Zoonotic Streptococcosis

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Importance

Members of the genus *Streptococcus* cause mild to severe bacterial illnesses in humans and animals. These organisms typically colonize one or more species as commensals, and can cause opportunistic infections in those hosts. However, they are not completely host-specific, and some animal-associated streptococci can be found occasionally in humans. Many zoonotic cases are sporadic, but organisms such as *S. equi* subsp. *zooepidemicus* or a fish-associated strain of *S. agalactiae* have caused outbreaks, and *S. suis*, which is normally carried in pigs, has emerged as a significant agent of streptoccocal meningitis, septicemia, toxic shock-like syndrome and other human illnesses, especially in parts of Asia. Streptococci with human reservoirs, such as *S. pyogenes* or *S. pneumoniae*, can likewise be transmitted occasionally to animals. These reverse zoonoses may cause human illness if an infected animal, such as a cow with an udder colonized by *S. pyogenes,* transmits the organism back to people. Occasionally, their presence in an animal may interfere with control efforts directed at humans. For instance, recurrent streptococcal pharyngitis in one family was cured only when the family dog, which was also colonized asymptomatically with *S. pyogenes*, was treated concurrently with all family members.

Etiology

There are several dozen recognized species in the genus *Streptococcus*, Gram positive cocci in the family Streptococcaceae. Almost all species of mammals and birds, as well as many poikilotherms, carry one or more species as commensals on skin or mucosa. These organisms can act as facultative pathogens, often in the carrier.

Nomenclature and identification of streptococci

Hemolytic reactions on blood agar and Lancefield groups are useful in distinguishing members of the genus *Streptococcus*. In clinical laboratories, an isolate may be reported only to this level (e.g., 'group C streptococcus'), without identifying its species. Many acute streptococcal diseases are caused by beta-hemolytic streptococci, which completely lyse the red blood cells surrounding the colony. Alpha-hemolytic organisms cause a partial or "greening" hemolysis, associated with the reduction of red cell hemoglobin. A third group is not hemolytic, a characteristic sometimes termed gamma-hemolysis. Because it is often of little value to distinguish alpha-hemolysis from gamma- hemolysis, the latter two groups may simply be called non-beta-hemolytic.

Lancefield grouping is based on the serological identification of cell wall antigens and, in group B streptococci, capsular antigens. The 20 Lancefield serogroups are identified with the letters A to H and K to V. Some species of *Streptococcus* have no traditional Lancefield group antigens. Each Lancefield group can contain more than one streptococcal species, and the members of some species can belong to more than one Lancefield group. However, sometimes a single pathogenic species predominates in a Lancefield group, which has become nearly synonymous with that organism. For instance, *S. pyogenes* is, by far, the most common beta-hemolytic group A streptococcus in humans, and 'group A streptococcus' generally indicates this organism. Likewise, group B streptococcus is often used as a synonym for *S. agalactiae* in people or animals, though there are minor beta-hemolytic group B streptococci, such as *S. troglodytidis.*

Zoonotic species of Streptococcus

Most streptococcal illnesses in people are caused by species normally maintained in humans, such as *S. pneumoniae*, *S. pyogenes* or human-adapted strains of *S. agalactiae*. As of 2020, zoonotic streptococci documented in people include *S. canis* (Lancefield group G; beta-hemolytic), *S. dysgalactiae* subsp. *dysgalactiae* (Lancefield groups C and L; alpha-hemolytic, beta-hemolytic or nonhemolytic), *S. equi* subsp. *zooepidemicus* (Lancefield group C; beta-hemolytic), *S. halichoeri* (Lancefield group B; non-hemolytic), *S. iniae* (no Lancefield group antigens; beta-hemolytic), *S. suis* (Lancefield group D-related; non-beta-hemolytic) and some animal-associated genotypes of *S. agalactiae* (Lancefield group B; mostly beta-hemolytic). Other organisms have also been proposed as zoonotic (e.g., *S. porcinus*, animal-adapted

S. gallolyticus subsp. *gallolyticus*), and it is possible that many animal streptococci might be able to infect humans under some circumstances.

