AABP & AASRP Joint Sessions

Diagnosis and control of small ruminant abortion

Paula I. Menzies, *DVM MPVM Dip. ECSRHM*
Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada N1G 2W1

Abstract

Abortion, as either an outbreak or enzootic disease issue, is an important production-limiting disease of sheep and goats. This article describes how to approach diagnosis and management of the more common causes of abortion in the US and Canada, i.e. *Campylobacter fetus* subspecies *fetus, Campylobacter jejuni, Chlamydophila abortus, Toxoplasma gondii*, and iodine deficiency goiter. It also gives an overview of the less-common causes of abortion in sheep and goats. Zoonotic implications of the various disease agents will also be addressed, as well as how to reduce risk to humans. *Coxiella burnetii* is covered in a separate lecture.

Résumé

L'avortement, qu'il résulte d'un problème épidémique ou enzootique, est une importante maladie limitant la production chez les ovins et les caprins. Cet article explique comment aborder le diagnostic et la maîtrise des causes les plus fréquentes de l'avortement chez ces animaux aux États-Unis et au Canada, à savoir, les microorganismes *Campylobacter fetus* subsp. *fetus, Campylobacter jejuni, Chlamydophila abortus, Toxoplasma gondii*, ainsi que le goitre résultant d'une carence en iode. Nous y donnons aussi un aperçu des causes les moins courantes de l'avortement chez les ovins et les caprins. L'article traitera aussi des implications zoonotiques des divers agents causals de ce grave trouble de la santé, et de la façon de réduire les risques de transmission chez les humains. L'agent causal *Coxiella burnetii* sera couvert dans une autre communication.

Introduction

Unfortunately, significant losses associated with abortion in sheep and goats are quite common, but fortunately laboratory diagnosis is often more rewarding than with other livestock species. In this presentation, I will cover how to approach diagnosis and management of small ruminant abortion, the more common causes and zoonotic implications.

Definition of Abortion

The definition of abortion is any pre-term loss of a fetus or embryo. Pregnancy loss prior to day 12 after conception will result in an early return to estrus when it occurs during the breeding season. Later pregnancy loss will present variably as one or more of the following observations: delayed return to estrus; a female believed to be pregnant, but that fails to give birth and no abortion is observed; a blood-tinged vaginal discharge observed, but no fetus or placenta is found; abortion occurs and a fetus and/or placenta is found; lambs or kids born at term (> 142 days of gestation) either stillborn and/or weak. Sometimes all of these may present in the same outbreak. The fetus may be delivered macerated, mummified, decomposed or freshly dead, and alive.

Investigating the Abortion Problem

Presenting complaint

The classical presenting complaint is usually numerous abortions clustered in time, generally starting one to two weeks before the ewes or does are due to start giving birth. Normally, no more than 2% of females should abort each gestation. A rate of 5 to 10% is abnormal and is seen in flocks with endemic disease. Abortion "storms" can affect a significant portion of the pregnant flock within a short period of time. The veterinarian should also remember that any of the following could indicate an abortion disease issue: decreased lambing or kidding rate; non-viable fetuses seen on ultrasound; increased rate of return to estrus; and/or increased stillbirth rate and poor viability of newborns.

History

The history will help create an appropriate list of diagnostic hypotheses. The following information will help:

- Number, proportion, type, age and source of animals aborting;

- Plotting out on a calendar when abortions occurred (clustering) and gestational age;
- Recent introductions to the flock (even virgin replacement females) or sharing of animals in the last year, including rams or bucks;
- Previously diagnosed abortions or illness in the flock;
- Vaccination history, including abortion vaccines, and timing and frequency of administration;
- Nutritional and grazing history, e.g. salt or mineral supplementation, silage feeding or toxic weed exposure;
- Potential exposure to toxins including drugs, e.g. an anthelmintic with a known teratogenic effect;
- Environmental factors, e.g. extreme heat during early pregnancy, stress, predation, presence of cats, rats on the property;
- Clinical illness in the individual ewe or doe before, during or after abortion.

General inspection

Assess the environment in which the animals are housed. Are the animals in good body condition, is there evidence of diarrhea, do they have access to water, palatable free-choice salt and mineral? Is there evidence of rodent or cat feces in the vicinity?

Clinical examination

The adult: examine both the pregnant at-risk animals as well as aborted. If the females are ill, this might support some hypotheses such as listerial abortion or salmonellosis. Often the females look healthy while aborting but may have had a history of being transiently off-feed, such as with *Campylobacter* spp.

The fetus: determine how premature the fetus is (size, crown-rump length, evidence of wool/hair coat). Was the fetus alive when aborted? Is the abortion fresh, macerated or mummified? Look for skin lesions that may indicate a mycotic or bacterial infection. Are there congenital defects such as arthrogryposis, spina bifida, cleft palate, or microopthalmia? Is the fetus meconium stained?

