

Brucellosis: *Brucella suis*

Porcine Brucellosis,
Rangiferine Brucellosis,
Enzootic Abortion,
Contagious Abortion,
Undulant Fever,

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Importance

Brucellosis is a zoonotic bacterial disease caused by several species in the genus *Brucella*. Reproductive losses are the most common syndrome in animals, while humans may suffer from a debilitating nonspecific illness or localized involvement of various organs. Each organism tends to be associated with a specific animal host, but other species can be infected, especially when they are kept in close contact. Domesticated and/or wild pigs are the usual hosts for biovars 1, 2 and 3 of *Brucella suis*. Biovar 4 circulates in caribou and reindeer in Arctic regions, while biovar 5 has been reported only in wild rodents. Most people become infected by direct contact with infected animals or their tissues, or by the ingestion of contaminated animal products.

B. suis is common in domesticated pigs in some parts of the world, such as Asia and Latin America. This organism has been virtually eradicated from commercial herds in some other regions; however, it is still maintained in wild or feral swine in many of these areas, including North America and Europe. This complicates brucellosis control, especially for domesticated pigs kept outdoors. In addition, clinical cases are sometimes reported in hunting dogs and people who hunt wild pigs. Occasionally, organisms from wild suids infect other livestock such as cattle, resulting in additional risks to human health. *B. suis* has also been weaponized, and there are concerns that it could be used in a bioterrorist attack.

Etiology

Brucella suis is a Gram negative coccobacillus in the family Brucellaceae (class Alphaproteobacteria). Five biovars with different host preferences are currently recognized. *B. suis* biovars 1, 2 and 3 are the *Brucella* species usually found in pigs, although *B. abortus* and *B. melitensis* may also be detected occasionally. (Information about *B. abortus* and *B. melitensis* is available in the respective factsheets at <http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.htm>) Biovar 4, the agent of rangiferine brucellosis, circulates in reindeer and caribou. Biovar 5 has only been found in rodents.

Note on 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. suis biovars 1, 2 and 3 mainly occur in domesticated pigs, feral pigs and wild boars, which all belong to the species *Sus scrofa*, and some other members of the pig family (Suidae). Biovars 1 and 3 circulate in domesticated swine, but they have also become established in feral pigs in some areas, and a biovar 1 organism was found in collared peccaries (*Tayassu tajacu*). Wild boar are the usual reservoir hosts for biovar 2 in Europe, but this organism can spread readily in domesticated pigs. Biovar 2 is also maintained in wild European hares (*L. europaeus*; formerly identified as *L. capensis*). Biovar 1 has been isolated several times from wild European hares in South America, suggesting that they might maintain *B. suis* in this location. One or more of the porcine *B. suis* biovars have also been detected in cattle, sheep, goats, horses, dogs, opossums (*Didelphis marsupialis*), armadillos (*Chaetophractus villosus*) and roe deer (*Capreolus capreolus*), with or without clinical signs. Rabbits (*Oryctolagus cuniculus*) were experimentally infected with a biovar 1 isolate from wild hares in South America. A cat infected with *B. suis* was identified after it transmitted the organism to six human contacts.

Biovar 4 is maintained in caribou and reindeer (*Rangifer tarandus* and its various subspecies). Other species known to be susceptible to infection and/or disease include cattle, moose (*Alces alces*), muskoxen (*Ovibos moschatus*), bison (*Bison bison*), Arctic foxes (*Alopex lagopus*), red foxes (*Vulpes vulpes*) and wolves (*Canis lupus*). Grizzly bears (*Ursus arctos horribilis*), white-tailed deer (*Odocoileus virginianus*)

and rodents have been experimentally infected. Seropositive grizzlies and dogs in the Arctic are thought to have been exposed to *B. suis* biovar 4, as this is the only species

of *Brucella* that circulates in terrestrial animals in this region. However, this has not yet been formally proven, as *Brucella ceti* and *B. pinnipedialis* infect marine mammals, and antibodies to the *Brucella* species that contain “smooth” lipopolysaccharide (LPS), cannot be distinguished with the current serological tests. Both *B. suis* and the species infecting marine mammals belong to this group.

