Streptococcosis

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Etiology

Streptococci are Gram positive cocci in the family Streptococcaceae. They often occur in pairs or chains, especially in fluids. Many members of the genus *Streptococcus* are pathogenic for humans and animals. Some species are proven or suspected to be zoonotic.

Nomenclature and identification of the streptococci

The classification of streptococcal species is complex and sometimes confusing. Many new species have recently been added to the genus *Streptococcus* and strains from some species have been reclassified. In the 1980s, some species of *Streptococcus* were moved to the new genera *Lactococcus* and *Enterococcus*. Recently, six more new genera — *Abiotrophia*, *Granulicatella*, *Dolosicoccus*, *Facklamia*, *Globicatella* and *Ignavigranum* — were established; these genera mainly contain organisms that previously belonged to the genus *Streptococcus*.

Clinical identification of the streptococci is based partly on their hemolytic reactions on blood agar and Lancefield grouping. There are three types of hemolysis: beta, alpha and gamma hemolysis. Beta-hemolytic streptococci are those that completely lyse the red cells surrounding the colony. These bacteria tend to cause most acute streptococcal diseases. Alpha-hemolytic streptococci cause a partial or "greening" hemolysis around the colony, associated with the reduction of red cell hemoglobin. Gamma-hemolysis is a term sometimes used for non-hemolytic colonies. In many cases, it is of limited value to distinguish alpha- from gamma- hemolysis; many species can be described simply as "non-beta-hemolytic." Hemolysis is not completely reliable for species identification. The species and age of the red cells, other properties of the medium, and the culture conditions affect hemolysis. Some species can be beta-hemolytic under some conditions but alpha- or non-hemolytic under others.

Lancefield grouping is based on the serologic identification of cell wall antigens and, in group B streptococci, capsular antigens. Lancefield's classification recognizes 20 serogroups, identified with the letters A to H and K to V. There are some streptococcal species that have no Lancefield group antigens and some with newly described antigens. The Lancefield groups do not necessarily correspond with streptococcal species. Members of a single species can belong to more than one Lancefield group, and the members of a single Lancefield group can belong to several different species. Only one known species (*S. agalactiae*, group B) can be identified solely by its Lancefield group; however, the human pathogen *S. pyogenes* is, by far, the most common beta-hemolytic group A streptococcus and "group A streptococcus" is often used as a synonym.

Which *Streptococcus* spp. are zoonotic?

Identifying the zoonotic species of streptococci and their importance to humans is difficult. Some species of *Streptococcus* are difficult to identify with conventional procedures. In many cases, clinical isolates are identified only by their Lancefield group (e.g., "group C streptococcus") and not to the species level. Even when a species is found in both humans and animals, different strains may exist and cross-species transmission may be rare or unimportant. An additional complication is that some species of *Streptococcus* are part of the normal flora in both humans and animals.

A few species with reservoirs in animals have been proven to be zoonotic.

- ***S. equi* subsp. *zooepidemicus*** (beta-hemolytic; Lancefield group C) is an opportunistic pathogen that causes a variety of infections in many species.
- ***S. suis*** (non-beta-hemolytic; Lancefield groups R, S and T) is a pathogenic or commensal organism usually associated with pigs. There are at least 35 serotypes of *S. suis* with varying virulence. Type 2 is usually isolated most often from clinical cases in pigs, but this can vary with the geographic region. Type 2 is also the predominant isolate from humans.

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- ***S. iniae*** (beta-hemolytic; no Lancefield group antigens) is a newly recognized zoonosis from fish. There seem to be both virulent and commensal strains of *S. iniae*.
- ***S. canis*** (beta-hemolytic; Lancefield group G) is an opportunistic pathogen found in dogs and other species.

Some *Streptococcus* spp. are adapted to humans and have no natural reservoirs in animals, but can be transmitted to animals (reverse zoonoses). The colonized animals can then re-transmit the infection to humans.

S. pyogenes (beta-hemolytic; Lancefield group A) is a human pathogen that causes pharyngitis (strep throat), skin disease and many other infections. *S. pyogenes* from humans can infect the bovine udder; as a result, contaminated raw milk can cause outbreaks of human disease. *S. pyogenes* has been isolated, in at least one case, from the family dog. Recurrent streptococcal pharyngitis in this family was cured only when the family dog was treated concurrently with all family members. Such cases seem to be unusual; in one study, numerous attempts to isolate *S. pyogenes* from pets, including those in households where the children had *S. pyogenes* infections, were unsuccessful.

