Sarcocystis: A Clinical Entity in Bovine Practice

Dr. Ronald Fayer
Animal Parasitology Institute, Beltsville, MD 20705

Between 1849, when it was first reported, and the early 1970's when its life cycle was unraveled, little was known about this mysterious widespread protozoan parasite except that it was found as visible or microscopic cysts in the muscles of nearly all food animals and in numerous wild animals. Although cysts had been reported in over 75% of the cattle and sheep examined in the United States only a tenuous link was established between *Sarcocystis* infection and economic losses. This association was made at slaughter plants where cattle and sheep carcasses were condemned for either unsightly cysts or for the blue-green coloration of muscles with eosinophilic myositis (E.M.). Because nearly all carcasses condemned for E.M. contained microscopic cysts of *Sarcocystis,* some meat inspection veterinarians hypothesized that E.M. resulted from *Sarcocystis* infection; this cause-effect relationship has not been proven. USDA meat inspection records for *Sarcocystis* and E.M. have shown whole cattle and sheep carcass condemnations averaging approximately $2 million per year; this loss does not include parts condemned. Nor does it reflect abortions, poor feed utilization, morbidity or mortality, or clinical manifestations of sarcocystosis which have only recently been discovered.

In the past ten years over 400 research papers have been written on the subject of *Sarcocystis*. Most papers have described either the life cycles and routes of transmission from one host animal to another, the clinical signs of disease, or methods of diagnosis. With such information now available practitioners and clinicians have been able to diagnose outbreaks in dairy and beef cattle that heretofore would have been misdiagnosed or would remain undiagnosed. Furthermore, they can explain to the producer how to prevent subsequent losses.

Life cycles and routes of transmission

All known species of *Sarcocystis* develop through the same sequence of stages as do coccidia but *Sarcocystis* species have a two-host life cycle in which one host is a prey animal and the other is a predator. There are at least three such species in bovines: *Sarcocystis bovicanis* (also calles *S. cruzi*) *Sarcocystis bovifelis* and *Sarcocystis hominis*. The bovine is the intermediate host for each species and the final hosts are dogs, cats, and humans, respectively. A typical life cycle will be illustrated with *S. bovicanis*. When a mature intramuscular cyst is eaten by a dog the tiny, infectious, crescent-shaped bradyzoites within the cyst are released and enter goblet cells in the dog's small intestine. They develop within a few hours to microgametes or macrogametes, the male and female stages. Fertilization takes place about 12 hours later and oocysts form from fertilized macrogametes. The occysts sporulate in the gut until each fragile oocyst contains two sporocysts which each contain four infectious sporozoites. The oocysts are passed in the dog's feces beginning 9 days after the infective meal was eaten. Most often, the oocysts break and individual sporocysts are passed in the feces. Sporocysts may be passed intermittently for nearly 3 months and tens of millions may be passed as a result of a single meal of infected beef. Dogs may be fed infected beef repeatedly without developing either clinical signs of infection or substantial immunity to reinfection. It is not known how long sporocysts survive in the environment but in the laboratory they remain infectious for nearly a year when kept in an aqueous suspension in a refrigerator. In addition to dogs, several wild carnivores can serve as final hosts for *S. bovicanis*. These include coyotes, wolves, foxes, and raccoons. The sporocysts produced by these animals are infectious for bovines but are not infectious for other carnivores.

Cattle become infected with *S. bovicanis* by ingesting the sporocysts passed in dog feces. As a result of the physiological conditions in the rumen followed by exposure to trypsin and bile the sporocyst wall breaks apart and the sporozoites are released in the small intestine. They find their way to endothelial cells lining small arteries and within two weeks undergo multiple nuclear division to form schizonts. Each nucleus in a schizont becomes incorporated into a motile crescent-shaped merozoite and numerous merozoites are released from each schizont approximately 2 weeks after ingestion of sporocysts. These merozoites travel in the bloodstream to capillaries where they again enter endothelial cells and begin a second generation of schizonts which mature 2 to 3 weeks later. Merozoites from the second generation schizonts again enter the bloodstream where they undergo one or more additional generations of nuclear division, each time forming two progeny. These progeny enter striated muscle cells (and to a lesser extent, nerve cells in the central nervous system) where they develop into cysts. The cysts are inapparent until about 50 days after the sporocysts were ingested. At that time they may be composed of only one, two or a few rounded bodies called metrocytes (mother cells); they are not yet infectious if eaten by a dog. At about 70 days cysts may contain dozens of

metrocytes, some of which have formed motile crescent-shaped bradyzoites; only those cysts containing bradyzoites are infectious for dogs. Cysts continue to increase in size as more metrocytes are formed and as other metrocytes develop into bradyzoites. Although cysts may be infectious at about 70 days, cyst development is not complete until about 5 months. The longevity of the cysts in living animals is not known. They can survive in the carcass of a dead animal for weeks; in three published reports beef purchased from retail food stores contained live infectious bradyzoites.

