Brucellosis in Marine Mammals

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Importance

Brucellosis is a zoonotic bacterial disease caused by several species in the genus *Brucella*. Each species tends to be associated with a specific animal host, but other animals can be infected, especially when they are in close contact. Brucellae appear to be widespread in marine mammals. Two species have been recognized to date: *B. ceti*, which primarily circulates in cetaceans (whales, porpoises and dolphins), and *B pinnipedialis*, which mainly infects pinnipeds (seals, sea lions and walruses). These organisms seem to infect many animals without causing clinical signs; however, infections have also been linked to reproductive losses, meningoencephalitis, orchitis, arthritis, discospondylitis, subcutaneous abscesses and other syndromes. The vast majority of clinical cases have been caused by *Brucella ceti*. There are particular concerns about the effects of brucellosis on endangered marine mammals, such as the critically endangered Maui's dolphin.

B. ceti and *B. pinnipedialis* seem to be able to infect some terrestrial mammals, but the frequency and significance of this event is unknown. Some polar bears, which feed on marine mammals, are seropositive for *Brucella*. Rare clinical cases have been reported in humans, including three cases in people who had no apparent exposure to marine mammals, and might have been exposed via the environment or undercooked seafood.

Etiology

Brucellae are Gram negative coccobacilli in the family Brucellaceae (class Alphaproteobacteria). Two species are currently recognized in marine mammals: *B. pinnipedialis* (previously called *B. pinnipediae*), which is primarily found in pinnipeds, and *B. ceti* (previously called *B. cetaceae*), which mainly occurs in cetaceans. *B. ceti* can be divided into two groups, one of which is generally associated with dolphins (Delphinidae) and beaked whales (Ziphiidae), and another that is usually found in porpoises. It has been proposed that the dolphin isolates be reclassified as *Brucella delphinii.* An organism that caused three of the four known clinical cases in people seems to belong to the species *B. ceti*, but it has some characteristics that do not fit with this group, and its classification is still debated. It is known as the ST27 genotype, after its multi-locus sequence typing (MLST) classification.

Little is currently known about the susceptibility of marine mammals to the species of *Brucella* found in livestock and other terrestrial animals. What appeared to be an organism from terrestrial livestock was detected by PCR in a California sea lion (*Zalophus californianus*); however, its species could not be definitively identified. More information about terrestrial brucellae (*B. abortus*, *B melitensis*, *B. suis* and *B. canis*) is available in the respective factsheets at http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.htm.

Note on *Brucella* taxonomy: At one time, the genus *Brucella* was reclassified into a single species, *B. melitensis*, based on the genetic and immunological evidence that all members of this genus are closely related. Under this system, the various species of *Brucella* were considered to be biovars. This proposal was controversial, and it has fallen out of favor for practical reasons.

Species Affected

B. ceti has been cultured or detected by PCR in many species of cetaceans including harbor porpoises (*Phocoena phocoena*), short-beaked common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), bottlenose dolphins (*Tursiops truncatus*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), white beaked dolphins (*Lagenorhynchus albirostris*), Maui's dolphins (*Cephalorhynchus hectori maui*), white-headed dolphins/ Hector's dolphins (*Cephalorhynchus hectori*), clymene dolphins (*Stenella clymene*), minke whales (*Balaenoptera acutorostrata*), killer whales (*Orcinus orca*), Sowerby's beaked whales (*Mesoploden bidens*), long-finned pilot whales (*Globicephala melas*), Southern right whales (*Eubalaena australis*) and narwhal (*Monodon monoceros*). There are also a few reports of *B. ceti* in harbor seals/ common seals (*Phoca vitulina*) and harp seals (*Pagophilus groenlandicus*). The ST27 genotype has been isolated from bottlenose dolphins and California sea lions (*Zalophus californianus*), and nucleic acids were found in minke whales.

Bacteriological evidence for *B. pinnipedialis* has been reported in many species of pinnipeds including harbor seals, ringed seals (*Pusa hispida*), harp seals, hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*), Northern fur seals (*Callorhinus ursinus*) and California sea lions. This organism has also been found in beluga whales (*Delphinapterus leucas*) and minke whales, as well as in sea otters (*Enhydra lutris*), which are marine mammals but neither cetaceans nor pinnipeds. One infection was detected in a European otter (*Lutra lutra*), a semiaquatic mammal that lives in freshwater environments.