Some *Streptococcus* spp. are found in both humans and animals, but zoonotic transmission seems to be nonexistent or insignificant. *S. agalactiae* (beta-hemolytic; Lancefield group B) is an important cause of human infections, particularly neonatal meningitis, sepsis, and pneumonia. It is also found in animals including cattle, horses, dogs, rabbits, guinea pigs and mice, and is an important cause of mastitis in cows. However, the strains that cause disease in humans are usually biochemically, metabolically or serologically different from strains that cause animal disease. The vast majority of human cases are thought to be caused by *S. agalactiae* that colonize asymptomatic human carriers and are transmitted from person to person. Zoonotic transmission is thought to be rare and, if it exists, of little significance.

The zoonotic significance of some streptococcal species is uncertain. Although these species are found in both animals and humans, whether humans are commonly infected by animal isolates is unknown.

The *S. bovis* group (non-beta-hemolytic; Lancefield group D) contains *S. bovis*, *S. equinus*, *S. gallolyticus*, *S. infantarius*, *S. pasteurianus* and *S. lutetiensis*. Until recently, these organisms were all known as *S. bovis* and their species specificity is still not well understood. Organisms in the *S. bovis* group are often found in the blood cultures of human patients with endocarditis, urinary tract infections, osteomyelitis, sepsis and other infections. They are also found among the normal flora of both humans and animals.

S. pneumoniae (non-beta-hemolytic; not grouped with Lancefield antigens) is an important human pathogen that can cause pneumonia, meningitis, otitis media, sinusitis and other diseases. It also causes respiratory disease in horses. The type 3 isolates identified in horses seem to be closely related to, but distinct from, the human type 3 pneumococci. *S. pneumoniae* is also a commensal or respiratory pathogen of other species, particularly guinea pigs and rats. In one case of septicemia and septic arthritis in a cat, the organism seems to have been transmitted from a child in the household (reverse zoonosis).

Streptococcus dysgalactiae subsp. *equisimilis* (beta-hemolytic; Lancefield groups A, C, G and L) is a pathogen or commensal of humans and animals. It can cause a variety of diseases.

Streptococcus porcinus (beta-hemolytic; Lancefield groups E, P, U, V, none or new) is normally found in pigs but has been isolated from the genitourinary tract of women. The incidence of human infection and significance of this finding is unknown.

The viridans group is a very diverse group of streptococci that often do not react with Lancefield grouping sera. Many are alpha-hemolytic. There are approximately 26 species of viridans streptococci but definitive species identification is difficult. These bacteria can be found in the mouth, gastrointestinal tract and vagina of healthy humans, as well as in animals, dairy products and other sources. They can also be isolated from patients with endocarditis, neutropenic patients with cancer and other infections. Some species may be zoonotic, but this is difficult to determine.

Non-zoonotic *Streptococcus* spp.

A few species of *Streptococcus* are found in animals but have not been isolated from humans: *S. equi* subsp. *equi* (beta-hemolytic; Lancefield group C) causes strangles and other diseases in horses. *S. dysgalactiae* subsp. *dysgalactiae* (non-beta-hemolytic; Lancefield group C) causes a variety of infections in animals, including mastitis in cows. *S. phocae* (beta-hemolytic; Lancefield groups C, F) was recently isolated from seals but has not, to date, been found in humans. *S. didelphis* (beta-hemolytic; no Lancefield group antigen) was recently isolated from opossums but has not, to date, been found in humans.

Some *Streptococcus* spp. were previously thought to be zoonotic but the human isolates have been reclassified, based on genetic studies. Based on human infections reported in the past, *S. acidominumus* (non-beta-hemolytic) was thought to be zoonotic. However, the human isolates have been recently reclassified as *Facklamia sourekii*, a species reported only in humans. *S. uberis* (non-beta-hemolytic), a cause of bovine mastitis, is no longer thought to be zoonotic. All of the isolates of *S. uberis* previously reported from humans have been reclassified as *Globicatella sanguinis*. *G. sanguinis* may be an important human pathogen but it has not, to date, been reported in animals.

Geographic Distribution

The zoonotic streptococci can usually be found worldwide in their animal hosts but human infections have, in some cases, been reported only in limited geographic regions. *S. suis* is present in pigs in the U.S. but human cases have not been seen. Most *S. iniae* infections have, to date, been reported in North America. Worldwide, type 2 is the most common serotype of *S. suis* isolated from seriously ill pigs; however, other serotypes can be important in some countries. Type 9 is also common in Belgium and Holland, and types 1 and 14 are isolated frequently in the United Kingdom.

Transmission

Streptococcus spp. are often carried as part of the normal flora of animals and humans. Their numbers are usually limited by nonspecific defense mechanisms and competition from other organisms. Some species cause disease, either when these mechanisms fail or when a new, virulent strain is acquired.