S. suis has at least 35 serotypes. A limited number of serotypes, such as 2, 3, 7 and 9, seem to cause most illnesses in pigs. Serotype 2 is found most often in human cases, but other organisms, including serotypes 5 and 14, have also been isolated. Certain genetically divergent *S. suis* isolates are referred to as *S. suis*-like, and new names (*S. orisratti*, *S. parasuis*, *S. ruminantium*) have been proposed for some of them.

Reverse Zoonoses

Organisms maintained in people, including *S. pyogenes*, *S. pneumoniae* and human-adapted genotypes of *S. agalactiae*, are isolated occasionally from asymptomatic or sick animals (reverse zoonoses). They can be transmitted back to people from this source, and can sometimes spread between animals.

Species Affected

Streptococcus agalactiae

Cattle are important reservoir hosts for *S. agalactiae*. This organism is also common in dromedary camels. There are reports of *S. agalactiae* or group B streptococcus in many other species such as small ruminants, llamas, horses, pigs, dogs, cats, rabbits, rodents (including guinea pigs), marine mammals (dolphins, seals), fish, reptiles (crocodiles, snakes, emerald monitors) and frogs. Some organisms, including those in sick crocodiles and farmed frogs, were thought to have come from humans.

Fish-associated *S. agalactiae* are most often reported in farmed freshwater and marine fish, but they have been found in free-living fish. Some of these organisms might come from people. The ST283 genotype of *S. agalactiae*, which has repeatedly caused human illnesses, seems to be maintained in fish. However, its reservoir has not yet been definitely identified, and it is possible that this organism is transferred from humans to fish (e.g., in sewage), or that another source is the actual reservoir.

Streptococcus canis

S. canis is usually found in dogs and cats, but it has been detected occasionally in other animals including cattle, horses, mink, foxes, rodents and rabbits.

Streptococcus dysgalactiae subsp. dysgalactiae

S. dysgalactiae subsp. *dysgalactiae* is most common in cattle, but it can also infect small ruminants, pigs, dogs, horses, vampire bats (*Desmodus rotundus*) and other hosts.

Streptococcus equi subsp. zooepidemicus

S. equi subsp. *zooepidemicus* is a common commensal and opportunistic pathogen in horses. Guinea pigs, pigs and monkeys also seem to be carriers, and it has been isolated from many other species including horses, cattle, sheep, goats, pigs, South American camelids, dogs and other canids, cats and other felids, ferrets, guinea pigs, non-human primates, seals and birds.

Streptococcus halichoeri

S. halichoeri seems to mostly occur in marine environments. It was originally found in grey seals (*Halichoerus grypus*) but it has been isolated from other marine mammals (e.g., a Steller sea lion, *Eumetopias jubatus*) and fish (herring). Reports from terrestrial species include cases in a European badger (*Meles meles*) and dogs. This organism infected captive mink (*Neovison vison*), blue foxes (*Vulpes lagopus*) and raccoon dogs (*Nyctereutes procyonoides*) during an outbreak that might have originated from fish in their diet. The source of the organism for other terrestrial hosts is uncertain.

Streptococcus iniae

S. iniae mainly seems to be a fish pathogen. Infections have been reported in more than 20 species of wild and farmed fish including rainbow trout (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), tilapia (*Oreochromis* spp.), yellowtail (*Seriola quinqueradiata*), red drum (*Sciaenops occellatus*), bass and European seabream; however, some species including common carp (*Cyprinus carpus),* Channel catfish (*Ictalurus punctatus*) and goldfish (*Carassius auratus*) seem to be resistant.

S. iniae has also caused clinical cases in captive Amazon freshwater dolphins (*Inia geoffrensis*) and a captive bottlenose dolphin (*Tursiops truncatus*). It was found in a group of sick bullfrogs (*Rana castesbeiana*) that suffered from recurrent bacterial infections, as well as in fruit bats (*Pteropus alecto*). Experimental infections were established in laboratory mice.

Streptococcus suis

S. suis is mainly a pathogen of suids, and is maintained in both domestic pigs and wild boar. It has been isolated occasionally from other species such as cattle, sheep, goats, bison, cats, dogs and horses, and appears to be common in some groups of wild rabbits (*Oryctolagus cuniculus*) in Europe and chickens in Vietnam. Rabbits and chickens seem to carry different *S. suis* genotypes than pigs.