Antibodies to *Brucella* suggest that these organisms may infect other marine mammals, including Steller's sea lions (*Eumetopius jubatus*), Australian sea lions (*Neophoca cinerea*), Atlantic walruses (*Odobenus rosmarus rosmarus*), and additional species of seals, porpoises, dolphins and whales. Antibodies to *Brucella* found in polar bears are thought to result from exposure to infected seals and other prey. Experimental infections with marine mammal isolates have been described in cattle, sheep, pigs and laboratory animals (mice, guinea pigs).

Zoonotic potential

Four clinical cases have been reported in humans, as of 2018. Three of them were caused by the ST27 genotype, and the fourth by another genotype of *B. ceti*.

Geographic Distribution

B. ceti and *B. pinnipedialis* are thought to be widespread in marine mammal populations. Culture-positive or seropositive animals have been found on the coasts of most continents and in many seas and oceans including in the Arctic and Antarctic. Most isolates have come from animals in the northern hemisphere, but this may reflect sampling rather than the true distribution of infection. As of 2018, the ST27 genotype has been isolated from animals in both the Pacific and Atlantic oceans, and in the Adriatic Sea.

Transmission

Transmission of *Brucella* is poorly understood in marine mammals, with only limited evidence to support any route. The species of *Brucella* found in terrestrial animals are often transmitted by exposure to infected birth products (e.g., placenta, fetus, fetal fluids) and vaginal secretions, and sometimes by venereal spread and other means, including nursing. Some young animals infected *in utero* can survive and continue to carry brucellae. Marine mammals might transmit brucellae by similar routes; *B. ceti* and/or *B. pinnipedialis* has been isolated from the male and female reproductive organs, birth products (including the placenta, fetal fluids and fetal organs) and the milk or mammary gland. They might also be spread by other forms of direct or indirect contact. Fecal shedding of *B. pinnipedialis* has been described in harbor seals, and bites were suggested as a possible source of some *Brucella*-associated abscesses. Respiratory nematodes have been proposed as potential vectors. *B. pinnipedialis* was found in lungworms (*Parafilaroides* sp.) in harbor seals and *B. ceti* was detected in *Pseudalius inflexus* in a harbor porpoise. Similarly, it has been suggested that liver flukes (*Pseudamphistomum truncatum*) in grey seals might be vectors for *B. pinnipedialis*. Some authors have suggested that brucellae might also be transmitted to marine mammals by the ingestion of other marine mammals or infected fish. Support for the latter comes from natural and experimental infection of Nile catfish by a terrestrial species, *B. melitensis*, and extended survival of *B. pinnipedialis* in Atlantic cod (*Gadus morhua*) after intraperitoneal injection.

The survival of *B. ceti* and *B. pinnipedialis* in the environment has not been studied. Terrestrial species of *Brucella* can remain viable in terrestrial and freshwater environments for periods ranging from less than a day to > 8 months, depending on factors such as temperature, humidity, exposure to sunlight and the presence of organic matter. Survival is longer when the temperature is low. In conditions of high humidity, low temperatures, and no sunlight, these organisms may remain viable for several months in water, aborted fetuses, manure, wool, hay and other materials. How long marine mammal isolates might survive in seawater is uncertain. Dilution of organisms would need to be considered for transmission in water.

People usually become infected with terrestrial species of *Brucella* by ingesting organisms or via contaminated mucous membranes (including the conjunctiva and respiratory tract) and abraded skin. One clinical case caused by marine brucellae occurred in a person who was working with *B. ceti* in the laboratory, but the source of three other infections is unknown. Potential routes of exposure in these three cases included eating raw fish or shellfish, handling raw fish and bait, and swimming in the ocean. None of the people had been directly exposed to marine mammals. Predation on infected seals has been suggested as a route of exposure for polar bears. Cattle have been infected experimentally by intravenous injection, and cattle and sheep by conjunctival inoculation.