S. equi subsp. *zooepidemicus* is a commensal on the tonsils, upper respiratory tract, skin and urogenital tract of horses, and can be transmitted by a variety of mechanisms including aerosols and wound infections. It has also been found in healthy carriers of some other species. Transmission to humans probably occurs by aerosols, ingestion or through the skin. Many human infections are linked to the consumption of unpasteurized dairy products. A few cases in Hong Kong were associated with eating raw or cooked pork. Cases have also been seen after direct contact with horses. In addition, transmission on fomites may be possible; one infection was reported in an elderly man who had no direct contact with animals and ate/drank no unpasteurized milk products but did collect fresh horse manure regularly for his garden.

S. suis can be transmitted between pigs by direct contact, aerosols, fomites and possibly ingestion. In asymptomatic carrier pigs, this species is found in the tonsils and upper respiratory tract. It also occurs in the reproductive tract of aborting and farrowing sows. Asymptomatic carriers transmit the infection to other pigs in close contact; most infections are spread between weaned pigs. Newborn piglets may also become infected during delivery. *S. suis* can survive for a period of time in feces, dust and carcasses, particularly under moist, cool conditions. It has been reported to survive in pig feces for a week, decomposing carcasses for almost 2 weeks, and on flies for up to 5 days. Most human infections are thought to occur through cuts and abrasions in the skin.

S. canis is a commensal and opportunistic pathogen on the skin and mucosa of dogs and other species. Transmission of *S. canis* to humans seems to require close contact; most cases, to date, were probably acquired by the colonization of open wounds or burns or in dog bites.

The methods of transmission and reservoir(s) for *S. iniae* in fish are unknown. Asymptomatic carriers have been found and horizontal transmission has been reported during outbreaks. *S. iniae* infections in humans have occurred mainly in people with skin injuries who handled live or freshly killed fish.

S. pyogenes is an airborne infection spread among humans by direct contact with infectious nasal and pharyngeal secretions, or with infected wounds. This species can be carried asymptomatically, particularly in children, but subclinical carriers are less likely to spread the bacteria than people who are ill. Fomites do not seem to be very important in transmission.

Disinfection

Streptococci are readily killed by detergents and common disinfectants. Effective disinfectants for *Streptococcus* spp. include 1% sodium hypochlorite, 70% ethanol, formaldehyde, glutaraldehyde and iodine-based disinfectants. They are also sensitive to moist heat (121°C for a minimum of 15 min) or dry heat (160-170° C for 1 hour or longer).

Infections in Humans

Incubation Period

The incubation period varies with the form of the disease. The incubation period for *S. iniae* infections ranges from less than 24 hours to approximately 2 to 3 days. *S. pyogenes* infections acquired from food can become symptomatic after 1 to 3 days. Acute bacterial meningitis usually appears within a few hours to a few days. Streptococcal toxic shock syndrome is a peracute disease that can be fatal within hours.

Clinical Signs

Streptococcus spp. cause a variety of diseases in humans including streptococcal pharyngitis, pyoderma, abscesses, cellulitis, endocarditis, polyarthritis, pneumonia and septicemia. Most human infections are associated with group A streptococci, which are usually *S. pyogenes*. A small percentage of infections are caused by species from other Lancefield groups.

Streptococcal pharyngitis ("strep throat") is very common in humans. Common symptoms include pain on swallowing, tonsillitis, a high fever, headache, nausea, vomiting, malaise and rhinorrhea. When it is accompanied by a rash, this disease is known as scarlet fever.

Streptococcal toxic shock syndrome is a severe and often fatal disease characterized by shock and multiorgan failure. Early symptoms include fever, dizziness, confusion and an erythematous rash over large areas of the body. Death can occur within a few hours. Most patients with group C or G toxic shock syndrome have had underlying

diseases such as cardiopulmonary disease, diabetes mellitus, malignancy, liver disease or kidney failure.

Necrotizing fasciitis ("the flesh-eating bacteria") is a severe invasive disease characterized by severe local pain and destruction of tissue including muscles, fat and skin. Early symptoms include fever, severe pain and swelling, and reddening of the wound site. Necrotizing fasciitis can be fatal.

Autoimmune phenomena can occur after some streptococcal infections. Rheumatic fever may be seen after infection with *S. pyogenes.* Poststreptococcal glomerulonephritis has been reported after infection with *S. pyogenes* and *S. equi* subsp. *zooepidemicus*.