Geographic Distribution

The organisms maintained in domestic animals - *S. canis*, *S. dysgalactiae* subsp. *dysgalactiae*, *S. equi* subsp. *zooepidemicus*, *S. suis* and mammalian *S. agalactiae* - are widespread and probably exist wherever their usual hosts can be found. The predominant serotypes of *S. suis* differ between regions, which may influence the incidence of disease in pigs and humans.

S. iniae has, to date, mainly been reported in North America, the Caribbean, parts of Asia (e.g., Japan, China, Singapore, Taiwan), Australia and the Middle East. *S. halichoeri* has been documented in parts of Europe and South Korea, and might also be widespread. *S. agalactiae* ST283 seems to occur mainly in Asia but was recently identified in farmed fish in South America.

Transmission

Members of the genus *Streptococcus* occasionally act as primary pathogens, but more often they are part of the normal flora of animals and humans, typically on the upper respiratory tract, urogenital tract or other mucous membranes, mammary gland or skin. These organisms sometimes cause opportunistic infections, often in the carrier, but their transmission between hosts does not necessarily result in disease.

Streptococci are often transmitted during close contact, but aerosols may occasionally play a role, and some organisms have been acquired in undercooked pork products (e.g., *S. suis*, *S. equi* subsp. *zooepidemicus*), horsemeat (*S. equi* subsp. *zooepidemicus)* or fish (*S. agalactiae* ST283 and probably *S. halichoer*i) or unpasteurized dairy products (*S. equi* subsp. *zooepidemicus* and other organisms). *S. iniae* often seems to infect humans through skin abrasions and punctures while they are cleaning fish. How it spreads between fish is incompletely understood; however, they can be infected either orally or via exposure to contaminated water baths, with or without abrasions, in the laboratory. Organisms that become established in wounds can disseminate to internal organs.

Streptococci can be transmitted on fomites, and they may persist for a few days to months in the environment, especially in organic material under moist, cool conditions. At 25°C (77°F), *S. suis* remained viable for about a week in pig feces and for almost 2 weeks in decomposing carcasses, but for less than a day in dust. At 4°C (39°F), it persisted in carcasses for 6 weeks and in dust or feces for a few months.

Disinfection

Streptococci are readily killed by detergents and common disinfectants. Some agents reported to be effective include 1% sodium hypochlorite, 70% ethanol, 2% peracetic acid, 3-6% hydrogen peroxide, quaternary ammonium compounds, phenolics, formaldehyde, glutaraldehyde and iodine-based disinfectants.

Infections in Animals

Incubation Period

The incubation period varies with the condition. Some streptococcal infections become apparent within a few days to a week or more, while toxic shock-like syndrome can develop into a serious illness within hours.

Clinical Signs

Streptococcus agalactiae

S. agalactiae is a common cause of subclinical mastitis in cattle. In some regions, it also seems to be fairly common in clinical or subclinical mastitis in sheep and goats, and it has been found in numerous diseases in camels ranging from skin and soft tissue infections to mastitis and caseous lymphadenitis. In China, this organism was responsible for a severe, life-threatening illness in rabbits characterized by fever, acute respiratory distress, paddling and convulsions. *S. agalactiae* has also been detected in mastitis in horses, an abscess in a llama, endocarditis in a dog, neonatal septicemia and other illnesses in dogs and cats, necrotizing fasciitis in crocodiles, and other conditions.

Streptococcus canis

S. canis is an opportunistic pathogen that mainly affects dogs and cats. It can cause a variety of diseases including skin and soft tissue infections, arthritis, reproductive disease, mastitis, pneumonia, septicemia and streptococcal toxic shock-like syndrome, as well as cervical lymphadenitis in 3-6 month old kittens and otitis externa in dogs. In cats, this organism sometimes causes neonatal septicemia. Affected kittens appear normal at birth but gain weight slowly and usually die when they are around 7-11 days of age. Death is often preceded by a transient fever, and some animals may have a swollen, infected umbilicus. More than one kitten in a litter can be affected but the whole litter does not usually become sick.

Streptococcal toxic shock-like syndrome, which can affect both dogs and cats, is a severe, febrile illness characterized by an acute onset, rapid progression and high mortality rate. Its clinical signs in dogs may include extreme weakness, vomiting, a non-productive cough, stiffness, rigidity, rapid uncontrolled muscle fasciculations, intense pain, and hemorrhagic signs such as bloody sputum, epistaxis and bloody diarrhea. The time from the onset of clinical signs to death can be as short as 7 hours.