Biovar 5 has only been described in wild rodents.

Zoonotic potential

B. suis biovars 1-4 are zoonotic. Biovar 5 has not been documented in people, as of 2018.

Geographic Distribution

B. suis is common among domesticated pigs in parts of Latin America and Asia. Control programs have eliminated or nearly eliminated this organism in some other areas, including a number of European nations, the U.S., Canada and Australia. However, *B. suis* is still maintained in feral pigs or wild boar in many of these regions, resulting in sporadic transmission to domesticated swine. Infected pigs have occasionally been documented in some African nations, but surveillance there is limited. Biovars 1 and 3 of *B. suis* occur worldwide, but biovar 2 appears to be limited to Europe, where it primarily circulates in wild boar.

Biovar 4 (rangiferine brucellosis) circulates in the Arctic regions of North America and Eurasia where its reservoir hosts are found (e.g., Siberia, Canada and Alaska).

Transmission

Most domesticated pigs are thought to acquire *B. suis* when they ingest feed or water contaminated by birth products (e.g., fetus, placenta, fetal fluids) or vaginal discharges from an infected sow, or eat dead fetuses and fetal membranes. Pigs also shed this organism in milk, urine and semen. Both symptomatic and asymptomatic boars can excrete bacteria, and venereal transmission is thought to be common in swine. Piglets can be infected during nursing or *in utero*. Some of these young animals may become seronegative carriers. In ruminants, latent carriers of *Brucella* usually become detectable after the first pregnancy, but it is not clear whether this is also true in swine. Pigs may sometimes acquire *B. suis* by inhalation, through the conjunctiva or via broken skin, but these routes seem to be of minimal epidemiological significance. Many animals seem to become chronically infected. Transmission of *B. suis* biovar 2 in wild boar, where this organism has been detected in aborted fetuses and the testes, is probably similar. In reindeer and caribou, *B. suis* biovar 4 can be transmitted by contact with aborted fetuses and other birth products, but there is little information about the importance of other routes, such as venereal or milk-borne transmission.

Potential iatrogenic sources of brucellae in livestock include contaminated syringes. There is no evidence that arthropods play any role in the epidemiology of brucellosis;

however, some species of *Brucella* have been detected in blood-sucking arthropods such as ticks, *B. abortus* has been transmitted to guinea pigs via tick bites in the laboratory, and transovarial transmission of *B. melitensis* was reported in ticks.

Other species can be infected with *B. suis* after contact with its maintenance hosts or their tissues, and seem to shed this organism by similar routes. Porcine biovars of *B. suis* can become established in the mammary gland of ruminants and are subsequently found in the milk. Colonization may occur during a systemic infection, or organisms can enter the mammary gland from the environment, via the teats. Some experimentally infected cattle shed this organism in milk for at least 2 years. Although most recent *B. suis* infections in hunting dogs occurred after direct contact with wild pigs or their tissues, dog-to-dog transmission was suspected in a few cases. Some young dogs might have been infected from the dam around the time of birth. *B. suis* has also been found in canine testes, salivary gland and kidneys.

Humans usually become infected by ingesting organisms or via contaminated mucous membranes (including the conjunctiva and respiratory tract) and abraded skin. *B. suis* can be transmitted to people in unpasteurized milk products from reindeer or other infected animals, including cattle. Some biovar 4 infections have been associated with uncooked caribou bone marrow, which is a regional delicacy. Routes implicated in rare instances of person-to-person transmission of brucellae include blood transfusion, bone marrow transplantation, exposure to contaminated material while assisting at a delivery, sexual intercourse and nursing (infants). There is no indication that members of the genus *Brucella* are transmitted between people by casual contact under ordinary conditions.

Brucella spp. have been reported to survive in the environment 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 can remain viable for several months in water, aborted fetuses, manure, wool, hay and other materials. They can withstand drying, particularly when organic material is present, and can survive in dust and soil. Survival times of years have been reported in frozen meat.