Bacteria with the group D Lancefield antigen have been associated with an acute, self-limiting gastrointestinal illness characterized by diarrhea, abdominal cramps, nausea, vomiting, fever, chills and dizziness. The illness is foodborne and usually occurs after an incubation period of 2 to 36 hours. Lancefield group D contains the *S. bovis* group and some of the enterococci including *Enterococcus faecalis*, *E. faecium*, *E. durans* and *E. avium*. (Enterococci are normal flora and opportunistic pathogens found in the gastrointestinal tract and other sites.)

Streptococcus pyogenes

S. pyogenes is, by far, the most common cause of streptococcal pharyngitis. It also causes relatively mild skin infections such as pyoderma and impetigo, as well as otitis media, sinusitis, abscesses, cellulitis, osteomyelitis, arthritis, endocarditis and, rarely, serious infections such as pneumonia, meningitis, septicemia, necrotizing fasciitis or streptococcal toxic shock syndrome. Rheumatic fever or glomerulonephritis can be sequelae. *S. pyogenes* can also be carried asymptomatically.

Streptococcus equi subsp. zooepidemicus

S. equi subsp. *zooepidemicus* has been isolated from humans with mild respiratory disease, pneumonia, endocarditis, endophthalmitis, septic arthritis, meningitis, septicemia and streptococcal toxic shock syndrome. Post-streptococcal glomerulonephritis has been reported, sometimes after mild illnesses. One large outbreak of acute nephritis, with 253 cases, was linked to the consumption of contaminated unpasteurized cheese in Brazil. The initial symptoms included fever, chills and malaise. The nephritis was severe; of 133 confirmed cases, three people died, seven required dialysis and 96 were hospitalized. Pneumonia, endocarditis, meningitis, pericarditis and abdominal pains were also reported in this outbreak.

Streptococcus suis

To date, *S. suis* has mainly been associated with meningitis. The initial symptoms are usually transient, resemble influenza and are followed by signs of meningitis such as a severe headache, fever, vertigo, nausea, vomiting, a stiff neck or mental changes such as confusion. After recovery, approximately half of all patients with *S. suis* meningitis have had some degree of hearing loss. Other sequelae have included arthritis, vertigo and endophthalmitis. *S. suis* has also been isolated from cases of endocarditis, septicemia without meningitis, and septic shock.

Streptococcus canis

Very few human infections with *Streptococcus canis* have been documented; however, human infections with this species may be underestimated because many clinical isolates are reported only as "group G streptococcus." Group G streptococci are isolated occasionally from a variety of human infections including streptococcal toxic shock syndrome and streptococcal pharyngitis. Syndromes that have been associated specifically with *S. canis* include septicemia, meningitis and peritonitis.

Streptococcus iniae

S. iniae has usually been found in cases of cellulitis. Rare cases of osteomyelitis, septic arthritis, endocarditis, meningitis and discitis (infection of the vertebral discs) have also been reported.

Communicability

S. pyogenes is transmitted by person-to-person contact and can occasionally be spread to the mammary gland of cattle and possibly to dogs. The communicability of the zoonotic species has not been established.

Diagnostic Tests

A presumptive diagnosis can be made if Gram positive cocci in pairs or chains are seen in smears, tissues or aspirates. Bacteria may be found in pharyngeal secretions, wounds, blood, CSF or other sites. Characteristic changes in the CSF such as neutrophilia are suggestive of meningitis. Streptococcal toxic shock syndrome is usually identified by the clinical signs and confirmed by culture.

The definitive diagnosis depends on culturing and identifying the organism. *Streptococcus* spp. can be identified by their hemolysis patterns on blood agar, colony morphology, biochemical reactions, and serology to detect antigens.

Beta-hemolytic streptococci can often be identified by Lancefield grouping and a few phenotypic tests. The capillary precipitation test is the classic test used to determine the Lancefield group but other serologic methods may also be used. *S. iniae* is difficult to identify.

Rapid identification tests including immunofluorescence and enzyme-linked immunosorbent assays (ELISAs) can be used to identify *S. pyogenes* in throat swabs.

Identification of some of the non-beta-hemolytic streptococci can be difficult with conventional procedures and tests. Lancefield grouping is of limited value for many of the non-beta -hemolytic streptococci other than *S. suis*

and the *S. bovis* group. Conventional tests cannot identify most species of the viridans streptococci.

All *Streptococcus* species can be identified by genetic tests such as DNA-DNA reassociation procedures, pulsed-field gel electrophoresis (PFGE) and 16S rRNA gene-sequencing; however, these tests are often unavailable in clinical laboratories.

Phage typing is used in research and epidemiologic studies but is not usually available in clinical laboratories

Streptococcus spp. are often identified only to their Lancefield group and not to the species level.

Serology is sometimes used to diagnose human streptococcal disease. Serologic tests include the antistreptolysin O (ASO) titer, the anti-hyaluronidase titer and anti-DNase B.