S. canis can cause illnesses in other species (e.g., cattle with mastitis), but this seems to be infrequent.

Streptococcus dysgalactiae subsp. dysgalactiae

S. dysgalactiae subsp. *dysgalactiae* is usually associated with clinical or subclinical mastitis in cattle, but it has been detected in other conditions in this species, including severe cellulitis and toxic shock-like syndrome. Some reports of *S. dysgalactiae* subsp. *dysgalactiae* in other hosts described mastitis in sheep and goats, suppurative polyarthritis in lambs, septicemia in fish and dogs, and septicemia and encephalitis in vampire bats.

Streptococcus equi subsp. zooepidemicus

S. equi subsp. *zooepidemicus* can affect many species, often as an opportunistic pathogen.

In horses, this organism sometimes invades the upper respiratory mucosa and lymph nodes after a viral infection, and may mimic strangles. It can also cause lower respiratory disease including pleuropneumonia, especially in young horses. These respiratory infections are opportunistic; however, the ST209 genotype caused an epidemic of respiratory illness in Iceland, apparently as the primary pathogen. Affected horses developed a mucopurulent nasal discharge and dry cough, which sometimes persisted for weeks. Although mortality was overall low, a few animals died of pneumonia or sepsis. Some other conditions that can be caused by *S. equi* subsp. *zooepidemicus* in horses are skin and soft tissue infections (e.g., abscesses), mastitis, cervicitis, metritis, placentitis with abortions, and foal septicemia.

S. equi subsp. *zooepidemicus* is also an important pathogen in guinea pigs. Opportunistic infections can result in cervical lymphadenitis, which is characterized by draining abscesses in the cervical lymph nodes and occasionally other organs, and may progress to torticollis, pneumonia or septicemia in some animals. It can also cause small uterine abscesses, which may affect fertility, or epidemics of septicemia and acute pneumonia with high mortality rates.

This organism can cause various illnesses in dogs (e.g., septicemia, pneumonia, wound infections, streptococcal toxic shock-like syndrome), but it is particularly important as an agent of hemorrhagic pneumonia, either alone or with other respiratory pathogens. Hemorrhagic pneumonia may begin with nasal discharge, moist cough and fever, and can progress to depression, anorexia, tachypnea, and in many cases, hemorrhagic nasal discharge or hematemesis. Affected dogs often develop severe respiratory distress and deteriorate rapidly, commonly dying within 24-48 hours, though milder cases limited to nasal discharge and pharyngitis are possible. Some cases were identified after sudden death.

There are occasional reports of *S. equi* subsp. *zooepidemicus* in other animals. In 1994, this organism caused a serious epidemic among pigs in Indonesia and also spread to monkeys. Syndromes reported in affected animals included polyarthritis, bronchopneumonia, pleuritis, diarrhea, epicarditis, endocarditis and meningitis. Most sick animals died within a few days. Although the outbreak subsided, the organism continued to circulate in this area, including in healthy carriers. A similar outbreak occurred in pigs in China in 1975, and unrecognized cases might occur elsewhere. Other examples of illnesses caused by *S. equi* subsp. *zooepidemicus* are an outbreak of mastitis in sheep; abscesses, pneumonia, metritis and endocarditis in ferrets; septicemia in poultry and small mammals; and fatal meningoventriculitis in a captive snow leopard, possibly linked to feeding horsemeat.

Streptococcus halichoeri

S. halichoeri has caused wound infections and systemic illnesses in gray seals. This organism was detected in a postmortem sample from a decomposed Steller sea lion, but whether it had any role in the animal's death was uncertain. It was found concurrently with *Arcanobacterium phocae*, another marine organism, during a novel disease outbreak termed 'fur animal epidemic necrotic pyoderma' (FENP) affecting farmed mink, blue foxes and raccoon dogs in Finland. The contribution of *S. halichoeri* to this disease was uncertain, as the primary pathogen appeared to be *A. phocae*; however, *S. halichoeri* was found in other bacterial infections in these animals, including pneumonia, metritis, conjunctivitis and dermatitis, either alone or with other pathogens.