The placenta: examine the cotyledons for evidence of inflammation (swelling, hyperemic, purulent debris), necrosis or calcification. Check the intercotyledonary space for evidence of inflammation, thickening, necrosis, or hyperemia. Normal intercotyledonary placenta should be transparent and thin, e.g. you can read the paper through it.

Submission for diagnostic testing

In almost all cases, laboratory support is necessary to make a definitive diagnosis. Have the producer gather up all the abortions and placentas available.

They should be placed in a clean, water-proof sac (e.g. garbage bag) and kept cool and away from scavenging animals (e.g. rodents, cats, and dogs) prior to submission. Instruct the client regarding the zoonotic risk and to wear gloves and protective clothing. Submission of placenta is critical.

When submitting, it is very helpful to indicate a list of diagnostic hypotheses and to direct the pathologist on what you consider the most likely cause(s) of the abortion. In many diagnostic laboratories, the pathologist cannot run tests unless you request them. For this reason, your input is critical for the success of the diagnostic investigation.

Submission of entire fetuses and placentas: gently remove debris but do not wash off; submit all specimens available; do not freeze before submitting, but do keep chilled; submit in leak-proof, clean containers.

Necropsy and submission of specimens from fetuses and placentas: it is not always possible to submit entire fetuses and placentas. In this case, perform a gross necropsy, make note of any abnormal findings, and submit as outlined below or follow your provincial / state diagnostic lab's recommendations on appropriate samples to submit. Submit a separate tissue sample for each lab section, i.e. bacteriology, virology, and mycoplasmology in separate, sealed, and labeled Whirl-Pak bags. Keep fresh tissues chilled using ice packs in insulated leak-proof containers. Submit tissues showing typical lesions.

- Placenta formalin-fixed. At least two cotyledons + intercotyledonary area. Include areas with obvious lesions.
- Placenta - fresh. Place into separate sealed bag. *Coxiella burnetii* may be present in large numbers on the placenta and should be carefully handled. Polymerase chain reaction (PCR) is useful for detection of *C. burnetii* and *Chlamydophila abortus*
- Fetal tissues - formalin-fixed. Eyelid, skeletal muscle, thyroids (submit with tracheal section), thymus, lung, myocardium, liver, kidney, adrenal, spleen, jejunum, spiral colon (with meconium), and brain. Immunohistochemistry can be requested for several of the disease agents, such as *Toxoplasma gondii*.
- Fresh in one bag. Lung, spleen, liver, thymus, and thyroid for isolation of border disease virus (BDV).
- Fresh in one bag. Lung and spleen for *Chlamydophila abortus* ELISA (do not include placenta).
- Fresh in one bag. Lung and liver for bacterial and mycoplasma culture.
- Stomach content (in sterile leak-proof container) for culture.
- Fresh in serum tube. Fetal thoracic fluid or

heart blood (serum) for analysis for titers to BDV and *Toxoplasma gondii*.

Serum from females: serology is not as rewarding, as a titer doesn't always indicate causality. However, if aborted fetuses and placenta can't be obtained, serology may offer some clues as to why the abortions occurred. Sample all aborting females and a portion (minimum of 10%) of pregnant ewes or does. Submit paired sera - acute and convalescent (10 to 21 days after acute sample)—to demonstrate a rising titer.

Managing the aborting flock

While developing a therapeutic plan, there are actions that may influence the severity of the outbreak or may reduce the risk to humans. Remove the *pregnant* females from *aborted* females, which should remain in the contaminated pen or pasture. If you have a working diagnosis, it may be prudent to initiate specific control measures before the diagnosis is confirmed. If the aborted females are to be culled, they should be sent directly to slaughter once the vaginal discharge has cleared. This practice avoids the risk of being taken into another flock as a breeding animal.

Zoonotic risks

Be aware of the zoonotic risks from many of the infectious agents. Advise the producer and others working with the animals to wear gloves, boots, and protective clothing that are changed before managing the rest of the flock. These clothing items should never go in the house, but should remain in the barn and should only be used when managing the aborting animals. Fitted N95 respirators are also recommended, as some of the disease agents can be aerosolized. These masks should be worn when assisting a birth or removing an abortion or cleaning the barn. Pregnant women or immune-compromised people should not assist at birthing and should, if possible, not have contact with the pregnant, aborting or newly lambed /kidded females and offspring.

Causes of Abortion in Sheep and Goats

There are many regional differences in diseases that cause abortion in these species. Sometimes, knowing the history of an area can help refine the list of reasonable hypotheses. Others can be eliminated based on clinical findings. But having a knowledge base of what can occur is critical to being able to propose an appropriate therapeutic plan.

