Malignant Catarrhal Fever

Malignant Catarrh, Malignant Head Catarrh, Gangrenous Coryza, Catarrhal Fever, Snotsiekte

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Importance

Malignant catarrhal fever (MCF) is a serious, often fatal, disease affecting many species in the family Artiodactyla (even-toed ungulates) including cattle, bison, deer, moose, exotic ruminants and pigs. At least ten MCF viruses have been recognized, including two well-known viruses carried by sheep and wildebeest; five MCF viruses have been linked to disease, while the others have been found, to date, only in asymptomatic carriers. Each MCF virus is highly adapted to its usual host and does not normally cause disease in that species, but can cause fatal infections if transmitted to other susceptible ruminants or pigs.

Malignant catarrhal fever occurs in many countries including the U.S. This disease is a particular problem in zoo animals, farmed bison and farmed deer, but cattle are also affected frequently in Africa and Indonesia. Although sporadic cases are the usual pattern of disease, serious outbreaks can also occur. During one recent U.S. outbreak, approximately half of the herd (800 bison) died. Malignant catarrhal fever is difficult to control, as the causative viruses are carried inapparently by the majority of sheep, goats and wildebeest, the incubation period can be long in susceptible animals, latency is possible, and the only reliable methods of control are to separate susceptible species from carriers or breed virus-free reservoir hosts.

Etiology

Malignant catarrhal fever is caused by several viruses in the genus *Rhadinovirus* of the family Herpesviridae (subfamily Gammaherpesvirinae). The MCF subgroup of viruses (MCFV or type 1 RuRV) contains at least ten members, five of which are known to cause disease. Ovine herpesvirus 2 (OvHV-2), endemic in most sheep, is the major cause of MCF worldwide. Alcelaphine herpesvirus 1 (AlHV-1), which is endemic in wildebeest (*Connochaetes* spp.), causes the wildebeest-associated form of MCF in cattle and other species. Caprine herpesvirus 2 (CpHV-2) is endemic in most domesticated goats and can cause MCF in cervids. A virus of unknown origin, currently called MCFV-WTD, has also been associated with MCF in white-tailed deer. In addition, a MCF virus found in asymptomatic ibex was recently linked to disease in bongo antelope (*Tragelaphus euryceros*). Several other MCFV have been found in exotic ruminants including musk ox, gemsbok/ South African oryx (oryx-MCFV), aoudads, hartebeest (alcelaphine herpesvirus 2 [AlHV-2]), topi (AlHV-2), and roan antelope (hippotragine herpesvirus-1 [HiHV-1]). HiHV-1 appears to be very similar or identical to the MCF identified in oryx. The latter group of viruses has not yet been definitely linked to disease; however, a virus resembling AlHV-2- was found in sick Barbary red deer.

Species Affected

MCF viruses are carried asymptomatically by their reservoir hosts, but can cause disease in other species. Wildebeest are the carriers for AlHV-1. All or most wildebeest in the wild, and most wildebeest in zoos, appear to be infected by this virus. Most sheep are infected with OvHV-2, and most goats are infected with CpHV-2. The normal host for MCFV-WTD is not known. Other exotic ruminants known to have MCFV include ibex, musk ox, gemsbok/ South African oryx, aoudads, hartebeest, topi and roan antelope.

Clinical disease occurs in members of the order Artiodactyla (even-toed ungulates). Most susceptible species are in the subfamily Bovinae (e.g. cattle, bison, water buffalo and exotic ruminants such as antelope, guar and banteng) and family Cervidae (e.g. deer, reindeer, moose), but other species such as giraffes (family Giraffidae) and pigs (family Suidae) are also affected. Susceptibility varies with the virus and the host. Most cattle (*Bos taurus* and *Bos indicus*) are susceptible to AlHV-1 but are relatively resistant to the sheep-associated (OvHV-2) form of MCF. Water buffalo and some species of deer are more susceptible to OvH-2, and bison, Père David's deer, white-tailed deer, axis deer and Bali cattle (*Bos javanicus*) are highly susceptible to this virus. Sheep-associated MCF has also been reported in pigs, and lesions have been reported in goats. CpHV-2 associated disease has been reported in cervids including moose, roe deer, sika deer and white-tailed deer. MCFV-WTD can

also cause disease MCF in white-tailed deer. The ibex-associated MCF virus has caused disease in bongo antelope (*Tragelaphus eurycerос*), and a virus resembling AlHV-2- has been found in sick Barbary red deer. Most cases of MCF have been reported in captive animals, but wild moose and deer can also be affected. Experimentally infected animals include a variety of ungulates, hamsters and rabbits.

In unusual cases, MCF viruses might be able to cause disease in their normal hosts. MCF-like disease can be produced in sheep infected experimentally with high doses of OvHV-2. This appears to be uncommon or nonexistent in nature.