Treatment

Streptococcal infections can be treated with various antibiotics including penicillin, amoxicillin, ampicillin, third-generation cephalosporins, vancomycin and clindamycin. Synergistic treatment with penicillin or ampicillin and an aminoglycoside is used for some streptococci; the penicillin weakens the cell wall and facilitates entry of the aminoglycoside. Some isolates may be drug resistant.

Dialysis may be needed in cases of glomerulonephritis. Supportive treatment for shock and other symptoms is crucial in the treatment of streptococcal toxic shock syndrome and necrotic fasciitis. Intravenous immunoglobulin (IVIG) therapy may also be used. Surgical debridement of necrotic tissues is often necessary.

Prevention

S. iniae, *S. suis* and *S. canis* seem to transmitted most often through wounds and abrasions. Protective clothing and gloves should be used when handling pig carcasses. Strict hygiene should be observed when butchering pigs or cleaning fish. Contact of open wounds with animals or animal products should, in general, be avoided, and wounds should be kept clean.

To prevent foodborne infections with *S. equi* subsp. *zooepidemicus*, raw milk and unpasteurized milk products should be avoided. Good hygiene should be observed when caring for horses with respiratory diseases and other *S. equi* subsp. *zooepidemicus* infections.

Morbidity and Mortality

Streptococcus equi subsp. zooepidemicus

Human infections with *S. equi* subsp. *zooepidemicus* seem to be rare. In one study, this species accounted for approximately 1% of 214 group C streptococcus isolates from clinical cases. Serious group C streptococcal infections are rare in humans, and are estimated to occur in less than 1% of all bacteremias. In many cases, they are seen in patients with concurrent diseases. Although *S. equi* subsp *zooepidemicus* is rare in humans, some authors suggest that it may cause a higher proportion of aggressive infections than some other species.

Most infections with *S. equi* subsp. *zooepidemicus* are sporadic but small to large outbreaks have also been reported. Outbreaks are usually associated with the consumption of unpasteurized dairy products.

The mortality rate varies with the syndrome. The mortality rate for group C bacteremia is approximately 20 to 30% and the case fatality rate for group C meningitis is approximately 57%. Many cases of streptococcal toxic shock syndrome are fatal, even with treatment.

Streptococcus suis

S. suis seems to be a rare zoonosis; to date, fewer than 100 human cases have been documented. Although virulent *S. suis* is found in pigs in the U.S, no human cases have been seen in this country. Most *S. suis* infections have been reported in producers, slaughterhouse workers, butchers, veterinarians and others in the swine industry. *S. suis* infections have been described mainly in immunocompetent hosts.

The mortality rate for *S. suis* meningitis, the most common syndrome, is 7%. Serious sequelae such as deafness and vertigo are common; hearing loss has been reported in approximately half of all cases of *S. suis* meningitis. Rare fatal cases of septicemia and toxic shock have also been seen.

Whether immunity develops is unknown. Reinfection and fatal septic shock were reported in one patient, 15 years after his first infection.

Streptococcus canis

Documented *S. canis* infections in humans are very rare, with fewer than ten cases reported in the literature; however, human infections with this species could be underestimated, as many clinical infections are reported only as "group G streptococcus". Some of the published human cases are considered to be unconfirmed because the data are contradictory or the species was not confirmed to be *S. canis* by a reference laboratory.

Streptococcus iniae

S. iniae infections have mainly been seen in people who handled live or freshly killed fish for cooking and had wounds on their hands. This infection has not been documented in aquaculture workers. Most cases have been seen in the elderly; the mean age of patients is 70 years, with a range of 40 to 81 years.

Streptococcus pyogenes

S. pyogenes is a very common human pathogen, accounting for more than 10 million non-invasive infections such as streptococcal pharyngitis or skin infections. Noninvasive disease is seen most often in children, particularly children in elementary school. Deaths are very rare with noninvasive disease.

In 2002, *S. pyogenes* caused approximately 9,000 cases of invasive disease in the U.S. Streptococcal toxic shock syndrome and necrotizing fasciitis each account for approximately 6% of these cases. The risk of invasive disease is highest in the elderly and in people who are immunosuppressed, have serious illnesses, or have breaks in the skin (such as chickenpox). The mortality rate is approximately 10%-15% in invasive disease overall, 20-25% in cases of necrotizing fasciitis, and 45% to greater than 50% in streptococcal toxic shock syndrome.

Infections in Animals

Species Affected

S. equi subsp. *zooepidemicus* is a common commensal and opportunistic pathogen in horses. This organism has also been found in healthy carriers of other species including guinea pigs, pigs and monkeys. It has been isolated from clinical cases in many species including horses, cattle, sheep, goats, pigs, dogs, foxes, ferrets, guinea pigs, non-human primates and birds.