In Canada and the US, most cases of infectious abortion in sheep and goats are linked to infection with *Campylobacter jejuni*, *Campylobacter fetus* subsp *fetus*, *Chlamydophila abortus*, *Coxiella burnetii* or *Toxoplasma gondii,* and sometimes a combination of those diseases. Most cases of non-infectious abortion are linked to io-dine deficiency - at least in parts of North America that are iodine-deficient. There are many other uncommon causes which can also result in dramatic losses. Some are briefly covered here. A more complete list is presented in Table 1.

Campylobacter species

The agent: both *Campylobacter jejuni* and *C. fetus* subsp *fetus* have been implicated in ovine abortion. Abortion in goats from these agents is unusual. The bacteria reside in the intestinal tract of sheep and many other species, including dogs and birds, including domestic poultry. Recent research suggests that *C jejuni* has a serovar which is more abortifacient. In central and eastern North America, it is the most prevalent cause of campylobacter abortion. *C fetus* subsp *fetus* appears to be more common in western North America in large range flocks and in New Zealand. There are several serotypes of *C fetus* subsp *fetus* (A2 and C versus B1 in New Zealand), although no recent work has been published on the types in North America. It is likely that strains do vary over time, which may affect vaccine efficacy. Recently the Animal Health Laboratory at the University of Guelph has found an equal distribution between *C. jejuni* and *C. fetus* subsp *fetus* (Dr. D. Slavic, personal communication April 2012).

Transmission and pathogenesis: the organisms are harbored in carrier sheep in the intestine and gall bladder. Sources of infection are from contamination of feed or water from feces, fetuses, placenta, and vaginal discharges from aborted ewes. Carrion birds such as crows may enable transmission between flocks. Incubation ranges from eight to 60 days.

Clinical picture: most abortions occur during the third trimester about three days following fetal death, with occasional stillbirth and weak lambs. Fetuses are expelled well preserved with the placenta. Ewes may have transient diarrhea and fever. The placenta tends to be edematous with congested, swollen cotyledons. The fetus may have subcutaneous edema and an enlarged abdomen with pleuritis, peritonitis, and hepatitis, with occasional target lesions of hepatic necrosis. Abortion levels of up to 70% have been reported, but levels of 10 to 20% are common in enzootically infected flocks. Immunity from one species of campylobacter is not cross-protective to another, but natural immunity of up to three years can occur.

Diagnosis: stain impression smears of cotyledons or fetal stomach contents will demonstrate the organism. The placenta and fetal abomasal contents should be cultured. Antibiotic sensitivity testing must be done on any isolates, as resistance to tetracycline is very common with *C. jejuni* in the north-central US and in Ontario.

Control and prevention: in the face of an outbreak, all pregnant ewes should be treated with an antibiotic

Table 1. Causes of abortion in sheep and goats in Canada and USA.

Infectious	Non - Infectious
Common	
Campylobacter jejuni – S, G (rare)	Congenital goiter due to iodine deficiency – S, G, R
Campylobacter fetus subspecies *fetus* - S	Trauma – S, G
Chlamydophila abortus – S, G	
Coxiella burnetii – S, G	
Toxoplasma gondii – S, G	
Border disease virus – S, G (rare)	
Listeria monocytogenes – S, G	
Uncommon	
Bacillus spp – S, Sp	Selenium deficiency – S, G, R
Bluetongue virus – S, R	*Astragalus spp and Oxytropis spp (locoweed)*– S, R
Brucella ovis – S, R	Starvation – S, G
Cache Valley virus – S, R	Overnutrition – S, G
Caprine herpes virus I – G	Heat shock – S, G, R, Sp
Leptospira interrogans serovars – S, G, R	Sheep / goat hybrids – G, Sp
Mycoplasma mycoides subsp. *mycoides* - G	Congenital enzootic ataxia (Cu deficiency) – S, G, R
Mycotic – S, G, Sp	Habitual abortion of Angora goats – G
Neospora canis – S, G	Drug toxicities such as levamisole - G
Sarcocystis tenella and *S arieticanis* – S, Sp	Prostaglandin products - G
Salmonella –pathogenic serovars – S, G, Sp	
Streptococcus dysgalactia – S, Sp	
Yersinia spp – S, Sp	
Infectious causes exotic to Canada and US at present	
Akabane virus – S	
Anaplasma phagocytophilum (tick-borne fever) – S, G	
Brucella melitensis – S, G	
Nairobi sheep disease virus – S, G	
Peste des petits ruminants virus – S, G	
Rift Valley fever virus – S, G	
Salmonella enteritica – abortifacient serovars (*montevideo, abortus ovis*) – S,	
Schmallenberg virus – S, G	
Wesselsbron disease virus – S, G	