Disinfection

Brucella spp. are readily killed by most commonly available disinfectants including hypochlorite solutions, 70% ethanol, isopropanol, iodophors, phenolic disinfectants, formaldehyde, glutaraldehyde and xylene. A 1% solution of citric acid was reported to be less effective. One study reported that xylene and calcium cyanamide decontaminated liquid manure after 2 to 4 weeks; however, some sources recommend storing such treated manure for

much longer. 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 period between infection and the development of reproductive signs is variable. Abortions have been seen as soon as 17 days after pigs were mated with infected boars.

Clinical Signs

Porcine brucellosis: biovars 1, 2 and 3

In pigs, the most common clinical signs are reproductive losses, which may include abortions, stillbirths, the birth of weak piglets (which may die early in life) and decreased litter size. Although abortions have been reported to occur at any time during gestation, they are noted to be most common in mid- to late gestation. Because fetuses may be cannibalized and vaginal discharge is often minimal, abortions can be mistaken for infertility. Pigs may not abort if some live fetuses are still present. Fetal losses early in gestation usually appear as a return to estrus 30-45 days after mating. Uncomplicated abortions are not usually accompanied by signs of illness; however, some cases may be complicated by retention of the placenta and secondary metritis. Epididymitis and orchitis are sometimes seen in males, and may result in infertility. Pigs that are not pregnant may remain asymptomatic; however, they sometimes become lame from arthritis, develop posterior paralysis from spondylitis, or have various complications related to abscess formation in other tissues and organs. While overt clinical signs occur in some herds, chronically infected herds may only have subtle signs such as nonspecific infertility, a slightly reduced farrowing rate, and irregular estrus cycles. Deaths are rare except in the fetus or newborn. Relatively little is known about the effects of *B. suis* biovar 2 on wild boar, but it has occasionally been implicated in abortions, metritis and orchitis.

In horses *B. suis* can cause inflammation of the supraspinous or supra-atlantal bursa; these syndromes are known, respectively, as fistulous withers or poll evil. The bursal sac becomes distended by a clear, viscous, straw-colored exudate and develops a thickened wall. It can rupture, leading to secondary infection. In chronic cases, nearby ligaments and the dorsal vertebral spines are also involved and may occasionally become necrotic. *Brucella*-associated abortions have been reported in horses, but seem to be uncommon.

Clinical signs typical of canine brucellosis, as well as subclinical infections, have been reported in dogs infected

with *B. suis*. The signs and syndromes have included nonspecific signs of illness, such as fever, lethargy and vomiting, as well as discospondylitis, lameness, orchitis, epididymitis, enlargement of the prostate, hematuria and abortion. Systemic signs are not necessarily observed in localized infections. Naturally-acquired and experimental infections in cattle generally suggest that *B. suis* infections are asymptomatic in this species, even in pregnant animals. One study found that this organism might be associated with an increased incidence of retained placentas in cattle, but further study is needed. Rabbits that were inoculated with a biovar 1 isolate from hares developed nonspecific signs (malaise, anorexia) and conjunctivitis. Biovar 2 was found in a moribund, emaciated roe deer fawn with respiratory lesions and an enlarged spleen.

Rangiferine brucellosis: biovar 4

B. suis biovar 4 can cause reproductive losses in caribou and reindeer. Abortions may sometimes be complicated by retained placenta and metritis. Arthritis, tenosynovitis, hygromas, subcutaneous abscesses, mastitis and nephritis have also been reported, and males can develop orchitis, epididymitis and seminal vasculitis. Only a few clinical cases caused by biovar 4 have been described in other species: bone abscesses, joint involvement and testicular lesions were reported in naturally infected muskox, and carpal pathology and osteomyelitis were documented in an emaciated, debilitated moose. An experimentally infected moose developed septicemia, with nonspecific signs of anorexia, fever and depression. Experimental infection of bison with biovar 4 did not result in abortions or other clinical signs.