Clinical signs of disease

The severity of bovine sarcocystosis is related both to the number of sporocysts ingested and to the isolate (strain) of the parasite. Experimental studies with the Beltsville isolate of *S. bovicanis* indicate that ingestion of 50,000 or fewer sporocysts usually results in no clinical signs whereas 100,000 sporocysts cause marked illness and 150,000 to 200,000 sporocysts is an LD_{50}. The following description is typical of experimental oral infection of cattle with 100,000 sporocysts. Either no clinical signs or only a mild pyrexia lasting one or two days coincides with maturity of first generation schizonts. Numerous clinical signs coincide with second generation schizonts and the blood-borne stages that follow. Pyrexia ranges from 103 to 107.5° F, and lasts about a week. Feed consumption is reduced or absent and weight is lost (in some cases as much as one fourth of the original weight has been lost). Anemia is acute and severe; packed cell volume may drop as low as 10 to 12% between weeks 4 and 5 and reach normal levels again by weeks 8 or 9. Serum enzymes (CPK, LDH, and SGOT) rise to high levels for 1 or 2 days between weeks 4 and 5. Temperament may vary from hyperexcitable to dull and lethargic. Young calves may be extremely weak and tired, unable to stand unless prompted and some unable to stand even then. Adult cattle may have signs of myositis, glossitis, and hypersalivation. Cows in the second and third trimesters of gestation abort at various times from the 5th to the 10th week after experimental infection with sporocysts. Similar studies with other species of *Sarcocystis* show them to be abortifacient in sheep, goats, and pigs. An outbreak of what is now confirmed as sarcocystosis was reported from a farm in Dalmeny, Ontario, Canada where acutely infected cows aborted. The mechanism of abortion is not known. Fetuses are rarely infected. A working hypothesis suggests that endothelial cell damage and/or leukocyte reaction to second generation schizonts, merozoites or their metabolic products results in release of large quantities of prostaglandin which lyses the corpus luteum thus causing progesterone levels to drop below the minimum necessary to maintain the fetus in utero. A similar sequence of events might also be followed as a result of drastically reduced feed consumption due to sarcocystosis. Studies are underway to test these hypotheses.

Hemorrhage is commonly found at necropsy of cattle that die during acute sarcocystosis. Hemorrhage may cause skeletal muscles, especially those just beneath the skin, to appear alternately dark and light striped. Petechiae are commonly found on the serosal surface of the stomach, small intestine, cecum, and within enlarged edematous mesenteric lymph nodes. Mesenteric and perirenal fat may undergo serous atrophy and become gelatinous. The pericardium may contain an excessive quantity of serosanguinous fluid and the ventricular epicardium and endocardium may have scattered petechial or ecchymotic hemorrhages. Serous atrophy of fat may be seen with or without petechiae in the coronary groove of the heart.

Histologically, the heart is usually the most severly affected organ, with multifocal, hemorrhagic, and, necrotizing pancarditis. Extremely large numbers of mononuclear cells, mostly lymphocytes with some macrophages and plasma cells, invade the interstitium, disrupt and disorient muscle fibers, and exacerbate damage from the hemorrhage and edema. Hemorrhage, edema, cullular infiltrate and tissue destruction also affect many other organs to a lesser extent, especially the kidneys, liver, and lungs.

Diagnosis

Diagnosis of sarcocystosis is difficult because the clinical signs are generalized and the tissue stages (schizonts) are short-lived and may not be present in histologic sections. During acute illness the antibody levels are usually not high enough to be of diagnostic value. However, an indirect hemagglutination test (IHA) using *S. bovicanis* bradyzoite antigen has been found useful for examining convalescent serum taken from a week until 3 months after acute illness. Young calves usually have no antibody titer or a very low titer—1:50 or 1:100. Adult cattle harboring cysts of *Sarcocystis* but displaying no clinical signs may have IHA titers of 1:500 or occasionally 1:1500. Convalescent serum from clinically ill young and adult cattle have IHA titers ranging from 1:500 to 1:100,000; most range from 1:4500 to 1:40,000. This IHA test (although still used exclusively in a research laboratory) has been important in diagnosing two reported outbreaks in the United States—one in New York and the other in Kentucky. Other serologic tests including the indirect fluorescent antibody (IFA) and the enzyme linked immunosorbent assay are being tested for possible distribution to diagnostic laboratories. An IFA test is also being developed to aid in detecting merozoites in frozen tissues from acutely infected animals.

Treatment

Prophylactic treatment of experimentally infected ruminants with the anticoccidial drugs amprolium and salinomycin have reduced or prevented clinical sarcocystosis as compared with unmedicated infected controls. However, therapeutic treatment following the observation of clinical signs in experimentally infected animals has been ineffective.

Apparently, the anticoccidial drugs that were tested possessed activity against the schizont stage responsible for lesions. Once lesions developed and then clinical signs appear it is too late to begin treatment because the schizonts have already completed their development.

Prevention

Prevention of bovine sarcocystosis depends on the ability of veterinarians and farm managers to break the life cycle. Because the only known source of infection for cattle is the sporocyst stage from the feces of carnivores, this stage must be eliminated from the environment. To accomplish this, the carcasses of animals that die on the farm, in the feedlot, or on the range must be removed from the environment before dogs, coyotes, wolves, foxes, or raccoons can eat any of the meat. When livestock are killed by farmers, ranchers, or slaughter plants for human consumption, raw meat scraps must not be fed to pet dogs or left in the environment where they can be eaten by feral carnivores.

***Sarcocystis* in wildlife species may ultimately affect domestic animals. Under experimental conditions *Sarcocystis* transmitted from bison to coyotes to cattle, resulted in illness and death in the cattle. In surveys of coyotes in northern Utah, Idaho, and Montana over 15% were passing *Sarcocystis* sporocysts in their feces and these sporocysts were found to be infective for cattle and sheep. Thus, feral carnivores should be avoided and prevented from access to grazing, or food storage areas where their feces could serve as a source of *Sarcocystis* infection for livestock.**