Disinfection

Brucella spp. are readily killed by most commonly available disinfectants including hypochlorite solutions, sodium hydroxide, quaternary ammonium compounds, 70% ethanol, isopropanol, iodophors, phenolic disinfectants, formaldehyde, glutaraldehyde and xylene. A 1% solution of citric acid was reported to be less effective. Brucellae are inactivated fairly quickly by acid pH < 3.5. They can also be destroyed by moist heat of 121°C (250°F) for at least 15 minutes, dry heat of 320-338°F (160-170°C) for at least 1 hour, gamma irradiation and pasteurization. Boiling for 10 minutes is usually effective for liquids.

Infections in Animals

Incubation Period

The incubation period is unknown.

Clinical Signs

Both *B. ceti* and *B. pinnipedialis* are frequently detected in asymptomatic animals. Most of the clinical cases reported, to date, have been in cetaceans. *B. ceti* was thought to be the causative organism in these animals, although some case reports do not provide definitive identification to the species level. Placentitis and/or abortions have been reported in a few dolphins, and one infection was found in a Maui's dolphin that was born alive but died before taking its first breath. *Brucella*-associated epididymitis or orchitis has been identified in several species including harbor porpoises, minke whales and Bryde's whales. Meningoencephalitis has been seen most often in striped dolphins, but it was also reported in a few other dolphin species, a Sowerby's beaked whale and a long-finned pilot whale. Some of the clinical signs associated with this syndrome in cetaceans include disorientation, incoordination, opisthotonos, tremors, seizures, and the inability to maintain buoyancy. Other syndromes that have been linked to brucellosis in cetaceans include metritis, endocarditis, subcutaneous abscesses (generally in the blubber layer), hepatic abscesses, peritonitis, discospondylitis, osteomyelitis, and joint lesions including arthritis. Large numbers of brucellae were also found in a skin ulcer in a harbor porpoise. Some cetaceans had pulmonary lesions suggestive of brucellosis (e.g., a *Brucella*-associated abscess in an Atlantic bottlenose dolphin, bronchointerstitial pneumonia), but *B. ceti* has also been found in normal lungs, and the pulmonary lesions associated with respiratory distress during stranding, as well as coinfection with other pathogens, may make definitive attribution difficult.

B. pinnipedialis has only been linked to disease in a few cases. This organism was associated with severe placentitis in a northern fur seal (*Callorhinus ursinus*). The fate of the pup was not known, although it was thought to have been born alive. *B. pinnipedialis* was also found in the placentas of sea lions that had aborted from domoic acid toxicity; however, these animals no lesions associated with brucellosis. It was detected in grey seals that were coinfected with liver flukes, and both organisms were thought to have contributed to the inflammatory lesions and abscesses in the liver. Other authors suggest possible roles for this organism in bronchopneumonia. It has been isolated from emaciated seals, especially pups, but whether it had any role in their condition is uncertain.

A wild southern sea otter (*Enhydra lutris nereis*) found to be infected with *Brucella* at necropsy had various clinical signs and lesions including osteomyelitis and arthritis in a hind foot and flipper, lumbar pain, subcutaneous abscesses and neurological signs, during two separate hospitalizations at a rehabilitation center. The causative organism appeared to be *B. pinnipedialis*, although it could not be identified with complete certainty. This animal was coinfected with *Toxoplasma gondii*, which might also have been responsible for the neurological signs, and it had apparently suffered a shark bite, which could have caused the abscesses. These abscesses resolved after antibiotic treatment during its first hospitalization.

No clinical signs or lesions have been associated with marine mammal brucellae, to date, in polar bears. *B. ceti* was detected in the lymph node of a European river otter that had been hit by a car, but it had no lesions suggestive of clinical brucellosis. Two of 3 pregnant cattle inoculated intravenously with an isolate from a seal aborted, while 3 animals inoculated via the conjunctiva had only transient infections and did not become ill or abort. No increase in reproductive losses was found in pregnant sheep infected with *B. ceti* or *B. pinnipedialis*. Infections in these animals were also usually transient, with no acute clinical signs and a low rate of seroconversion. *B. pinnipedialis* was, however, detected in the placenta and amniotic fluid of one sheep that lambed prematurely with moribund triplets. It was unclear whether the organism had any role, as it was not found in the lambs, and the conditions in this experiment resulted in stillbirths unrelated to brucellae in all groups of sheep. Young, nonpregnant pigs became infected only transiently after oral and conjunctival inoculation with an ST27 isolate from a human patient. Guinea pigs injected intramuscularly with marine mammal brucellae showed signs typical of infection with *Brucella*, especially splenomegaly, but these organisms were less virulent for both guinea pigs and mice than terrestrial brucellae.