Post Mortem Lesions [Click to view images](#)

Aborted fetuses may appear normal, be autolyzed, or have evidence of a generalized bacterial infection, such as excess serohemorrhagic fluid in the body cavities and subcutaneous tissues. The placenta may be edematous and hyperemic.

Abscesses, granulomas, other purulent or inflammatory lesions, or calcified foci may be found in the testes and accessory sex organs of boars, particularly the epididymis and seminal vesicles. The tunica vaginalis may have hemorrhages or exudates, and it may be thickened, with fibrosis and adhesions. The lesions tend to be unilateral. In chronic cases, the testes may be atrophied. Nodules, abscesses and exudates are sometimes detected in the gravid or non-gravid uterus. Miliary uterine brucellosis, which is characterized by numerous small, pale yellow nodules containing caseous exudate, has been described in some pigs. The nodules may coalesce into plaques. Some pigs also have small erythematous granulomas on the surface of the uterus. Abscesses and other purulent lesions can sometimes be found in other organs and tissues, particularly the lymph nodes, spleen, liver, kidneys, joints, tendon sheaths, bones, mammary gland and urinary bladder. Lesions also occur occasionally in the brain.

Hares infected with *B. suis* biovar 2 had granulomatous nodules of varying sizes, often with central necrosis, in internal organs. These nodules were especially common in the reproductive organs, spleen and liver, but they were also found in the lungs, kidney and other internal organs, and in the skin and subcutaneous tissues. Some hares with internal lesions appeared to be in good body condition. Similar lesions were reported in rabbits experimentally infected with a biovar 1 isolate. A roe deer fawn infected with biovar 2 was emaciated and had fibrinous pleuritis, lung atelectasis and an enlarged spleen.

Little information has been published recently about the pathology of *B. suis* in reindeer and caribou, but the lesions are probably similar to those in other species.

Diagnostic Tests

B. suis may be detected by microscopic examination of stained smears from tissues, secretions and exudates (e.g., the placenta, vaginal swabs, aborted fetuses or lymph nodes), using modified Ziehl-Neelsen (Stamp) staining. Brucellae are not truly acid-fast, but they are resistant to decolorization by weak acids. They appear as coccobacilli or short rods, usually arranged singly but sometimes in pairs or small groups. Other organisms can resemble *Brucella*. If available, immunostaining may be helpful. Definitive diagnosis requires culture and/or the detection of nucleic acids by PCR or other genetic techniques.

B. suis may be isolated from aborted fetuses (tissues such as the stomach contents, spleen and lung), the placenta, vaginal swabs, semen, the testis or epididymis, and sites of clinical localization such as infected joints. At necropsy, recommended tissues in pigs have included lymph nodes (e.g., those associated with the head, mammary gland and genital tract), the late pregnant or early post-parturient uterus, udder and spleen. Organisms may also be found in the male reproductive tract (testes, epididymis, vesicular glands, prostate and bulbourethral glands), liver, kidney and any tissues with lesions, such as bones. *B. suis* can be cultured on a variety of nonselective media, or on selective media such as Farrell's, Thayer-Martin's or CITA medium. Enrichment techniques can also be employed. Some isolates may not grow readily on certain media, and the use of more than one type is often recommended. Biovar 2 is reported to be more difficult to isolate on selective media than biovars 1 and 3. Some commercial bacterial identification systems can misidentify *Brucella* as another organism. Treatment with antibiotics or bacterial overgrowth in nonsterile samples can interfere with culture. *B. suis* can also be isolated by inoculation into guinea pigs or mice, but this is rarely done.

B. suis 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 often done at reference laboratories, as it is complicated by the high genetic similarity between brucellae and the possibility of

ambiguous phenotypic tests. *B. suis* and *B. canis* are particularly difficult to distinguish with genetic methods. Most PCR tests only identify *Brucella* to the genus level, but multiplex PCR assays that can specifically identify *B. suis* and distinguish it from other brucellae (e.g., the Bruce-ladder assay) can be used for species identification. Other tests that can be employed for species identification, such as single nucleotide polymorphism (SNP) typing and matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS), have been described. Techniques such as multiple-locus variable number tandem repeat analysis (MLVA) can be used in epidemiological investigations of outbreaks.