S = sheep; G = goat; Sp = sporadic; R = regional incidence

that is likely to be efficacious. Long acting oxytetracycline at the label dose once (9.1 mg/lb or 20 mg/kg) or in the feed (250-300 mg/head/day) until lambing is finished can be used, but a recent study found that most abortion isolates of *C. jejuni* are resistant to tetracyclines. The authors did find that the isolates were susceptible to tilmicosin, florfenicol, tulathromycin, and enrofloxacin, and 97% were sensitive to tylosin. In Canada, there is one commercial vaccine available, but there is no published efficacy information. Vaccination can be done in the face of an outbreak, but takes two weeks to develop sufficient immunity to stop abortions. In flocks in which campylobacteriosis has been diagnosed, it is preferred that vaccination be routinely done according to label directions. This involves vaccinating all breeding ewes with a bivalent killed bacterin twice, the first before breeding and the second injection 60 to 90 days later. Annual re-vaccination before breeding should be maintained, although some debate this necessity. A lack of efficacy of the vaccine may be due to several factors. The vaccine may not contain the correct serotype of *Campylobacter fetus* subsp *fetus*, or the abortion is due to another species of campylobacter bacteria.

Chlamydophila abortus (enzootic abortion)

The agent: *Chlamydophila abortus*, previously *Chamydia psittaci* sheep abortion strain, is one of the most common causes of abortion in sheep and goats in North America.

Transmission and pathogenesis: transmission may occur from exposure to aborted materials, vaginal discharge or from environmental contamination and ingestion. Infected males may have *C abortus* isolated from the semen and seminal vesicles. When the infected female becomes pregnant, the organism moves via a haematogenous route to the chorium. By 95 days of gestation, the infection has spread from the cotyledons to the intercotyledonary areas. The fetus also becomes infected, but pathological changes are minor.

Clinical picture: abortion rarely occurs at less than 100 days gestation, but can occur. Females infected in late gestation or when not pregnant, will abort at the subsequent pregnancy – making the purchase of replacement stock from infected flocks an important method of disease introduction. Immunity post-abortion lasts at least three years, but organisms may be shed in vaginal secretions during estrus. The placenta is necrotic, with lesions affecting both cotyledons and intercotyledonary spaces (Navarro 2004). Fetuses may be aborted necrotic, well preserved, rarely mummified, stillborn or alive and weak. Abortion levels can be very high (up to 30%) in the first year of the disease, but decrease in subsequent years to 10 to 15%, and then may only affect ewe-lambs/doelings and new introductions in subsequent years.

Diagnosis: the severe placentitis is typical but not diagnostic. Smears made from the chorionic villi and stained appropriately will demonstrate clumps of intracellular elementary bodies. The organisms can be confused with *Coxiella burnetii*. Immunohistochemistry can differentiate these infections. Use of a specific quantitative PCR can be used on placental tissues. *C. abortus* organisms can be present when it is not the cause of abortion, but numbers tend to be lower (AHL Newsletter). Serology must use acute and convalescent samples to differentiate from vaccination titers.

Prevention and control - vaccination: only an inactivated vaccine, a whole-cell killed vaccine, is available in North America and is approved for sheep only. The vaccination procedure is to initially inject 60 days prior to breeding and administer a second dose 30 days later. Annual revaccination is required. Inactivated vaccines do not prevent shedding of chlamydiae in birth fluids, so the environment remains contaminated, serving to continue the infection cycle.

Prevention and control - antimicrobials: in an outbreak or commencing after 80 days of gestation in sheep flocks known to be infected, injections of long-acting oxytetracycline at label dose (9.1 mg/lb or 20 mg/kg BW) and repeated every two to three weeks may prevent some abortions, although likely fewer than 50%, and there is disagreement whether multiple treatments are justified. Often the placental damage is so severe that antimicrobial therapy is of limited efficacy in the face of an outbreak. Replacement females should be managed as a separate flock/herd until after lambing/kidding to reduce exposure. In chronically infected flocks, feeding levels of 250 to 500 mg/head/day of tetracycline, starting 60 days prior to the first expected lambing/kidding date, is thought to be helpful. Higher levels are generally fed during an outbreak of abortion and lower levels are fed prophylactically, although there is no published information on true efficacy and there is a risk of development of antimicrobial resistance. If dairy animals are treated with antimicrobials during gestation, the veterinarian must assure that at lambing or kidding no antimicrobial residues remain in the milk. Canadian gFARAD has established that the milk withdrawal for a single injection of long-acting oxytetracycline should be a minimum of seven days, but it is strongly recommended to test individual goats prior to shipping the milk.

Zoonotic risk: occasionally *C. abortus* can cause significant human disease, particularly in pregnant women working with aborting or lambing/kidding females.