Post Mortem Lesions

Common gross lesions in cetaceans with meningoencephalitis include hyperemia of the meninges and brain, and increased amounts of cloudy cerebrospinal fluid. Secondary hydrocephalus has been described in some animals. In striped dolphins, CNS lesions were reported to be most severe in the brainstem. Epididymitis and orchitis, with granulomatous lesions, abscesses or calcified foci, have been reported in male cetaceans. Endometritis with suppurative granulomatous lesions and nodular granulomas has been seen in females. Other lesions that have been associated with *B. ceti* include placentitis, lymphadenitis, mastitis, osteomyelitis, discospondylitis, arthritis, peritonitis, and an enlarged liver and spleen with hepatic and splenic necrosis and inflammation. *Brucella*-associated abscesses have been found in subcutaneous tissues (usually in the blubber layer) and internal organs such as the liver and lung. Bronchointerstitial pneumonia was also suspected to be associated with this organism in some animals.

B. pinnipedialis caused suppurative placentitis with necrosis in a northern fur seal, and chronic granulomatous arthritis in a sea otter. It was probably also responsible for chronic granulomatous osteomyelitis and multifocal nodular granulomatous myelitis in the latter animal, and might have caused some of its other lesions, including lymphadenopathy. This sea otter had chronic cavitated and

partially mineralized brain lesions, described as mild, multifocal nonsuppurative meningoencephalitis; however, they could have been caused by either *Brucella* or *T. gondii*.

No gross lesions were observed in experimentally infected cattle or their aborted fetuses. Microscopic examination revealed necropurulent placentitis and endometritis in the two animals that aborted, but no lesions in other tissues.

Diagnostic Tests

Brucellae are coccobacilli or short rods, usually arranged singly but sometimes in pairs or small groups. They are not truly acid-fast; however, they are resistant to decolorization by weak acids, and stain red with modified Ziehl-Neelsen (Stamp) staining. A few other organisms stain similarly. A definitive diagnosis can be made by culturing *B. ceti* or *B. pinnipedialis* from affected tissues or detecting their nucleic acids by PCR. In marine mammals, brucellae have been found in the male and female reproductive organs, placenta, fetal fluids, fetal organs, mammary gland, lymph nodes and sites of clinical localization. At necropsy, samples should be collected from all tissues with gross lesions; however, organisms may also be present in tissues that only have microscopic lesions and normal tissues. Postmortem blood cultures collected from the heart are occasionally successful. Oral, nasal, tracheal, vaginal and anal swabs can be submitted from live animals. Milk and feces sometimes contain marine brucellae. The occurrence of *B. ceti* and *B. pinnipedialis* in many healthy animals can complicate diagnosis.

Most species of *Brucella* can be cultured on a variety of nonselective media, or on selective media such as Farrell's or Thayer-Martin's medium. Enrichment techniques can also be employed. The new CITA medium, with components that have been optimized to isolate the major species of terrestrial brucellae, does not appear to have been evaluated yet for *B. ceti* and *B. pinnipedialis*. Some marine mammal isolates grow poorly on Farrell's medium, and may require additional incubation time, if they grow at all. Concurrent inoculation onto a nonselective medium is suggested. Some commercial bacterial identification systems can misidentify *Brucella* as another organism. Treatment with antibiotics or bacterial overgrowth in nonsterile samples can interfere with culture.

Brucellae can be identified to the species and biovar level by phenotypic methods (phage typing and cultural, biochemical and serological characteristics) or genetic techniques. Species identification is complicated by the high genetic similarity between *Brucella* species and the possibility of ambiguous phenotypic tests. Marine mammal isolates are sometimes misidentified initially as terrestrial strains. *B. ceti* can often (though not always) be distinguished from *B. pinnipedialis* by its phenotypic characteristics, including the latter organism's requirement for CO_2. The ST27 organisms are not capnophilic, suggesting that they belong to *B ceti*, but some other characteristics indicate that this group might be unique.