Additional reports of *S. halichoeri* in terrestrial mammals include a case of fatal pyogranulomatous pleuropneumonia and severe pericarditis in an injured wild European badger at a rehabilitation facility; a cerebral infection in a black bear; an outbreak of otitis media in dogs that responded poorly to standard treatment; and abscesses, postsurgical infections and other superficial infections in dogs. Mixed infections were common in the cases in dogs, but *S. halichoeri* was the sole agent in the badger.

Streptococcus iniae

S. iniae mainly seems to affect fish. Meningoencephalitis, panophthalmitis, skin lesions and necrotizing myositis are common syndromes in farmed fish. Wild tropical reef fish with *S. iniae* septicemia became moribund with only a few signs that included respiratory distress, occasional petechiae around the fins, and erratic swimming. In freshwater dolphins, this organism has been isolated from single or multiple subcutaneous abscesses, as well as a case of septicemia with encephalitis, subcutaneous abscesses and pneumonia.

Streptococcus suis

S. suis tends to cause sporadic cases of polyarthritis or peracute meningitis and septicemia in suckling pigs, or, more often, acute meningitis and other illnesses in recently weaned and growing animals. Pigs with meningitis may have subtle signs at first (squinting, ears back), followed by ataxia, unusual posture (e.g., dog sitting), blindness, nystagmus, convulsions and other neurological signs. Labyrinthitis, otitis interna and otitis media may lead to deafness and vestibular dysfunction. It can also cause other syndromes in pigs, such as endocarditis, myocarditis, abortions and abscesses.

S. suis can occasionally cause illnesses in other species, with reports of meningitis, arthritis, bronchopneumonia, peritonitis, abortion or septicemia in cattle; meningitis, pneumonia, guttural pouch infection or osteomyelitis in horses; pneumonia, meningoencephalitis or dermatitis in cats; endocarditis in a lamb; meningitis in bison; sudden death or urinary tract infection in dogs; and septicemia in birds. Some of these animals were coinfected with other pathogens but *S. suis* was the sole agent in others.

Post Mortem Lesions

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The gross lesions depend on the syndrome and tissues affected, and may include abscesses, cellulitis or skin lesions; signs of arthritis, osteomyelitis, endocarditis, mastitis, lower airway inflammation, pneumonia, pleuritis, enteritis and other conditions; and/or generalized signs of septicemia. Abortions are usually associated with placentitis. Hemorrhagic pneumonia and severe pleural effusion, often with blood-stained froth in the nasal cavity and airways, are the major lesions in dogs with hemorrhagic pneumonia caused by *S. equi* subsp. *zooepidemicus*. Intracranial edema and severe hemorrhagic panophthalmitis are reported to be the most consistent gross lesions in fish infected with *S. iniae*. Some fish may also have mild peritonitis, ascites, and scattered hemorrhages or petechiae in the body cavity and around the anal zone.

Common necropsy lesions in pigs infected with *S. suis* are patchy erythema of the skin, lymphadenopathy, enlargement of the spleen, arthritis with excessive clear or turbid fluid, and, in some cases, fibrinous polyserositis. The brain may look grossly normal in cases of meningitis, or there may be congestion, edema, and excess clear or cloudy CSF. The lungs are sometimes consolidated and may have signs of fibrinopurulent or interstitial bronchopneumonia.

Diagnostic Tests

A presumptive diagnosis of streptococcosis is supported by finding Gram positive cocci in pairs or chains in stained smears from affected tissues, exudates, blood or cerebrospinal fluid (CSF). Streptococcal toxic shock-like syndrome is usually identified by the clinical signs, though confirmed by bacterial isolation.

The definitive diagnosis is usually made by culturing the organism. Streptococci can be identified by their colony morphology, hemolysis patterns on blood agar, biochemical reactions and serology They can usually be distinguished from staphylococci with the catalase test (streptococci are catalase-negative); however, *S. halichoeri* can be weakly catalase-positive even on blood-free media. In the clinical laboratory, streptococci are often identified only to their Lancefield group. Serological methods (e.g., the capillary precipitation test) are traditionally used for Lancefield determination, but genetic techniques such as multiplex PCR can also be employed. The common beta-hemolytic streptococci can often be presumptively identified by their Lancefield group and a few phenotypic tests, but some streptococcal species can be difficult to recognize or may be confused with other organisms. Identification of non-beta-hemolytic streptococci tends to be more difficult.