Geographic Distribution

MCF viruses can be found worldwide, but the occurrence of disease depends on the presence of both an appropriate virus and a susceptible host. Disease caused by OvHV-2 and CpHV-2 can be seen throughout the world. AlHV-1 associated disease mainly occurs in cattle in areas of Africa south of the Sahara desert where wildebeest are found. Malignant catarrhal fever is also seen frequently in cattle in Indonesia, where OHV-2 susceptible Bali cattle are common, but it is rare in countries where *Bos taurus* and *Bos indicus* cattle are the predominant species. Several MCF viruses, including AlHV-1, can cause disease in zoos and wild animal parks that contain both virus carriers and susceptible species.

Transmission

MCF viruses, like other herpesviruses, establish lifelong, latent infections. AlHV-1 is transmitted mainly by wildebeest calves, which can become infected *in utero*, by direct contact with other wildebeest, or in aerosols during close contact. Contamination of pastures may also contribute to transmission. Infected calves, particularly animals one to two months of age, shed the virus in nasal and ocular secretions. Wildebeest calves over the age of six months rarely shed virus. In these animals and in adult wildebeest, AlHV-1 occurs mainly in a cell-associated, rarely transmitted form; however, cell-free virus can be isolated from the nasal secretions of some animals that are stressed or given corticosteroids. Most cases of wildebeest-associated MCF are seen when susceptible animals are exposed to parturient wildebeest or young calves. Close contact is usually necessary, but transmission has been reported when the animals were separated by at least 100 meters. Cell-associated MCFV is very fragile, and infectivity disappears after 72 hours in the environment; however, cell-free virus can survive for more than 13 days in humid environments. MCF viruses are inactivated quickly by sunlight.

OvHV-2 appears to be transmitted mainly by the respiratory route, probably in aerosols. This virus is shed intermittently in nasal secretions, particularly by 6 to 9 month old lambs. OvHV-2 DNA has also been reported in the semen of rams. Unlike AlHV-1 in wildebeest, OvHV-2 is rarely transmitted transplacentally or in colostrum or milk; most lambs do not become infected until they are at least two months of age. Susceptible animals usually become infected when they are in close contact with sheep, but cases have been reported when sheep and cattle were separated by 70 meters, as well as in bison herds up to 5 km from a lamb feedlot.

Ruminants that develop malignant catarrhal fever are usually dead end hosts. A few instances of animal-to-animal transmission have been suspected in cattle and OvHV-2 infected deer, but definitive evidence for horizontal transmission does not exist. Subclinical, possible latent, infections have been reported in some incidental hosts including cattle, bison and cervids. Recrudescence might be possible in these animals. Case reports suggest that some non-reservoir hosts might be able to transmit MCF viruses to their offspring.

Incubation Period

The incubation period varies with the virus, host and other factors, and is incompletely understood. Cattle can become ill in as little as nine days, but some cases occur 70 days or longer after exposure. In bison exposed to sheep, the incubation period is often a month or more. Latent infections are also possible. Epidemiological evidence suggests that some cattle may be infected subclinically for more than 20 months before developing disease. In one outbreak in subclinically infected bison, clinical cases tended to occur 3 to 14 days after the animals were stressed by handling.

Clinical Signs

Malignant catarrhal fever is a broad syndrome with a variety of symptoms in different species. Subclinical infections are usual in reservoir hosts, and have also been reported in some incidental hosts such as cattle and bison. Clinical MCF is very similar whether it is caused by OvH-2 or AlHV-1. Peracute disease, which tends to occur in highly susceptible species, is characterized by few clinical signs, rapid progression and death. Sudden death can occur in this form, or death may be preceded by 12 to 24 hours of depression, weakness, diarrhea or dysentery. More apparent clinical signs are seen when animals survive longer Animals with acute disease develop a high fever and inappetence. Cattle often have bilateral corneal opacity that begins at the corneoscleral junction and progresses inward. Serous oculonasal discharge is common early; later, this discharge becomes mucopurulent. The muzzle and nares are usually encrusted, and dyspnea, open-mouthed breathing and salivation may be seen. The oral mucosa is often hyperemic and may contain multifocal or diffuse areas of necrosis. Erosions may be found at the tips of the buccal papillae. The skin is sometimes erythematous or ulcerated, and hardened scabs may develop, particularly on the perineum, udder and teats. In some animals, the horn and hoof coverings may be loosened or sloughed.

The joints may be swollen, milk production often drops, and the superficial lymph nodes are markedly enlarged in cattle. Diarrhea, hemorrhagic gastroenteritis or hematuria also occur. Occasionally, animals have nervous signs including hyperesthesia, incoordination, disorientation, tremors, nystagmus, or head pressing. Although many animals die, chronic infection or recovery is possible. Skin lesions have been reported in cattle without other clinical signs, and may resolve spontaneously.