Most PCR tests only identify *Brucella* to the genus level. PCR assays reported to be more sensitive for marine brucellae have been described. They target a genetic sequence present in higher copy numbers in *B. ceti* and *B. pinnipedialis*, compared to terrestrial brucellae. The Bruce-ladder assay, a widely performed PCR test that can identify multiple species of *Brucella*, can distinguish marine brucellae from terrestrial species. Although this test can also distinguish some *B. ceti* isolates from *B. pinnipedialis*, it has been reported to misidentify dolphin strains as *B. pinnipedialis*. Multiple-locus variable number tandem repeat analysis (MLVA) and MLSA can be used for species identification of marine brucellae. Single nucleotide polymorphism (SNP) typing, which is reliable for terrestrial brucellae, was reported to be unreliable for distinguishing marine species. A PCR test reported to specifically detect ST27 strains has been published. Immunostaining has been used to demonstrate *Brucella* in tissues in some research laboratories.

Serology is generally used in surveillance. It can also be employed in individual animals, though it is not always reliable. Marine mammal brucellae contain "smooth" lipopolysaccharide like the terrestrial species *B. abortus*, *B. melitensis* and *B. suis*, and some livestock *Brucella* assays have been used to detect antibodies in marine mammals. They include tests such as the buffered *Brucella* antigen tests (rose bengal test and buffered plate agglutination test), serum agglutination tests (tube or microtiter tests), complement fixation, fluorescence polarization assay, agar gel immunodiffusion, and ELISAs. Agglutination tests and ELISAs have been employed most often. It should be noted that livestock assays have not always been validated for pinnipeds and cetaceans. A few tests have been developed to specifically detect serological reactions to brucellae in marine mammals. They include a competitive ELISA for cetaceans and pinnipeds and an indirect ELISA for odontocetes. In terrestrial mammals, serological tests for brucellosis are known to cross-react with some other bacteria. Cross-reactivity might also be an issue for marine mammals.

Treatment

Antibiotic treatments used for other brucellae have occasionally been employed in captive dolphins, but no reports of successful treatment have been published. In terrestrial mammals, organisms might persist in lymph nodes or other tissues after treatment, and could later re-emerge. For this reason, as well as the potential zoonotic risks, some authors suggest that euthanasia should be considered in marine mammals with brucellosis.

Control

Disease reporting

Veterinarians who encounter or suspect brucellosis should follow their national and/or local guidelines for disease reporting. In the U.S., state authorities should be consulted for reporting requirements. The National Marine

Fisheries Service (NMFS) Marine Mammal Health and Stranding Response Program considers brucellosis a reportable disease. Finding brucellae in marine mammals does not affect a country's status for international trade in livestock.

Prevention

Specific control methods have not been established for brucellosis in marine mammals. General principles of infection control, including isolation, disinfection and good hygiene, should be used with infected animals in marine mammal facilities. Some authors suggest that centers involved in marine mammal rehabilitation should routinely screen animals for *Brucella*.

Morbidity and Mortality

B. ceti and *B. pinnipedialis* seem to be fairly common in marine mammals. Estimates of their prevalence vary with the species, test conducted, geographic location and population sampled (e.g. stranded animals). Published seroprevalence rates range from < 10% to 30-50%, with occasional reports of higher rates. The morbidity and mortality rates in marine mammals are unknown, but illnesses seem to be relatively infrequent in cetaceans, and rare in pinnipeds. However, some syndromes such as reproductive losses could be readily missed in wild species. Meningoencephalitis has been disproportionately found in striped dolphins, suggesting that they might be unusually susceptible to this syndrome.

In the Arctic, 5-10% of polar bears were found to have antibodies to *Brucella*, probably from eating infected seals. Whether these infections result in any clinical signs is uncertain. Marine brucellae appear to be significantly less virulent for cattle and sheep than *B. abortus* or *B. melitensis*. One study suggested that these organisms might be able to cause reproductive losses in cattle if the number of organisms is high, as abortions occurred in animals inoculated intravenously but not via the conjunctiva. However, it should be noted that intravenous inoculation also bypasses some natural defenses against microorganisms. *B. ceti* and *B. pinnipedialis* also appeared to be attenuated in rodent models, compared to the terrestrial brucellae that infect livestock.