Coxiella burnetii: this is covered in a separate presentation.

Toxoplasma gondii

Agent: *Toxoplasma gondii* is a protozoan parasite that, in many countries, is one of the most commonly diagnosed causes of ovine and caprine abortion. The sexual part of its life cycle is completed only in domestic and wild cats. The oocysts shed in their feces are infective for up to 18 months when protected from desiccation and sunlight. The asexual component of its life cycle may occur in any warm blooded animal.

Transmission and pathogenesis: non-immune cats, particularly kittens first learning to hunt, may become infected by ingesting food or animals containing cysts, e.g. rodents, offal from slaughtered farm animals, birds, and aborted fetuses and placentas. Cats will shed millions of oocysts from four to 12 days after ingestion, and then become immune. Oocysts, which will remain infective for up to six months, are ingested by small ruminants through contamination of feed, water or pasture. Naïve non-pregnant animals develop immunity without disease, but naïve pregnant animals will also experience fetal infection as the organism has a predilection for the pregnant uterus. Infections in mice populations are persistent due to vertical transmission.

Clinical picture: infection of the fetus prior to 40 days results in resorption; between 40 to 120 days in maceration, mummification or abortion; and after 120 days, stillbirths or birth of weak or healthy immune offspring. Abortion levels within the flock may vary from

5% to 100%. The history usually includes contact with kittens, either directly or from fecal-contaminated forages or grain. A few weeks to days before the expected onset of lambing/kidding, ewes or does may start to abort. Often all levels of infection happen within the same outbreak and sometimes within the same litter, e.g. a weak lamb may be born with a mummified fetus. The ewes and does do not appear ill. Sheep are immune, but goats may abort in subsequent gestations.

Diagnosis: the fetuses may be mummified or aborted in a decomposed state. Subcutaneous edema and blood-tinged fluid with strands of fibrin in the body cavities may be seen. The placental cotyledons appear bright to dark red, and are speckled with white calcified foci of necrosis 2 mm in diameter. The intercotyledonary placenta appears normal. The toxoplasms are not numerous, and are often seen only on the periphery of lesions. Immunohistochemical techniques help to demonstrate organisms more clearly, even in decomposed tissues. Approximately two weeks post-infection, antibody titers rise and remain high for several years. A positive titer in a ewe or doe is not diagnostic. However, a positive titer from an aborted fetus indicates congenital infection. Negative titers in the dam will aid in ruling out toxoplasmosis.

Control and prevention: often little can be done during an abortion "storm", so control measures are important. Feeding monensin at a dose rate of 16.8 mg/head/day or decoquinate at 0.91 mg/lb (2.0 mg/kg)/day in the final 14 weeks of pregnancy has been shown to be an effective prophylactic. Lasalocid does not appear to be effective. A modified-live vaccine has been developed which confers excellent immunity for at least 18 months and probably for life, but is not available in North America. Removing all cats from the farm or spaying all the queens to eliminate new crops of kittens will reduce contamination of the environment. Cats should also be prevented from defecating on hay and grain. Kitty litter boxes can be kept in the barn near where the cats tend to congregate in order to encourage their use instead of the feed. The top layer of hay bales should be fed only to non-pregnant animals and the grain should be stored in metal containers to prevent access by rodents. All of these measures may help to reduce incidence but will not prevent all possible routes of exposure. Feral cats, purchased feeds, and vertical transmission within rodents may help to perpetuate infection within a farm.

Zoonotic disease: pregnant, non-immune women are the most at risk of disease. *T. gondii* can cause congenital neurological disease and blindness in human fetuses. It is an important cause of encephalitis in humans suffering from Acquired Immunodeficiency Syndrome. Most humans probably become infected from consuming undercooked meat, although handling of cat feces should be considered as a source. Freezing meat to 10.4°F (-12°C) for one day or cooking meat to 150°F (67°C) will kill tissue cysts. Microwave cooking is uneven, and may leave some cysts viable.

Congenital goiter due to iodine deficiency

The entire Great Lakes region, as well as many of the Prairie provinces and northwestern states, have soils deficient in iodine. Most outbreaks are associated with failure to provided iodized salt to gestating females, or the salt is not readily available free choice (e.g. buried under hay or bedding, spoiled with feces).

Clinical picture and diagnosis: abortion and stillbirth due to iodine deficiency goiter occur often at very high levels. The fetuses exhibit swellings on either side of the neck region that are shown to be enlarged goitrous thyroid glands. Normal thyroid glands are very small (< 2-3 mm) and enlarged glands can measure up to 2-3 cm (about one inch) in size. Absence of wool or hair is also commonly seen with late-term abortions, and in severe cases, myxedema is evident in the limbs and abdomen. Lambs and kids born alive are very weak and, unless supplemented with iodine, usually die. Boer goats appear to be more at risk of congential goiter.