PCR tests have been developed for some organisms including *S. equi* subsp. *zooepidemicus, S. canis, S. suis, S. dysgalactiae* and *S. iniae*, but how often these tests are used in clinical laboratories is unclear. Other genetic tests may occasionally be available, but are more likely to be employed in research. There are a few published antigen detection tests for pathogenic species, such as an immunofluorescent antibody test for fish infected with *S. iniae*, which is used with nasal swabs.

Treatment

Streptococcal illnesses are treated with antibiotics, especially beta-lactams, macrolides and quinolones. Additional measures, such as surgical debridement of necrotic tissues, may sometimes be necessary. Supportive treatment, administered quickly, is critical for streptococcal toxic shock-like syndrome.

Control

Disease reporting

Veterinarians who encounter or suspect a streptococcal infection should follow their national and/or local guidelines for reporting. Although these organisms are generally not reportable, there may be exceptions. State regulations should be consulted in the U.S.

Prevention

It can be difficult to prevent animals from becoming colonized asymptomatically with streptococci; however, stressors and other factors that predispose animals to illness (e.g., overgrown teeth in guinea pigs) should be minimized, wounds should be kept clean, and good hygiene including good milking technique should be practiced. Good water quality and decreased fish density may reduce the severity of outbreaks caused by *S. iniae* on fish farms.

S. equi subsp. *zooepidemicus* outbreaks in guinea pigs usually occur when sick animals are added to a healthy colony or naïve animals are mixed with asymptomatic carriers. Guinea pigs with enlarged cervical lymph nodes should be removed from the colony or treated until the abscesses have healed. Depopulation may be necessary in some colonies with widespread clinical signs.

All-in/all-out management of pigs, with cleaning and disinfection of the premises between groups, can be helpful against *S. suis*. In herds where this organism is an issue, pigs should be observed closely for signs of illness and treated promptly with antibiotics. Prophylactic antibiotics have also been employed, but there is a risk of generating antibiotic-resistant strains.

Vaccines are available for a few organisms. Killed autogenous or commercial *S. suis* vaccines for pigs may decrease the incidence of disease, but do not eliminate the infection from the herd. These vaccines are serotype-specific; universal vaccines against all variants of this organism are not currently available. Commercial vaccines are used for *S. iniae* in some regions, and autogenous vaccines for *S. equi* subsp. *zooepidemicus* were made at one time for guinea pigs (the availability of the latter vaccines is currently unclear).

Morbidity and Mortality

Streptococci are carried asymptomatically by a significant number of healthy animals, and typically cause opportunistic infections. However, some organisms can act as primary pathogens. They include the *S. equi* subsp. *zooepidemicus* strain associated with hemorrhagic pneumonia in dogs; the ST209 genotype of this organism that caused an epidemic of equine respiratory disease in Iceland in 2010; and probably the organisms that caused outbreaks among pigs in China and Indonesia in 1975 and 1994, respectively. Most outbreaks of hemorrhagic pneumonia in dogs occur in kennels, though sporadic cases are also seen.

Morbidity and mortality rates vary with the syndrome. *S. canis* can cause high mortality in newborn kittens when it first enters a cattery but this usually drops to less than 5% within a year unless the cats are immunosuppressed. Litters from young queens are affected most often. Mortality of 30-50% has been reported in outbreaks of *S. iniae* meningoencephalitis among farmed fish, and *S. agalactiae* caused 42% mortality in rabbits during an outbreak in China. Hemorrhagic pneumonia in dogs is frequently fatal. Deaths were uncommon during the equine respiratory disease epidemic caused by *S. equi* subsp. *zooepidemicus* ST209 in Iceland; however, morbidity was high, with this organism spreading to almost the entire population of 77,000 animals.

S. suis causes sporadic clinical cases in some herds of pigs, and outbreaks in others. Outbreaks seem to mainly occur in large, intensively managed herds. Newborn piglets may become infected with this organism during delivery or from the dam soon after birth, but most infections are spread between weaned pigs by asymptomatic carriers, resulting in the colonization of up to 60-100% of this age group. Whether pigs develop clinical signs is influenced by the serotype of *S. suis*, stressors such as poor ventilation and overcrowding, and the age of the pigs. About 2-15% of the herd is affected in most cases, but concurrent diseases or poor management can result in higher morbidity, occasionally > 50%. Mortality is usually around 5% but it may reach 20% in untreated animals.