S. suis is found mainly in pigs but has also been isolated from other species including cattle, sheep, goats and bison.

S. canis has been found in dogs and a variety of other animals including cats, cattle, rats, mink, mice, rabbits and foxes.

S. iniae has been found in freshwater dolphins and wild and farmed fish. Some fish such as tilapia and barramundi carry this organism asymptomatically. Disease outbreaks have been reported in rainbow trout, tilapia, yellowtail, red drum, coho salmon, bass, bream and wild spine foot. Experimental infections have been reported in mice.

Colonization of the udder by *S. pyogenes* has been reported occasionally in cattle. Asymptomatic colonization was also documented in a dog.

Incubation Period

The incubation period varies with the form of the disease. In streptococcal toxic shock syndrome, healthy animals can become seriously ill within several hours and may die within seven hours.

Clinical Signs

Streptococcus equi subsp zooepidemicus

S. equi subsp. *zooepidemicus* is an opportunistic pathogen in many species and is isolated from a wide variety of infections.

In horses, *S. equi* subsp. *zooepidemicus* is often isolated from secondary bacterial infections. It can invade the upper respiratory mucosa and lymph nodes after a viral infection, sometimes mimicking strangles. In susceptible mares, it can cause cervicitis, metritis and placentitis (as an ascending infection from the vagina) resulting in abortions. It is the most common cause of mastitis in horses and has been associated with numerous other infections including wound infections, septicemia in colts, and lower airway inflammation in young horses. Lower airway inflammation can occur repeatedly in young horses and can adversely affect subsequent racing performance.

S. equi subsp. *zooepidemicus* is also an important pathogen in guinea pigs. In its endemic form, this organism causes cervical lymphadenitis, characterized by draining abscesses in the cervical lymph nodes and occasionally other organs. Some infections can progress to torticollis, pneumonia or septicemia. Small uterine abscesses cause decreased fertility. Epidemics of septicemia and acute pneumonia, with high mortality rates, are also seen in susceptible populations.

In 1994, *S. equi* subsp. *zooepidemicus* caused a serious epidemic among pigs and monkeys in Bali, Indonesia. The disease was first seen on a pig farm and spread to nearby villages as well as to wild monkeys. Syndromes reported in affected animals included polyarthritis, bronchopneumonia, pleuritis, diarrhea, epicarditis, endocarditis and meningitis. Most of the affected animals died within a few days. Although the outbreak subsided, this organism continues to circulate in the pig and monkey population of Bali, including healthy carriers.

Sporadic cases of mastitis are seen in cattle and goats, and an outbreak of mastitis due to *S. equi* subsp. *zooepidemicus* was reported in sheep. In ewes, the mastitis was unilateral, with watery secretions containing small flecks of pus and a dramatic drop in milk production. The affected quarters became dry 5 days after the onset of the symptoms and did not recover milk production. No systemic signs were seen and the udder did not become acutely inflamed.

Feeding raw horsemeat containing *S. equi* subsp. *zooepidemicus* to carnivorous and insectivorous small mammals can sometimes cause septicemia and death.

S. equi subsp. *zooepidemicus* has also been isolated from a variety of infections in other species including septicemia, pneumonia and streptococcal toxic shock syndrome in dogs; abscesses, pneumonia, metritis and endocarditis in ferrets; and septicemia in poultry.

Streptococcus suis

S. suis is carried asymptomatically by many pigs but more virulent strains can cause serious disease. Sporadic cases of polyarthritis or peracute meningitis and septicemia are sometimes seen in suckling pigs. More often, *S. suis* causes acute meningitis, with high mortality rates, in recently weaned and growing pigs. The symptoms may include depression, anorexia, fever, trembling, incoordination, opisthotonos, convulsions and blindness. Labyrinthitis, otitis interna and otitis media can lead to deafness and possibly vestibular dysfunction. In addition, *S. suis* sometimes causes pneumonia, endocarditis myocarditis

or abortions. *S. suis* has also been isolated sporadically from other species including a lamb with endocarditis, bison with meningitis, and ruminants with purulent lesions in the lungs.

Streptococcus canis

S. canis is an opportunistic pathogen in dogs and cats. In dogs, *S. canis* is isolated from a variety of diseases including skin infections, infections of the reproductive tract, mastitis, pneumonia, septicemia and streptococcal toxic shock syndrome.