Control and prevention: once diagnosed, the rest of the pregnant group should be supplemented with oral iodine. It has been suggested that Lugol's iodine be added to the water or that 1 to 2 mL of tincture of iodine be painted on the skin once per week. To prevent problems, iodine should be fed at a rate of 0.23 to 0.36 mg/lb (0.5 to 0.8 mg/kg) of dry matter (DM) diet, with the higher end recommended for lactating ewes and does (NRC, 2007). Sheep grazing goitergenic brassicas such as kale, cabbage or turnip tops may require higher levels of supplementation, up to 0.91 mg/lb (2 mg/kg) DM. These plants interfere with I uptake or interfere with T_4 - T_3 conversion. Toxicity will occur at levels around 90 mg/kg DM, but at lower levels iodine may be excreted in the milk of dairy animals, which may pose a risk to human health. Sources of I are ethylene diamine dihydroiodide (EDDI) (~365 gm/lb or 800 gm/kg) and potassium iodide (KI) (~275 gm/lb or 600 gm/kg). Another source of I commonly used is kelp. Analyses vary with different products but average about 0.05% or 225 mg/lb (500 mg/kg) DM. Adult dairy does during lactation need between 2 and 4 mg/day. Therefore, kelp products should not be fed at a rate higher than 4 to 8 gm/day (~ 1/5 to 1/4 of an ounce). There is no zoonotic risk.

Listeria monocytogenes

Agent: *Listeria monocytogenes* causes abortion, encephalitis, and septicaemia in sheep, goats, cattle, and humans. It is found widespread in the environment and may contaminate feed and objects, as well as be present in rodents and insects. *L. ivanovii* has been implicated only in sheep abortions.

Transmission and pathogenesis: *Listeria* spp grow well in poor-quality, alkaline silage (pH > 6.0). Contamination of the silage occurs from soil and mouse, bird or other animal feces which are inadvertently ensiled. Outbreaks have also occurred on pasture, where it is likely that the pastures were contaminated with feces containing the organism. *Listeria* causing encephalitis probably enters through the oral cavity and invades up the facial nerves to the brain. Abortion occurs less commonly, some seven to 30 days after infection.

Clinical picture and diagnosis: abortion is accompanied by metritis with marked illness. The liver and brains of aborted fetuses reveals microabscessation of those organs. Culture will confirm the diagnosis.

Control and prevention: in an outbreak, prophylactic treatment with long-acting oxytetracycline (9.1 mg/lb or 20 mg/kg) may avoid further cases. Prevention should focus on providing only good quality silage and taking measures to avoid soil contamination and ensure anaerobic conditions are maintained. Addition of acidifying agents at ensiling time may help reduce the pH, thus inhibiting growth of *Listeria*. Holes in bags, or a wide front to the bunker, will invite growth of *Listeria*. Silage that appears spoiled should not be fed to sheep or goats.

Zoonotic disease: listeriosis is an important foodborne disease, particularly of improperly pasteurized milk products (e.g. soft cheeses) and processed meats. Additionally, the organism can grow at refrigerator temperatures. It is not known if disease in a flock or herd increases the risk of foodborne transmission.

Border disease virus

The agent: border disease virus (BDV) is a pestivirus closely related to bovine viral diarrhea virus (BVDV). There are many strains of BDV isolated from clinical cases of border disease, and occasionally some of the outbreaks are actually due to infection with BVDV from exposure to persistently infected cattle. Mostly the disease occurs in sheep, but can also occur in goat herds.

Transmission and pathogenesis: after the virus invades immunologically naive females, it attacks the placenta but does not cause illness in the females. Most fetuses infected in utero prior to day 60 to 85 of gestation are reabsorbed, aborted, macerated or mummified. Those that survive are congenitally damaged. Myelination of nerve cells is disturbed, particularly in the cerebellum. Hair follicles will produce hair rather than wool. Surviving lambs are born persistently infected (PI) with BDV, and shed virus in urine, feces, and saliva. Fetuses infected after day 85 may abort or be born weak or unaffected, virus negative, and with a pre-colostral titer to BDV. It is possible to have several levels of signs present in the same litter of lambs.

Clinical picture: abortion is seen in the flock, followed by the birth of congenitally affected and/or weak, PI lambs. These lambs have shortened facial and long bones with a wool coat that is frequently hairy and darkly pigmented, particularly over the shoulders and neck. They may show mild to severe body tremors and are commonly termed "hairy shakers". Case fatality rates in PI lambs are very high.