Infections in Humans

Incubation Period

The incubation period varies with the form of the disease, but many infections can become apparent within a few days, and streptococcal toxic shock-like syndrome can appear and be fatal within hours.

Clinical Signs

Streptococcus spp. can cause many different illnesses in humans including skin and soft tissue infections (e.g., abscesses, cellulitis, pyoderma); streptococcal pharyngitis, pneumonia and other respiratory diseases; septic arthritis, osteomyelitis, endocarditis, meningitis and other localized infections of internal organs; and septicemia and streptococcal toxic shock-like syndrome. Sequelae of streptococcosis can include autoimmune phenomena, particularly poststreptococcal glomerulonephritis.

Zoonotic streptococci generally cause the same syndromes as organisms maintained in humans. *S. equi* subsp. *zooepidemicus*, in particular, has been isolated from a wide range of mild to severe illnesses, from skin infections to toxic shock syndrome and poststreptococcal glomerulonephritis. Foodborne outbreaks caused by this organism or *S. agalactiae* ST283 can result in serious illnesses such as pneumonia, meningitis, endocarditis, septic arthritis and acute nephritis. *S. canis* and *S. dysgalactiae* subsp. *dysgalactiae* also seem to cause a variety of syndromes. However, *S. iniae* is most often found in localized conditions, particularly cellulitis, though rare cases of osteomyelitis, septic arthritis, endocarditis, meningitis and other syndromes have been reported. *S. halichoeri* has been mainly recovered from skin and soft tissue infections or sinus infections, though there is at least one published report of sepsis.

S. suis is associated particularly with meningitis in parts of Asia. The neurological signs often appear after an initial transient illness that resembles influenza, and may include severe headache, vertigo, ataxia, a stiff neck and, in some cases, mental changes. Some patients also had a rash, ecchymoses, myalgia or joint pain. Some degree of hearing loss is common after recovery, and other sequelae, including arthritis, vertigo and endophthalmitis, have been reported. *S. suis* can also causes other illnesses in humans including endocarditis, pneumonia, septicemia, ocular disease, peritonitis and streptococcal toxic shock-like syndrome. The latter syndrome is characterized by the sudden onset of high fever, often accompanied by an erythematous blanching rash on the extremities, hypotension, diarrhea, petechiae, ecchymoses and multiorgan dysfunction, and can be fatal within hours.

Diagnostic Tests

Diagnosis of streptococcal infections in humans is similar to animals. However, zoonotic streptococci, particularly organisms such as S. *iniae*, are sometimes misidentified by human clinical laboratories and automated bacterial identification systems, and Gram stains of CSF in *S. suis* meningitis may initially suggest pneumococcal meningitis. PCR tests are sometimes used to identify *S. suis* in CSF. Most of these tests specifically recognize serotype 2 organisms, and a general PCR test for *S. suis* should be employed concurrently to detect cases caused by other serotypes.

Treatment

Streptococcal infections are treated with antibiotics, combined with supportive therapy as necessary. Most cases are treated with the same drugs used in animals, but agents usually reserved for humans, such as vancomycin, may be used occasionally.

Prevention

To help prevent skin and soft tissue infections, breaks in the skin should be kept from contact with animals or animal products, and wounds should be kept clean. Particular care should be taken when cleaning fish or butchering pigs. Avoidance of unpasteurized milk products, undercooked pork products or raw fish helps prevent foodborne illnesses caused by *S. equi* subsp. *zooepidemicus*, *S. suis* or *S. agalactiae* ST283, respectively. Protective clothing and gloves should be used when treating sick animals. Eye and respiratory protection may be warranted in some instances, such as when handling dogs with hemorrhagic pneumonia or during *S. suis* epidemics in regions where zoonotic serotypes are prevalent.

Morbidity and Mortality

Zoonotic species are infrequently detected in streptococcal illnesses in humans, but some organisms might be underdiagnosed. Many infections are sporadic, but outbreaks can occur after exposure to contaminated foods or infected animals.