Both *S. canis* and *S. equi* subsp. *zooepidemicus* have been isolated from dogs with streptococcal toxic shock syndrome. This severe invasive disease is characterized by an acute onset, rapid progression, clinical course as short as 7 hours, and high mortality rate. A high fever greater than 105ºF is typical. The symptoms may also include vomiting, a non-productive cough, lateral recumbency, shock, extreme weakness, stiffness and rigidity, mild convulsions, intense pain and rapid uncontrolled muscle fasciculation. Spontaneous hemorrhaging may lead to bloody sputum, epistaxis and bloody diarrhea. Cellulitis and necrotizing fasciitis are seen in some cases. Death can occur very quickly.

S. canis also causes various infections in cats, including arthritis, wound infections, cervical lymphadenitis in 3 to 6 month old kittens, septicemia, pneumonia and streptococcal toxic shock syndrome.

S. canis sometimes causes neonatal septicemia in kittens, particularly kittens born to younger queens. Affected kittens appear normal at birth but gain weight slowly and usually die when they are approximately 7 to 11 days old. Death is preceded by transient fever 24 hours before death. Occasionally, a swollen, infected umbilicus is seen. More than one kitten in a litter can be affected but the whole litter does not usually become sick.

Streptococcus iniae

S. iniae infects some fish asymptomatically. It also causes sporadic disease in some species and, occasionally, serious outbreaks on fish farms. Meningoencephalitis and panophthalmitis are the most common syndromes in trout and tilapia. Skin lesions and necrotizing myositis are seen most often in red drum. This species has also been isolated from a subcutaneous abscess in a freshwater dolphin.

Streptococcus pyogenes (reverse zoonosis)

S. pyogenes acquired from humans can cause mastitis in cattle. Disease has not been reported in other species.

Communicability

All of the zoonotic streptococci can be transmitted directly to susceptible animals or humans; however, transmission does not necessarily result in disease. *S. equi* subsp. *zooepidemicus* and *S. pyogenes* can also be found in dairy products, *S. equi* subsp. *zooepidemicus* in horse meat, *S. suis* in pork and *S. iniae* in fish.

Diagnostic Tests

A presumptive diagnosis can be made if Gram positive cocci in pairs or chains are seen in smears, tissues or aspirates. Depending on the infection, bacteria may be found in pharyngeal secretions, wounds, blood, cerebrospinal fluid (CSF), the placenta, tissues from aborted fetuses, or other sites. Streptococcal toxic shock syndrome is usually identified by the clinical signs and confirmed by culture.

The definitive diagnosis depends on culturing and identifying the organism. *Streptococcus* spp. can be identified by their hemolysis patterns on blood agar, colony morphology, biochemical reactions, and serology to detect antigens.

Beta-hemolytic streptococci can often be identified by Lancefield grouping and a few phenotypic tests. The capillary precipitation test is the classic test used to determine the Lancefield group but other serologic methods may also be used. *S. iniae* is difficult to identify.

Identification of some of the non-beta-hemolytic streptococci can be difficult with conventional procedures and tests. Lancefield grouping is of limited value for many of the non-beta -hemolytic streptococci other than *S. suis* and the *S. bovis* group. Conventional tests cannot identify most species of the viridans streptococci.

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Phage typing is used in research and epidemiologic studies but is not usually available in clinical laboratories. *Streptococcus* spp. are often identified only to their Lancefield group and not to the species level.

Treatment

Streptococcus spp. have been treated with various antibiotics including penicillin, amoxicillin, ampicillin, clindamycin, chloramphenicol and enrofloxacin. Some isolates may be drug resistant. Supportive treatment for shock and other symptoms is critical for streptococcal toxic shock syndrome. Surgical debridement of necrotic tissues is often necessary.

Prevention

Streptococcus equi subsp. zooepidemicus and Streptococcus canis

It is difficult to prevent infections with *S. equi* subsp. *zooepidemicus* or *S. canis*, as they are part of the normal flora in some species. There are no commercial vaccines for either organism; however, autogenous vaccines for *S. equi* subsp. *zooepidemicus* may be used in guinea pigs. In all species, stress and other factors that can predispose to

infections should be minimized, wounds should be kept clean, and good hygiene should be practiced.

Poor husbandry and stress predispose guinea pigs to clinical disease caused by *S. equi* subsp. *zooepidemicus*. Biting and overgrown teeth increase the risk of illness. Outbreaks 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. If clinical disease is widespread in a colony, depopulation may be necessary.

Good hygiene during milking can reduce exposure to environmental streptococci and decrease the risk of mastitis in ruminants. The environment and the cow's udder should be kept clean, the udder hair should be kept short, and the teats should be cleansed and sanitized before milking. Milking machines should be checked regularly and any problems corrected. Milkers should wear gloves. Some cases of *S. equi* subsp. *zooepidemicus* mastitis in ruminants were associated with hand milking and are suspected to have resulted from contact with horses or donkeys.