Diagnosis: BDV can be isolated from aborted fetuses and from the buffy coat of affected lambs. Antigen-capture ELISA can be used on the sera of suspected persistently infected adults and lambs older than two months. Serum titers from the aborted ewes tend to show high antibody levels, although this is not diagnostic. If an aborting ewe is a PI, then antibody levels will be low or absent, but virus can be isolated or detected from the serum or buffy coat.

Control and prevention: after an outbreak of BDV abortion, all congenitally affected lambs should be kept separate from the breeding flock and sent to slaughter as young as possible. Replacement lambs older than two months should be screened for virus. Cattle and sheep should be kept separated, including no shared feeders or water sources, and an effective vaccination program for BVDV should be maintained in the cattle herd. There is evidence that cross protection is poor between BVDV and BDV, so there is no advantage to vaccinating sheep with a killed or modified-live BVDV vaccine unless BVDV has been isolated.

Zoonotic disease: BDV is not zoonotic.

Uncommon Causes of Abortion in North America

Salmonellosis: many salmonella serovars have been implicated in ovine abortion. Three serovars *S abortusovis*, *S montevideo*, and *S arizonae* have a predilection for ovine pregnancies. Abortion rates in these outbreaks can be very low (< 1%) to as high as one-third of the pregnant flock. Many other species of salmonella have been implicated in ovine abortion, with significant adult mortality. *S dublin, S typhimurium, S schwarzengrund, S brandenburg*, as well as others, have been reported as associated with abortion and ewe death due to metritis and septicemia. These organisms may be introduced through contaminated feed, carrion birds, and carrier animals such as dogs, cats, rats, and livestock. Usually these sporadic, opportunistic outbreaks disappear from the flock and don't persist to the following season. All serovars of Salmonella can be considered zoonotic, and care should be taken.

Brucellosis (*Brucella ovis* and *Brucella melitensis*): *B. ovis* is a common cause of epididymitis in rams in some countries, and occasionally causes abortion in ewes. The organism is spread through contact between mucous membranes (vaginal, preputial, conjunctival), both ram to ewe and ram to ram, but not ewe to ewe. Abortion is

rare, but levels of 25 to 35% have been reported. Placentitis is marked, with the organism easily cultured. Examination and serology of the breeding rams should also be performed. Rams should not be shared between flocks. *B melitensis,* exotic to the US and Canada, should be considered as a rule-out, particularly in states bordering Mexico. *B. ovis* is not zoonotic, but *B. melitensis* is an important zoonotic disease in many parts of Asia, Africa, and Mediterranean countries.

Leptospirosis: the most common agent in sheep is *Leptospira interrogans* serovar Harjo although *L. pomona* has been isolated from cases. It is an unusual cause of abortion in sheep, but should be considered in areas where leptospirosis is a problem in cattle, pigs or wildlife. Ewes abort or have stillborn lambs and may also have high fevers, flaccid agalactia, hemoglobinuria, and jaundice. An important rule-out is copper toxicosis.

Bluetongue virus: bluetongue virus (BTV) is an arthropod transmitted orbiviral disease of domestic and wild ruminants. The virus requires an arthropod midge vector *Culicoides veriipennis* for transmission. In North America, it is found endemically in the southern and western United States, as well as parts of the Caribbean, Mexico, and Central America. At this time, it is exotic to Canada. Clinical expression of the disease tends to be seasonal (fall) and linked to the midge's seasonal cycle, which prefers a wet and warm environment. Sheep infected with BTV show signs of high fever, swollen ears, face and tongue, oral and nasal ulcers, and lameness. Up to 20% of fetuses infected in early gestation have varying degrees of hydranencephaly and skeletal deformities, and may be aborted or carried to term.

Cache Valley virus: Cache Valley virus (CVV) is an arthropod-borne virus associated with ovine abortion. In North America, CVV has been implicated in outbreaks of congenital deformities in the southwestern US, particularly Texas, and occasionally in the northeast and southern Ontario. CVV is transmitted mainly by mosquitoes that feed on wild (e.g. deer) or domestic large ruminants. Abortion occurs in early January, as the ewes must be in early gestation during the fall when the viral load in the mosquito population is at its peak. Signs are early embryonic death, mummification, arthrogryposis, and CNS deformities. A titer in the fetus is diagnostic, and occasionally tissues are positive on PCR. Lack of a titer in the aborting ewe rules out the disease. If CVV is a regional problem, avoid breeding sheep in mosquito-infested pastures, or wait until after a killing frost before turning in the ram. CVV has only rarely been implicated in encephalitis in humans, but is not caught from sheep but rather from infected mosquitoes.

Neospora canis: *N. canis*, a protozoal parasite of livestock and companion animals, is one of the most commonly diagnosed causes of abortion in dairy and beef cattle. However, there are few reports in the literature of naturally occurring *Neospora* infection in sheep or goats. However, sheep and goats are susceptible to this organism, so it should be considered as a diagnosis in cases of protozoal abortion when toxoplasmosis is ruled out.

