used in humans exposed to aerosols, as human anthrax vaccines are not live. Postexposure prophylaxis may also be needed for anyone who has eaten contaminated undercooked or raw meat. It is not generally recommended after cutaneous exposure; however, any exposed areas should be washed immediately, and the skin should be monitored for early signs of infection.

Morbidity and Mortality

Anthrax is still a significant risk in some countries, and outbreaks occasionally occur in humans. In Africa, estimates suggest that each cow with anthrax can result in up to ten human cases; however, the incidence of anthrax has declined sharply in developed nations. In the U.S., approximately 130 human cases occurred annually during the early 1900s, but only one or two cases of cutaneous anthrax are now generally seen in a year. In many countries, cases of anthrax occur infrequently and sporadically, mainly as an occupational hazard among veterinarians, agricultural workers, and workers who process hides, hair, wool, and bone products.

The cutaneous form accounts for at least 90-95% of natural anthrax infections. The gastrointestinal form seems to be uncommon, but can occur in outbreaks associated with contaminated meat. Natural cases of inhalational anthrax are rare; however, aerosolized biological weapons would be expected to produce a high percentage of this form. In 2001, 11 cases of inhalational anthrax and 11 cases of cutaneous anthrax were associated with a bioterrorist attack via anthrax-contaminated mail.

The mortality rate varies with the form of the disease. for Cutaneous anthrax is thought to be fatal in 5-20% of untreated cases, and less than 1% of patients treated with antibiotics. In contrast, the mortality rate is high for inhalational anthrax, even when treated appropriately. Earlier estimates suggested that the case-fatality rate for this form approached 90-100%, but newer, more intensive treatment regiments may decrease the mortality rate. In the 2001 mail-associated bioterrorist attack, six of eleven patients with inhalational anthrax recovered with treatment (case fatality rate of 45%). However, once a patient reaches the fulminant stage,, one study suggests that the mortality rate is 97% regardless of treatment.. Anthrax meningoencephalitis is also deadly, with an estimated case fatality rate of 95-100%.

Only limited information exists for gastrointestinal anthrax. The case fatality rate for the abdominal form is unknown, but it is estimated to be from 25% to 60%-75%. Asymptomatic or mild infections have been described among adults in some outbreaks in endemic areas, with higher mortality rates in children. In one report from Uganda, gastroenteritis occurred in 134 of 155 people (92%) who ate meat from an infected zebu. Twelve adults remained asymptomatic. Nine deaths occurred, all in children. The remaining people were treated with antibiotics and rehydration therapy and all recovered. The overall case fatality rate in this outbreak was 7%. In Thailand, 28 cases of cutaneous anthrax and 74 cases of gastrointestinal anthrax were reported in one outbreak. Seven people with gastrointestinal anthrax had severe symptoms; acute diarrhea was the only symptom in the remainder. Three patients died, for a case-fatality rate of 4%. Reports of the oropharyngeal form of gastrointestinal anthrax are rare; however, published case fatality rates range from 12% during an outbreak in Thailand to 50% in a report from Turkey.

Infections in Animals

Species Affected

Virtually all mammals and some birds can contract anthrax, but susceptibility varies widely and most clinical cases occur in wild and domesticated herbivores. Cattle, sheep, and goats are considered to be highly susceptible; horses somewhat less so. Pigs, other omnivores, and carnivores are more resistant to disease, but they may become ill if the dose is high. Birds are highly resistant.

Incubation Period

The incubation period varies from 1 to 20 days. In herbivores, infections become apparent after 3 to 7 days. The incubation period in pigs is usually 1 to 2 weeks.

Clinical Signs

In animals, anthrax can be a peracute, acute, subacute, or chronic disease.

In ruminants, peracute systemic disease is common, and sudden death may be the only sign. Staggering, trembling, and dyspnea may be seen in some animals, followed by rapid collapse, terminal convulsions, and death. In the acute form, clinical signs may be apparent for up to 2 days before death. In this form, fever and excitement may be followed by depression, stupor, disorientation, muscle tremors, dyspnea, and congested mucous membranes. Pregnant cows may abort, and milk production can drop severely. Bloody discharges from the nose, mouth, and anus are sometimes seen. Occasionally, infections in ruminants are characterized by subcutaneous edematous swellings, most often in the ventral neck, thorax, and shoulders. Anthrax in wild herbivores varies with the species, but tends to resemble the disease in cattle.

Horses typically develop acute disease. Common symptoms in this species include fever, chills, anorexia, depression, severe colic, and bloody diarrhea. Swellings may be seen in the neck, sternum, lower abdomen, and external genitalia. Dyspnea can occur due to the swelling of the neck. Affected animals usually die within 1 to 3 days, but some animals can survive up to a week.

Septicemia and sudden death occurs occasionally in pigs. More often, pigs have mild subacute to chronic infections characterized by localized swelling and systemic signs, such as fever and enlarged lymph nodes. Some animals develop rapidly progressive swelling of the throat, with dyspnea and difficulty swallowing; these animals may suffocate. Intestinal involvement with anorexia, vomiting, diarrhea, or constipation is less common. Some pigs with anthrax recover. Recovered, asymptomatic animals may have signs of localized infections in the tonsils and cervical lymph nodes at slaughter.