Brucella PCR tests are mainly used to identify organisms in culture; however, some laboratories may use these tests directly on clinical samples. A few PCR tests that can specifically identify *B. suis* have been published, but they do not seem to have been extensively evaluated. Antigen detection techniques, such as immunohistochemistry, are sometimes employed in research, but they are not usually used to diagnose porcine brucellosis. An immunohistochemical method for diagnosing *B. suis* infections in European hares has been published.

Serology can help identify infected herds of swine, but it is not considered to be reliable in individual animals. Some serological tests employed in pigs include indirect or competitive ELISAs, the buffered *Brucella* antigen tests (rose bengal test and buffered plate agglutination test), complement fixation and the fluorescence polarization assay. Interactions between pig and guinea pig complement can reduce the sensitivity of the complement fixation test in swine. Low agglutinin titers can be seen in most herds, even if they are not infected. Serological tests can cross-react with other bacteria such as *Escherichia coli* O:157, *Salmonella* and *Yersinia enterocolitica* O:9. Reactivity to *Y. enterocolitica* O:9 is relatively common in pigs, and it is particularly difficult to distinguish from antibody reactions to *Brucella*. A few infected pigs do not have a detectable titer to *B. suis*. Serological tests cannot distinguish reactions to any of *Brucella* species that have "smooth" LPS in the cell wall, which include *B. suis*, *B. melitensis*, and *B. abortus*.

A brucellin skin test has been used to help identify infected herds of pigs in some countries. This test is performed by injecting the allergen intradermally at the base of the ear. Skin tests are not sensitive enough to detect infections in individual animals.

Similar tests are used to diagnose *B. suis* infections in species other than pigs, but each test must be validated for that species. Agglutination tests and complement fixation have been employed in reindeer and caribou. A combination of the rose bengal test and complement fixation has been recommended for detecting *B. suis* antibodies in dogs in Australia. Agglutination tests have also been used in dogs.

Treatment

Antibiotics may mitigate the clinical signs or clear *B. suis* from an animal, but this organism might persist in treated animals, and recrudescence is possible. For this reason, euthanasia of infected animals is often recommended. Some *B. suis*-infected dogs have been treated successfully with a combination of antibiotics, such as rifampicin and doxycycline. Isolating dogs is advised during treatment, and neutering is recommended if the animal is intact. Periodic serological monitoring might be able to detect rising antibody titers if organisms persist and begin to replicate again in treated animals.

Treatment of livestock is generally discouraged due to the zoonotic risks, and it may also not be cost-effective. One study reported that a combination of oxytetracycline and tildipirosin appeared to clear *B. suis* from pigs, though further research is needed. Oxytetracycline alone temporarily suppressed clinical signs in an experimental herd, but abortions and transmission of the organism increased once antibiotic use ended.

Control

Disease reporting

Veterinarians who encounter or suspect brucellosis should follow their national and/or local guidelines for disease reporting. Brucellosis caused by *B. suis* is a notifiable disease in the U.S. All cases should be reported immediately to state or federal authorities.

Prevention

B. suis is usually introduced into a herd in an infected animal. *B. suis*-free herds should not be allowed to contact potentially infected animals, including wild and feral swine, or contaminated environments, such as those where animals recently aborted. Good biosecurity and double fencing have been used to protect pigs raised outdoors; however, some herds in Europe have apparently been infected from environmental sources despite these measures. If possible, replacement stock should be selected from *Brucella*-free herds. Herd additions should be quarantined and tested before being released into the herd. Some asymptotically infected animals may be difficult to detect with the current tests. Semen for artificial insemination should only be collected from *Brucella*-negative animals that are tested regularly.