Sarcocystosis: abortion due to *Sarcocystis* species is unusual, but there are difficulties with definitive diagnosis. Sheep may be infected by four species of *Sarcocystis*. Two are pathogenic - *S. tenella* and *S. arieticanis,* and may cause abortion during the acute phase infection. Detection of infection with pathogenic species can be done using a species-specific PCR on blood samples of infected sheep, and will help to differentiate infection with other protozoal parasites of sheep.

Selenium deficiency: this has been associated with early embryonic death and abortion due to congenital white muscle disease. Se supplementation in many regions of North America is nutritionally critical for sheep and goats, as deficiency in the soils is widespread, particularly in eastern and western regions. Se should be added to the ration at a rate of 0.045 to 0.14 mg/lb (0.1 to 0.3 mg/kg) DM diet, with 0.11 mg/lb (0.25 mg/kg) the probable optimum level for supplementation when feeding deficient rations. The Se may also be fed as a supplement or salt-mineral mixture to be consumed at a rate of 0.23 - 0.46 mg/sheep/day from the breeding period forward. Injection of the pregnant ewe of Se commercial preparations at a rate of 0.025 mg/lb (0.056 mg/kg) body weight, one month prior to lambing, has been shown to decrease the risk of congenital myopathy, but needs to be repeated every two weeks.

Energy/protein deficiency: at the time of breeding, energy and to a lesser extent protein deficiency, is associated with embryo loss. If the female is not fed adequately for the first and second trimesters, this will adversely affect placental growth and attachment to caruncles. Reduced birth weights and mummification are outcomes of this. Inadequate energy in the third trimester will inhibit fetal growth. Lambs or kids will be born small with poor body fat reserves, and be more at risk of hypothermia.

Overnourishment of adolescent ewes: if peripubertal ewe lambs are fed a balanced ration intended to promote rapid growth, there is a marked detrimental effect on placental mass, the number of cotyledons per placenta, and subsequent birth weight of the lambs. Laboratory data on these lambs reveals elevated serum urea and on postmortem, these lambs have abnormal kidneys and gut.

Astragalus spp and *Oxytropis* spp (locoweed): ingestion of locoweed can cause abortion, birth defects such as arthrogryposis, right heart hypertrophy resulting in hydrops amnios and hydrops allantois, reduced birth weight and weak lambs. The severity of the effect is dose-dependent on the amount of plant ingested and the time of gestation. The toxin is the indolizidine alkaloid

swainsonine. It appears to cause these pathologies through delaying embryo implantation, interruption of vascular development and inducing alternations in fetal fluid balance. It has been suggested that for some geographic regions where these plants grow commonly, i.e. the western United States, locoweeds are a very important cause of abortion and reproductive failure.

Stress/trauma: abortion can be seen after an unusual stress, e.g. predator attack, shearing, inappropriate handling. While it is possible to handle late-gestation ewes and does, care should be taken. Associated with inappropriate handling is the risk of fetal trauma (ruptured liver or kidney). This may happen in a chute or being run through a gate, but fighting and shoving between females at a feeder is also a cause.

Habitual abortion of angora goats: a suspected genetic cause of abortion in Angora goats is linked to finer fiber diameter and overproduction of maternal cortisol. This results in third parity-plus does aborting at 90 to 120 days of gestation. It may be a genetic linked to fiber quality, or it may be management. Regardless, when investigating abortion problems in Angora goats, it is best to first eliminate the possibility of other causes.

Sheep-goat hybrids: does housed with rams can become pregnant, but most often abort by 60 days, or occasionally later. The cotyledons are large and unusual in appearance, and the fetus may have an anasarca appearance. Occasionally, the abortion may be associated with dystocia and maternal death. For this reason, it is important not to house mature does with rams. It appears that ewes bred by bucks do not conceive.

There are many other miscellaneous causes of abortion in sheep and goats. Prompt and appropriate investigation of an abortion problem will often lead to a diagnosis, and thus will yield valuable information to the practitioner to help control the abortion problem and protect the health of the producer and family.

Additional Sources of Information

Blasco JM, Molina-Flores B. Control and eradication of *Brucella melitensis* infection in sheep and goats. *Vet Clin North Am Food Anim Pract* 2011;27:95-104.

Menzies PI. Control of important causes of infectious abortion in sheep and goats. *Vet Clin North Am Food Anim Pract* 2011;27:81-93.

Menzies PI. Vaccination programs for reproductive disorders of small ruminants. *Anim Repro Sci* 2012;130:162-172.

Stuen S, Longbottom D. Treatment and control of chlamydial and rickettsial infections in sheep and goats. *Vet Clin North Am Food Anim Pract* 2011;27:213-234.