Clinically apparent anthrax in dogs, cats, and wild carnivores resembles the disease in pigs. A recent review of published cases in dogs suggests that massive swelling of the head, neck, and mediastinum is the most common symptom in this species. In the published cases, death was usually the result of toxemia and shock, but swelling of the throat and suffocation could also have been a factor. Hemorrhagic gastroenteritis was reported in one dog, in addition to a swollen foreleg and ptyalism. Severe acute gastroenteritis has also been reported in other carnivores and omnivores.

Communicability

Large numbers of bacteria are present in the carcass and in bloody discharges from body openings. These bacteria can contaminate the environment or be a source of exposure for humans and other animals. Skin and wool can contain spores, which remain viable for long periods.

Post Mortem Lesions   📷 Click to view images

Rigor mortis is usually absent or incomplete, and the carcass is typically bloated and decomposes rapidly. Dark, tarry blood may ooze from the body orifices; some sources suggest this is not a common sign. Edema may be noted, particularly around the throat and neck in horses. **Necropsies should be avoided, to prevent contamination of the surrounding area with spores.**

If a ruminant carcass is opened, signs of septicemia will be evident. The blood is dark, thick, and does not clot readily. Edematous, blood-tinged effusions may be seen in the subcutaneous tissues, between skeletal muscles, and under the serosa of organs. Petechiae and ecchymoses are often noted in the lymph nodes, the serosal surfaces of the abdomen and thorax, and the epicardium and endocardium. Hemorrhages and ulcers are also common in the intestinal mucosa; ulcers occur most often over the Peyer's patches., but can also be found in other locations. Peritonitis and excessive peritoneal fluid may be noted. The spleen is usually enlarged and has a 'blackberry jam' consistency. The lymph nodes, liver, and kidneys may be swollen and congested. Meningitis can also occur. Similar internal lesions can be seen in some horses; in others, the lesions may be limited to edema of the neck and throat.

Septicemic lesions may also be found in omnivores and carnivores, but are less common than edema and inflammation of the pharyngeal area, or gastrointestinal lesions. Pigs with chronic anthrax usually have lesions only in the pharyngeal area. The tonsils and cervical lymph nodes are typically enlarged and have a mottled salmon to brick-red color on cut surface. The tonsils may be covered by diphtheritic membranes or ulcers. The pharynx is usually edematous. A chronic intestinal form, with inflammation and lesions in the mesenteric lymph nodes, is also reported in pigs. Severe gastrointestinal inflammation, sometimes accompanied by hemorrhages and necrosis, has been reported in some omnivores and carnivores. Peritonitis can also occur.

Diagnostic Tests

A presumptive diagnosis can be made if the characteristic bacteria are found in blood or other tissues. Blood clots poorly with anthrax and samples may be obtained by making a small cut in an ear vein, or with a

syringe from any available vein. In pigs, bacteremia is rare and a small piece of aseptically collected, affected lymphatic tissue is often used. Tissue aspirates and pharyngeal swabs have also been examined in some animals. Air-dried, fixed smears should be stained with polychrome methylene blue (M'Fadyean's stain) or Giemsa stain. With M'Fadyean's stain, *B. anthracis* organisms are square-ended, blue-black bacilli surrounded by a pink capsule. In a Gram stain, *Bacillus anthracis* is a large, Gram positive rod that may occur singly, in pairs, or in chains. Gram stains do not reveal the capsule. Endospores are not found in host tissues unless they have been exposed to air. Antibiotic treatment may result in false negatives.

Bacterial culture may be used for diagnosis. After overnight incubation, *B. anthracis* colonies on blood agar are white or gray, approximately 3-5 mm in diameter, and nonhemolytic, with a rough, ground-glass appearance, and a very tacky, butyrous consistency. T Tails – wisps of growth trailing back toward the parent colony – may sometimes be seen; this characteristic has been described as a "Medusa head" appearance. Capsules are not found when this organism is grown aerobically *in vitro,* but may be demonstrated in mucoid colonies from cultures grown on nutrient agar with 0.7% sodium bicarbonate and incubated overnight at 37ºC (98.6°F) under CO_2. Capsules can also be induced by incubating the bacteria in blood for several hours. Unlike the other members of the *B. cereus* group, *B. anthracis* is non-motile. *B. anthracis* is susceptible to specific bacteriophages (the gamma bacteriophage), and exhibits a characteristic 'string-of-pearls' formation when grown with penicillin; however, these latter characteristics may be absent with some isolates.

In decomposing carcasses, putrefactive bacteria may outcompete and eliminate *B. anthracis* inside the body. In this case, anthrax may be confirmed by isolating the organism from soil contaminated by the terminal discharges; however, recovery of this organism from decomposed carcasses, processed animal products such as bone meal or hides, and environmental samples can be difficult and may require specialized laboratory procedures.