Infections in Humans

Incubation Period

The acute symptoms of brucellosis often appear within 2-4 weeks of exposure, but the onset can be insidious, and some cases have been diagnosed as late as 6 months after exposure. The incubation period for cases caused by brucellae from marine mammals is unknown.

Clinical Signs

Very few clinical cases in humans have been caused by brucellae from marine mammals. The consequences of infection with other species of *Brucella* range from asymptomatic infections to diverse syndromes that may appear insidiously or abruptly. Acute brucellosis is usually a febrile illness with nonspecific flu-like signs such as fever, chills, headache, malaise, back pain, myalgia and lymphadenopathy, which may be accompanied by splenomegaly and/ or hepatomegaly. Patients may experience drenching sweats, especially at night. Nonspecific gastrointestinal signs including anorexia, vomiting, diarrhea and constipation may also be seen. Some people recover spontaneously, while others develop persistent nonspecific symptoms (e.g., fever, weakness) that typically wax and wane. Localized infections in various organs and tissues can result in a wide variety of syndromes. Fever may be absent or mild in these cases. Infections in bones and joints, the most common sites of localization, can manifest as arthritis, spondylitis, sacroiliitis, osteomyelitis, bursitis and tenosynovitis. Other syndromes have included neurological involvement (e.g., meningitis, meningoencephalitis, brain abscesses), ocular signs (uveitis, optic neuritis, endophthalmitis and other signs), anemia, thrombocytopenia, nephritis, cardiovascular complications (e.g., vasculitis, aneurisms, endocarditis), respiratory involvement (e.g., bronchopneumonia or pulmonary abscesses), peritonitis, pancreatitis, myelitis, and cutaneous rashes, ulcers or abscesses. Epididymo-orchitis, prostatitis and seminal vesiculitis can be seen in males, and pregnant women may abort or give birth prematurely. Sepsis, pneumonia and other syndromes have been reported in congenitally infected infants, but some infected newborns are asymptomatic. Deaths are uncommon except in infants, and are usually caused by endocarditis or infections affecting the brain. After treatment, recovery may take a few weeks to months.

The four published clinical cases caused by marine brucellae are generally consistent with this description. A laboratory-acquired infection was characterized by headaches, fatigue and severe sinusitis, which resolved completely after antibiotic treatment. Neurobrucellosis and intracerebral granulomas were the primary syndromes in two other people. One of these patients had a 3-month history of periorbital pain, headaches and periodic seizures. The other had a one-year history of headaches, nausea, vomiting and progressive deterioration in eyesight. The fourth person had spinal osteomyelitis, with a 2-week history of fever, rigors and tenderness in the lumbar region. Two of these cases were acquired in Peru. A marine mammal researcher in Peru developed a nonspecific illness with clinical signs of undulating fever, headache, profuse night sweats, chronic fatigue, anorexia, weight loss, seizures, severe myalgia and backache. Researchers speculated that marine brucellae might have caused this illness, and that they might also have been responsible for similar clinical signs in a Peruvian woman who sold whale meat.

Diagnostic Tests

Clinical cases caused by terrestrial brucellae are diagnosed by culture, PCR on tissue samples, and/or serology. Serological tests used to detect human infections

with livestock brucellae include the rose bengal test, the serum tube agglutination test (SAT) with or without 2-ME or DTT, the microagglutination test (MAT), Coombs test, BrucellaCapt® (a commercial immunocapture agglutination test) latex agglutination tests, competitive ELISAs, complement fixation and other assays. Some of these tests may also be able to detect antibodies to *B. ceti* and *B. pinnipedialis*.

The four clinical cases caused by marine mammal brucellae were diagnosed by isolation of the organism, supplemented by serology. An infection in a laboratory worker was confirmed by serology and the isolation of *B. ceti*. In two patients with neurological signs, brucellae were found unexpectedly in clinical samples collected for fungal culture or mycobacterial culture. One of these patients was seropositive in the SAT. The other was seronegative for *Brucella*, although he had been ill for a year. In the fourth patient, an ST27 isolate was isolated from the blood but from not a bone affected by osteomyelitis. He was seropositive in a screening agglutination test, the SAT, and a Coombs anti-*Brucella* test. Both of the agglutination tests in this case used *B. abortus* antigens. His antibody titers in the SAT and Coombs test declined after treatment.