In an infected herd, the placenta, any abortion products and contaminated bedding should be removed promptly and destroyed, and contaminated fomites should be disinfected. *B. suis* can be eradicated from infected herds by depopulation or test and removal methods. Programs to eradicate this organism from a country also include movement controls on infected herds, surveillance, and tracing of infected animals. There is no vaccine for swine brucellosis in most countries, and the RB51 and strain 19 *B. abortus* vaccines do not seem to protect cattle from infection by *B. suis*. A *B.*

suis strain 2 vaccine has been used to immunize pigs and other animals in China, but its efficacy is unclear and it has not gained acceptance elsewhere.

Infections in other species are generally prevented by controlling *B. suis* in its maintenance hosts and avoiding contact with potentially infected animals. Dogs should not be fed raw tissues from domesticated or wild swine, caribou, reindeer, hares or other wild animals that may carry *B. suis*.

Morbidity and Mortality

Porcine brucellosis remains a significant issue in pigs in parts of Asia and Latin America, but the prevalence of *B. suis* in livestock has become very low in some other regions. Even where control programs have virtually eliminated this organism from commercial herds, however, pigs still become infected occasionally from wild and feral swine. The risk is higher in pigs kept outdoors. *B. suis* prevalence in feral pigs can vary significantly between regions. Animal density was reported to influence the prevalence of biovar 2 in wild boars in some studies, but not others. Hares have been implicated occasionally in transmitting biovar 2 to domesticated animals.

When it is introduced into a herd of pigs, *B. suis* can spread quickly to infect more than 50% and often up to 70-80% of the herd. There may be a significant increase in returns to service and overt clinical signs, and the pre-weaning mortality rate usually increases. Morbidity can be highly variable, but in some cases, reproductive losses may reach 80%. Once this organism has become established in a herd, brucellosis may appear only as nonspecific infertility, a slightly reduced farrowing rate, and irregular estrus cycles. Deaths are rare except in the fetus and newborn. Natural resistance to *B. suis* has been reported in some breeds of experimentally infected pigs. There is little information about the effects of *B. suis* on wild and feral pigs, but the incidence of reproductive losses is thought to be lower than in domesticated pigs. In one endemically infected wild boar population, biovar 2 did not seem to have a significant effect on rates of reproduction.

B. suis has emerged as a significant pathogen among dogs in Australia, where more than 70 cases have been documented since 2011. Most infections occurred in dogs that participated in pig hunting or were fed raw pig meat. A few sick dogs had been exposed to infected dogs but not directly to pigs; however, investigations of dogs in contact with canine cases suggest the overall risk of dog-to-dog transmission is low. Approximately 40% of the known infections were asymptomatic. *B. suis* has also been identified in dogs in parts of South America, where it may be relatively common in this species, and in the U.S., Europe and other locations.

Infections in Humans

Incubation Period

The acute symptoms of brucellosis often appear within 2-4 weeks, but the onset can be insidious, and some cases have been diagnosed as late as 6 months after exposure.

Clinical Signs

The consequences of infection with *B. suis* 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, particularly 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. Elevations in the liver enzyme alanine aminotransferase (ALT), with only mild increases in aspartate aminotransferase and no unusual liver pathology, were reported to be common in people infected with *B. suis* on 2 islands in Polynesia. 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.

Diagnostic Tests

B. suis may be cultured from blood or clinical samples from affected organs, as in animals. It is more likely to be recovered from bone marrow than blood; however, collection of bone marrow samples is more difficult, and this is generally reserved for people with suspected brucellosis who cannot be diagnosed by other means. *B. suis* cannot always be isolated, especially in chronic cases.

PCR is sometimes used to detect nucleic acids in clinical samples.

Clinical cases in people are often diagnosed by serology. Serological tests used for screening or confirmation include the rose bengal test, serum tube agglutination test (SAT) with or without 2-ME or DTT, the microagglutination test, Coombs test, BrucellaCapt® (a commercial immunocapture agglutination test), latex agglutination tests, ELISAs, complement fixation and others. A universal indirect ELISA that can recognize antibodies to both smooth and rough *Brucella* was recently published. A fourfold rise in titer is definitive in serological tests, but it may not be seen by the time some cases are diagnosed. Cerebrospinal fluid is also tested for antibodies in cases with neurological involvement. Cross-reactivity with other microorganisms (e.g., *Y. enterocolitica* O:9, *Salmonella urbana* group N, *Leptospira* sp., *Vibrio cholerae*, *Francisella tularensis*, *E. coli* O157, *Stenotrophomonas maltophilia*) can be an issue, especially in agglutination tests.