The symptoms are similar in other species, but often vary in some aspects. Bison frequently die of acute MCF without developing purulent rhinitis or keratoconjunctivitis. Anorexia, depression, corneal opacity, lacrimation, mild serous nasal and ocular discharge, coughing, salivation, diarrhea, melena, hematuria and neurological signs may be seen in some cases, but in many bison herds, the symptoms are subtle. Unlike cattle, which develop prominently enlarged lymph nodes, lymphadenomegaly is usually minimal. In the last stage of the disease, bison often develop an edematous band at the corneoscleral junction; this lesion is difficult to recognize in live animals. Bison attempt to mask the clinical signs until they are near death. Inhalation pneumonia is common in the last stage of the disease, and some sick bison may be attacked by herdmates, resulting in trauma. Recumbent animals generally die within a few hours.

In deer, malignant catarrhal fever is usually acute or peracute, and the characteristic signs may not be seen. In one outbreak, all affected deer died within 1 to 2 days of the onset of symptoms. In other outbreaks, more typical MCF symptoms including corneal opacity, hemorrhagic diarrhea and bloody urine are seen, and some animals survive for up to three weeks after the onset of disease. Unusually, skin lesions have been the primary complaint in some deer infected with CpHV-2. In white-tailed deer infected with this virus, the major lesions were widespread alopecia; thickening, crusting, hyperkeratosis, and focal ulceration of the skin; weight loss; and impaired vision. The hoof walls were shed in some animals. Similarly, sika deer infected with CpHV-2 had skin lesions, weight loss and diarrhea. One sika deer developed seizures but had no other clinical signs before it was euthanized.

Fever, anorexia, dyspnea, foul-smelling nasal discharge, erosions on the nasal and oral mucosa, abortions, stillbirths, smaller-than-normal litters, reddened foci on the skin, and sudden death have been reported in pigs. Neurological signs including ataxia, tremors, convulsions and hyperesthesia have also been seen. Most cases in swine are acute or peracute, but chronic cases have been reported in some outbreaks. Although younger pigs may be affected, most cases of MCF have been reported in gilts and sows. In one outbreak, only pregnant animals on the farm were affected.

Post Mortem Lesions

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In hosts with clinical disease, lesions can be found in any organ. The characteristic signs are inflammation and epithelial necrosis in the gastrointestinal, respiratory and urinary tracts, with lymphoproliferation, infiltration of nonlymphoid tissues (particular the renal cortex and periportal areas of the liver) by lymphoid cells, and vasculitis.

The lesions vary with the severity and course of the disease. In cattle that die suddenly, there may be few abnormalities other than hemorrhagic enterocolitis. In less acute cases, the carcass may be dehydrated, emaciated or normal. The muzzle is often raw and encrusted with a serous, mucopurulent or purulent nasal discharge. Hyperemia, edema and small focal erosions or ulcers may be found on the nasal mucosa. Generalized exudation, crusting and matting of the hair is common on the ventral thorax and abdomen, inguinal region, perineum and sometimes the head. Skin ulcers may also be found. The lymph nodes are usually markedly enlarged in cattle. On cut surface, they may be firm and white, hemorrhagic or necrotic. Prominent raised white foci, 1-5 mm in diameter, may be seen in some tissues, particularly the kidney. These nodules are sometimes surrounded by a thin hemorrhagic zone. The gastrointestinal tract can contain erosions and hemorrhages; in severe cases, the intestinal contents may be hemorrhagic. The respiratory tract often has catarrhal exudates and erosions, and a diphtheritic membrane may be present. Ecchymotic hemorrhages, hyperemia and edema are common in the mucosa of the urinary bladder. In more chronic cases, the small arteries in the subcutaneous tissues, thorax, abdomen and central nervous system are very prominent and tortuous, with thickened walls. Fibrinous polyarthritis is also common.

Similar lesions have been reported in other species, including goats, deer, moose, bison and pigs, but some species-specific differences may be noted. In bison, vasculitis tends to be milder than in cattle and the lymph nodes are less likely to be markedly swollen, but hemorrhagic cystitis and hemorrhagic colitis are more common. Bison that die with few clinical signs may have advanced lesions on necropsy. Pigs can have lesions in the uterine wall as well as more typical MCF lesions.

Morbidity and Mortality

In cattle, malignant catarrhal fever usually occurs sporadically in one to a few animals, but outbreaks may also be seen. Morbidity rates of 28% to 45% have been reported in some outbreaks. The mortality rate is classically described to be 90-100% in symptomatic animals, but a few studies have suggested that up to 35% of cattle may recover from disease. Subclinical and chronic cases, including cattle with skin disease, have also been reported. Residual corneal opacity is often seen in recovered cattle, but one cow without ocular lesions was reported to make a complete recovery.