Streptococcus suis

It is difficult to keep *S. suis* out of a herd. Although disease is often introduced into the herd in a carrier animal, it is difficult to distinguish virulent from avirulent serotypes and strains, and healthy carriers are very common. In addition, *S. suis* can be introduced by flies and mildly pathogenic endemic strains may mutate to become more virulent. Good management and decreased stress can reduce the risk of clinical disease. All-in/all-out management, with cleansing and disinfection of the premises between groups, can be helpful. Killed vaccines or prophylactic antibiotics may decrease the incidence of disease but do not eliminate the infection from the herd.

Streptococcus pyogenes

S. pyogenes is introduced into cattle by a human carrier, usually an infected milker. People with strep throat or other streptococcal diseases should not participate in milking or handle milk. (People with strep throat who have been on antibiotics for at least 24 hours usually are no longer contagious.) Good hygiene during milking can also decrease the chance of introducing this organism into the udder. The environment and the cow's udder should be kept clean, the udder hair should be kept short, and the teats should be cleansed and sanitized before milking. Milking machines should be checked regularly and any problems corrected. Milkers should wear gloves.

Morbidity and Mortality

Streptococcus equi subsp. Zooepidemicus and Streptococcus canis

The morbidity and mortality rates vary widely, depending on the form of the disease. Invasive diseases such as septicemia and streptococcal toxic shock syndrome are particularly serious and often fatal. Most infections with *S. canis* and *S. equi* subsp. *zooepidemicus* are sporadic but *S. equi* subsp. *zooepidemicus* can cause outbreaks of septicemia in pigs, guinea pigs and monkeys, and mastitis in sheep. Both the morbidity and mortality rates can be very high in outbreaks of septicemia.

S. equi subsp. *zooepidemicus* mastitis is not usually fatal in ruminants, but premature drying off and a high morbidity rate (13 of 58 ewes in one outbreak) make this a potentially serious disease.

S. canis can cause high mortality rates in newborn kittens when it first enters a cattery but the mortality rate usually drops to less than 5% within a year unless the cats are immunosuppressed. Litters from young queens are most often affected by this disease.

Streptococcus suis

S. suis is carried asymptomatically by as many as 60-100% of pigs but clinical disease usually affects only 2-15% of the herd. Some subtypes are common in herds but cause only sporadic disease in pigs up to 2 months old. The virulent strains associated with outbreaks are less common, mainly occur in large, intensively managed herds, and affect pigs up to market weight. Stressors such as poor ventilation and overcrowding predispose pigs to outbreaks of meningitis. Type 2 strains can have a high mortality rate.

Streptococcus iniae

In fish, *S. iniae* can be carried asymptomatically but is also associated with sporadic disease and outbreaks. Mortality rates of 30% to 50% have been reported in outbreaks of meningoencephalitis in aquaculture farms. The only reported epidemic in a wild species was associated with an outbreak in farmed fish.

Post Mortem Lesions

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Streptococcus equi subsp. zooepidemicus and Streptococcus canis

The gross lesions vary with the syndrome and may include abscesses, arthritis, endocarditis, mastitis, pneumonia, pleuritis, lower airway inflammation with increased production of mucous, and signs of septicemia. Abortions are usually associated with placentitis; in horses, the placenta is usually edematous with brown fibronecrotic exudate near the cervical star and the fetus may be severely necrotic.

Streptococcus suis

Common necropsy lesions in pigs include patchy erythema of the skin, enlarged and congested lymph nodes, and fibrinous polyserositis. The joint capsules may be thickened and contain excessive amounts of clear or turbid fluid. The brain may look grossly normal in cases of meningitis, or there may be congestion, edema, and excess clear or cloudy CSF. The lungs may be consolidated and have signs of fibrinopurulent bronchopneumonia.

Streptococcus iniae

Lesions reported in fish include exudative meningitis, panophthalmitis and systemic disease with diffuse visceral hemorrhages.

Internet Resources

Centers for Disease Control and Prevention (CDC)
http://www.cdc.gov/ncidod/diseases/submenus/sub_streptococcus.htm

International Veterinary Information Service (IVIS)
http://www.ivis.org

Material Safety Data Sheets –Canadian Laboratory Center for Disease Control
http://www.hc-sc.gc.ca/pphb-dgspsp/msds-ftss/index.html#menu

Medical Microbiology
http://www.ncbi.nlm.nih.gov/books/NBK7627/

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

U.S. FDA Foodborne Pathogenic Microorganisms and Natural Toxins Handbook (Bad Bug Book)
http://vm.cfsan.fda.gov/~mow/intro.html

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