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

Human exposure can be reduced by controlling brucellosis in pigs and other livestock. Pasteurization is recommended to destroy *B. suis* in milk products. The fermentation time necessary to ensure safety in ripened, fermented cheeses made from unpasteurized milk is unknown, but it has been estimated to be approximately 3 months. The World Health Organization (WHO) recommends storing soft cheeses > 6 months if they were made from unpasteurized milk. Meat, blood and internal organs from animals should be handled carefully and cooked thoroughly.

Good hygiene, together with personal protective equipment (e.g., gloves, face/ eye protection, protective clothing, respirators, as appropriate) can decrease human exposure, especially during births and abortions or when large numbers of animals are shedding organisms in a concentrated area. Wounds should be covered. Particular care should be taken during activities that may aerosolize organisms (e.g., pressure washing, sawing into infected tissues). Detailed precautionary measures for specific settings such as contaminated farms, abattoirs and laboratories have been published by sources such as the World Health Organization. Precautions should be used

when butchering or field dressing potentially infected carcasses of wildlife and feral pigs, as well as when handling domesticated animals or their tissues.

Prophylactic antibiotics and/or monitoring may be offered to laboratory workers who have been exposed to *B. suis*. A few countries have employed brucellosis vaccines for humans; however, commercial vaccines that meet international quality standards are not currently available.

Morbidity and Mortality

Brucellosis can affect all ages, including children. It is often an occupational disease among people in contact with pigs, reindeer or their tissues, such as farmers, butchers, abattoir workers, veterinarians and laboratory personnel. In the Arctic, some groups' tradition of eating raw bone marrow and internal organs from freshly killed caribou contributes to the risk of brucellosis. The consumption of unpasteurized dairy products (including milk from cattle or small ruminants) also increases the risk of infection. In Australia, biovar 1 has been responsible for a number of cases of brucellosis in feral pig hunters. Occasional cases are also reported among hunters in the U.S. and other areas. The incidence of human brucellosis varies widely. Typically, < 1 case per 100,000 population is reported in developed countries where this disease has been eradicated from animals and most infections occur in travelers or immigrants. Rates from 10 to more than 100 cases per 100,000 population have been documented where brucellosis is more common in animals; however, a high proportion of these cases are thought to be caused by *B. melitensis*. The prevalence was 19 cases per 100,000 population in two Polynesian islands where *B. suis* is common in pigs but other species of *Brucella* are absent. Many human infections with brucellae are thought to be missed.

B. suis biovars 1 and 3 can cause mild to severe illnesses. Some sources suggest that *B. suis* is more virulent for humans than *B. abortus*; however, most of this information is based on old studies from the 1940s and 1950s. One recent case series found that the complication rate and clinical presentation were roughly similar to cases caused by other species of *Brucella*. Estimates of the case fatality rate for untreated brucellosis are usually in the range of 1-2% or less, although rates as high as 5% have been reported in smaller series.

Biovar 2 infections have been reported infrequently in people, and many of these patients have had chronic illnesses and/or immunosuppressive conditions. However, illnesses caused by biovar 2 have been documented in a few healthy people. To date the clinical conditions resembled brucellosis caused by other brucellae. One recent report from France suggests that biovar 2 infections may be underdiagnosed.

Internet Resources

Alaska Native Tribal Consortium. Center for Climate and Health. Factsheets for the Public on Rangiferine Brucellosis http://www.anthctoday.org/community/climate_health.html

Centers for Disease Control and Prevention (CDC). Brucellosis <http://www.cdc.gov/brucellosis/>

CDC. Brucellosis reference guide. Exposures, testing and prevention <https://www.cdc.gov/brucellosis/pdf/brucellosis-reference-guide.pdf>

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* Link is defunct