Streptococcus agalactiae

Most infections caused by *S. agalactiae* are from strains carried in humans, but this organism also seems to be transmitted occasionally between cattle and people who work with these animals. Humans colonized with the latter organisms are often asymptomatic, but opportunistic infections may be possible. Clinical cases caused by the fish-associated ST283 genotype of *S. agalactiae* can occur sporadically or in outbreaks. One large outbreak was seen in Singapore in 2015, among people who ate a popular dish of raw fish, and affected healthy younger people as well as those who were elderly or immunocompromised. Post-harvest contamination might play a role in some fish-associated outbreaks: one study found that the prevalence of *S. agalactiae* in fish increased from 1% at port to 28% in markets.

Streptococcus canis and Streptococcus dysgalactiae subsp. dysgalactiae

Documented *S. canis* infections in humans are very rare, however, they could be underestimated, as many group G streptococcal infections are not identified further. Likewise, there are very few known human infections caused by *S. dysgalactiae* subsp. *dysgalactiae*, which was only recently recognized as zoonotic.

Streptococcus equi subsp. zooepidemicus

S. equi subsp. *zooepidemicus* is most often reported in immunocompromised individuals with comorbidities, but healthy people can be affected. Clinical cases have occurred after exposure to healthy colonized animals as well as those that were sick, such as horses or dogs with respiratory disease. There were also a few outbreaks linked to the consumption of unpasteurized dairy products, and some cases with no obvious zoonotic or foodborne source. The mortality rate varies with the syndrome. Streptococcal toxic shock-like syndrome is particularly serious due its rapid onset and clinical course, and many cases are fatal even with treatment. One report suggested a case fatality rate of 63%.

Streptococcus halichoeri

S. halichoeri was originally thought to be a zoonotic risk mainly for seal handlers and veterinarians; however, its isolation from herring, as well as dogs, mink and other terrestrial animals, indicates that exposure might be more widespread. Some illnesses caused by this organism were severe. To date, the few recognized human infections all occurred among people in their 40s or older, with an average age of 63 years.

Streptococcus iniae

S. iniae has been seen mainly in people who handle live or freshly killed fish for cooking and have wounds on their hands. Most clinical cases are reported in those over 50 years of age or immunocompromised, with a mean age of 70 years. However, young, healthy people can be affected. One recent case occurred in a healthy 24-year-old who developed cellulitis after being pinched by a crab.

Streptococcus suis

Human infections caused by *S. suis* were thought to be rare at one time. Increased awareness of this organism during the last 10-20 years has resulted in a rapid increase in the number of known cases, which numbered about 1600 as of 2019. Most illnesses have been documented in countries with intensive swine production, and often occur in otherwise healthy people. Case fatality rates for the various syndromes range from < 1% to > 20%, with estimates for *S. suis* meningitis varying from 1% to 7%. Some people exposed to pigs also seem to become colonized asymptomatically on the skin and upper respiratory tract. Human *S. suis* carriers might develop opportunistic infections, especially if they become immunocompromised. How long colonization persists in the absence of contact with swine is still unclear.

Occupational exposure (swine workers, slaughterhouse employees, butchers, veterinarians and others in the swine industry) accounts for some clinical cases, but foodborne infections are also important in parts of Asia where undercooked pork products, especially undercooked blood, intestines and other viscera, are eaten regularly. Meningitis is a prominent syndrome in these cases. *S. suis* does not cause many foodborne illnesses in China, but one strain of this organism caused animal-associated outbreaks in 1998 and 2005. Twenty-five cases and 14 deaths were reported in the first incident, which occurred during disease outbreaks in pigs that apparently spread to humans in close contact. The second outbreak was larger, with more than 200 cases, 66 of them laboratory confirmed, and a case fatality rate of 18%. Some patients in the latter outbreak had been exposed to pigs, but the source of the organism was not clear in others. Most people in the Chinese outbreaks had systemic illnesses (mainly sepsis or toxic shock) rather than meningitis, though the latter was also seen. It is possible that this organism also causes smaller outbreaks or sporadic cases in China that have been overlooked.

Internet Resources

Centers for Disease Control and Prevention (CDC). Streptococcus Laboratory

Public Health Agency of Canada. Pathogen Safety Data Sheets

The Merck Veterinary Manual

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