Treatment

In humans, brucellosis is usually treated with a prolonged course of antibiotics, combining two or more drugs for part or all of the treatment course. Monotherapy is reported to have a high relapse rate. Different antibiotics may be recommended, depending on the patient's age, pregnancy status and syndrome. Relapses can be seen (most often within 3-6 months) if brucellosis treatment is inadequate. Surgical intervention may occasionally be required for localized foci.

Prevention

Good hygiene, together with personal protective equipment (e.g., gloves, face/ eye protection, protective clothing and respirators, as appropriate) can decrease human exposure. Wounds should be covered. Particular care should be taken during activities that may aerosolize organisms (e.g., pressure washing, sawing into infected tissues). More detailed precautions and PPE recommendations for people who work with marine mammals may be available from sources such as the CDC and professional organizations. The potential for zoonotic infections, especially in immunosuppressed people, should be considered if the public is allowed to contact captive marine mammals. Undercooked tissues from marine mammals should not be eaten. This might also be applicable to raw fish or shellfish, as eating these foods was a possible risk factor in some clinical cases.

Prophylactic antibiotics and/or monitoring may be offered to laboratory workers or others after high risk exposure to *B. ceti* or *B. pinnipedialis*. People who become ill after contact with marine mammals should visit a physician and mention the possibility of exposure to brucellae.

Morbidity and Mortality

Brucellosis can affect all ages, including children. People who hunt marine mammals are likely to be at increased risk of exposure to *B. ceti* or *B. pinnipedialis*, especially when dressing carcasses or consuming raw meat. Other risk groups include some veterinarians, zoologists, laboratory workers, fishermen, and people who work in marine mammal rehabilitation or display centers, as well as anyone who approaches a beached animal or carcass.

As of 2018, only four clinical cases have been described in humans. One patient was a researcher exposed to *B. ceti* in the laboratory. The source of the organism could not be determined in the other three cases, which were all caused by the ST27 genotype and occurred in people who had not been directly exposed to marine mammals. Two of these patients regularly consumed raw fish (in ceviche) and unpasteurized cheese. One of them also swam regularly in the ocean. The fourth patient was a fisherman, who had frequent contact with uncooked fish bait and raw fish, and had also eaten raw, freshly caught fish. One of these three cases occurred in New Zealand. The other two were acquired in Peru and diagnosed in the U.S. All four people recovered after treatment. Estimates of the case fatality rate for untreated brucellosis caused by other species of *Brucella* are usually in the range of 1-2% or less.

The overall risks to humans from *B. ceti* and *B. pinnipedialis* are uncertain. Infections with marine brucellae might be underdiagnosed, due to the lack of clinical suspicion and the vague clinical signs. A limited number of published and unpublished studies have not detected illnesses suggestive of brucellosis or antibodies to brucellae in people occupationally exposed to marine mammals. However, one article noted that a researcher who regularly necropsied marine mammals in Peru had an undiagnosed illness consistent with brucellosis, and a woman who sold whale meat at a local market had similar symptoms. Studies in rodents, sheep and cattle suggest that *B. ceti* and *B. pinnipedialis* are probably less virulent for terrestrial mammals than the brucellae commonly associated with human disease (*B. melitensis*, *B. abortus* and *B. suis*). Strains of *B. ceti* and *B. pinnipedialis* might differ in their ability to cause illness. *In vitro* studies with human cells found that, while several isolates of *B. pinnipedialis* did not readily enter and/or replicate in these cells, one proliferated well. Isolates of *B. ceti* also differed in their ability to enter and replicate in these cells.

Internet Resources

American Association of Zoo Veterinarians

Centers for Disease Control and Prevention (CDC). Brucellosis.

CDC. Brucellosis reference guide. Exposures, testing and prevention (includes recommendations for marine mammal exposure)

European Centre for Disease Prevention and Control. Brucellosis

Public Health Agency of Canada. Pathogen Safety Data Sheets

The Merck Manual

The Merck Veterinary Manual

U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries. Policies and Best Practices Marine Mammal Stranding Response Rehabilitation and Release

World Health Organization. Brucellosis

World Organization for Animal Health (WOAH)

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* Link is defunct