PCR is also be used for diagnosis. This technique detects the bacterial toxin and capsule genes. Mouse or guinea pig inoculation to confirm virulence has largely been replaced by PCR; however, animal tests may be considered if other tests have failed. Although it has been superceded in many locations, some countries use a thermoprecipitin test (Ascoli test) to detect thermostable anthrax antigens in decomposed carcasses and animal products. Research laboratories may use immuno-fluorescence to detect *B. anthracis* capsules in blood or tissues, but this method is not generally used for diagnosis.

Immunoblotting (Western blotting) and ELISAs are available; however, serology is mainly used in research and rarely used for diagnosis. A skin hypersensitivity test using AnthraxinT is widely used in some countries for the retrospective diagnosis of anthrax in animals and humans.

Treatment

Antibiotics may be effective if treatment is started early. Supportive therapy may also be necessary.

Prevention

In endemic areas, modified live vaccines can prevent anthrax in livestock. Livestock are vaccinated annually, before the season when outbreaks generally occur. Livestock vaccines have also been used to protect cheetahs and endangered ruminants, including black rhinoceros.

Anthrax is a reportable disease. Quarantines, effective carcass disposal techniques, and decontamination can help prevent dissemination during outbreaks. Sick animals should be isolated. To prevent sporulation, carcasses should not be opened. Scavengers should also be prevented from accessing the carcass. Local regulations determine carcass disposal; however, incineration is considered to be the most effective disposal method for carcasses, contaminated manure, bedding, and other materials. Deep burial may also be used, but is less desirable. Barns, pens, and equipment should be cleaned and disinfected. Once the soil has been contaminated by spores, it is very difficult to decontaminate; however, procedures such as soil removal and/or treatment with formaldehyde may be used in some circumstances. Insect repellents help prevent flies from spreading the organism. If a pet has been exposed to anthrax, the fur should be decontaminated by repeated bathing to mechanically remove the organism.

During an outbreak,. prophylactic antibiotics are given to exposed and at-risk animals. Prophylactic treatment is well understood for outbreaks due to natural causes, but prolonged treatment could be necessary in a bioterrorist attack with aerosolized spores. Simultaneous vaccination and antibiotic treatment are not used in animals because animal vaccines are live; however, animals can be vaccinated after antibiotic treatment. Grazing animals should be moved away from areas of possible contamination, and contaminated feed should be removed.

Good hygiene should be observed by anyone exposed to infected animals or contaminated areas, both to avoid spreading the disease and for personal protection.

Morbidity and Mortality

The worlwide incidence of anthrax is difficult to determine; however, this disease has been reported from nearly every continent. Outbreaks occur periodically in some countries. These epizootics may be seen in domesticated or wild animals, and are typically associated with droughts, heavy rains, or flooding. Outbreaks are uncommon among domesticated animals in developed nations. Approximately 25 outbreaks were reported in the U.S. between 1994 and 2000. Sporadic cases occur between outbreaks. Sporadic cases of anthrax are reported almost every year in domesticated or wild animals in the U.S.; the estimated annual mortality rate in U.S. livestock is one animal per one million animals at risk. Recently,

more severe outbreaks have been reported on U.S. game ranches with non-traditional species, such as white-tailed deer. This may be related to difficulties in vaccinating exotic ungulates.

The mortality rate for anthrax varies with the species. Clinical infections in ruminants and horses are usually fatal; pigs often recover. In carnivores, mortality is also relatively low. Mortality rates are not widely available for wild animals; however, in 2004, an outbreak in the Malilangwe Wildlife Reserve in Zimbabwe killed almost all of the approximately 500 kudu in the reserve, as well as 68% of the nyala (*Tragelaphus angasi*), 48% of the bushbuck (*Tragelaphus scriptus*), 44% of the waterbuck (*Kobus ellipsiprymnus*), and 42% of the roan antelope (*Hippotragus equinus*). Approximately 6% of the buffalo (*Syncerus caffer*) in the area also died.

Internet Resources

American College of Physicians. Physicians Information and Education Resource (PIER). Anthrax
http://pier.acponline.org/physicians/public/d892/d892.html

Centers for Disease Control and Prevention (CDC)
http://www.cdc.gov/ncidod/dbmd/diseaseinfo/anthrax_t.htm

CDC Emergency Response and Preparedness: Anthrax
http://www.bt.cdc.gov/agent/anthrax/

Food and Agriculture Organization of the United Nations. Manual on Meat Inspection for Developing Countries
http://www.fao.org/docrep/003/t0756e/t0756e00.htm

Medical Microbiology
http://www.gsbs.utmb.edu/microbook

Public Health Agency of Canada.
Material Safety Data Sheets
http://www.phac-aspc.gc.ca/msds-ftss/index.html

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http://www.cdc.gov/ncidod/eid/vol9no6/02-0377.htm

The Merck Manual
http://www.merck.com/pubs/mmanual/

The Merck Veterinary Manual
http://www.merckvetmanual.com/mvm/index.jsp

World Health Organization. Guidelines for the Surveillance and Control of Anthrax in Humans and Animals
http://www.who.int/csr/resources/publications/anthrax/WHO_EMC_ZDI_98_6/en/

World Organization for Animal Health (OIE)
http://www.oie.int/

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals
http://www.oie.int/eng/normes/mmanual/a_summry.htm

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