Malignant catarrhal fever is a serious concern in highly susceptible species such as farmed cervids and bison. The clinical course is usually shorter in these

animals than cattle, and the case fatality rate is higher. In bison, the morbidity and mortality rate can be very high. During a recent outbreak in the U.S., approximately half of the bison (800 animals) died in one feedlot. In another herd pastured more than a kilometer from a sheep feedlot, nearly all of the bison died over two years. In one group of 300 healthy bison followed up to seven months, twenty-two animals died, with fifteen of the deaths caused by MCF. The incidence of clinical disease in wild cervids is unknown, but the seroprevalence rate in wild deer, moose and ruminants usually ranges from 0% to 9%. However, in one Alaskan elk herd, 35% of the animals were reported to be infected with MCFV.

Pigs may recover from malignant catarrhal fever. On one pig farm, the most severe cases and deaths were reported early in the outbreak; pigs infected later had milder signs and tended to recover without treatment.

Diagnosis

Clinical

Malignant catarrhal fever should be suspected in susceptible animals with the characteristic clinical signs, particularly if they have been in contact with sheep, goats, wildebeest (especially near calving) or other species known to carry MCF viruses. Many cases are characterized by either sudden death or fever with nasal and lacrimal discharges, erosions of the mucosa, and bilateral corneal opacity, but other syndromes may be seen. For instance, malignant catarrhal fever may be a consideration in animals with skin disease or enteritis. Postmortem lesions that support a diagnosis of MCF include corneal opacity, enlarged lymph nodes (in cattle), inflammation and erosions in the nasal passages and/or gastrointestinal mucosa, hemorrhagic cystitis, and prominent tortuous small arteries in the subcutaneous tissue, thorax and abdomen.

Differential diagnosis

Malignant catarrhal fever must be differentiated from bovine virus diarrhea (BVD) mucosal disease, bluetongue, rinderpest, infectious bovine rhinotracheitis, vesicular diseases such as foot and mouth disease and vesicular stomatitis, ingestion of caustic materials, and some poisonous plants and mycotoxins. This disease should also be included among the differentials in susceptible ruminants with an undiagnosed subacute or chronic disease, particularly when alopecia or weight loss is present.

Laboratory tests

Malignant catarrhal fever is often suspected based on histopathologic demonstration of multisystemic lymphoid infiltration, disseminated vasculitis, and degenerative epithelial lesions. Because some MCF viruses cannot be isolated from infected animals, polymerase chain reaction (PCR) tests have become the diagnostic method of choice. PCR can detect both AlHV-1 and OvHV-2, as well as other MCF viruses. Intermittently positive PCR tests have been reported in some asymptomatic OvHV-2-infected cattle.

AlHV-1 infections, but not OvHV-2 infections, can also be confirmed by virus isolation in bovine thyroid cells or other susceptible cell lines. AlHV-1 can be recovered from peripheral blood leukocytes, lymph nodes or other affected tissues. Viable cells are necessary, as the virus cannot be isolated from dead cells. Cell-free virus is usually found only in nasal swabs from wildebeest calves. Isolation of OvHV-2 is unsuccessful.

Serology is sometimes helpful, but antibodies may not be found in acute cases, particularly in cervids. In addition, latent infections can occur and some animals may not seroconvert until after they become positive by PCR. In one study, the time between a positive PCR assay and seroconversion varied from one to 17 months in cattle. In pigs, one study suggests that seroconversion to OvHV-2 may be found only in animals with protracted disease. Neutralizing antibodies do not usually develop in clinically affected ruminants. In these species, non-neutralizing antibodies can be detected by immunofluorescence, immunocytochemistry (immunoperoxidase test) or immunoblotting. Enzyme-linked immunosorbent assay (ELISA) tests are useful for AlHV-1, AlHV-2, OvHV-2, CpHV-2 and MCFV-WTD, as well as other MCF viruses. Serology can also be used for surveillance in the natural hosts. In wildebeest, antibodies to AlHV-1 can be detected by virus neutralization, immunoblotting, ELISA, immunofluorescence or immunocytochemistry. In sheep, antibodies to OvHV-2 can be found by immunofluorescence or immunoblotting. Latently infected animals cannot always be identified with the current antibody and PCR tests.

Samples to collect

In sick animals, the preferred tissues to collect for PCR include anticoagulated blood, kidney, lymph nodes, intestinal wall and brain, but other tissues may also be positive. Ten to 20 ml of blood can also be collected in EDTA for virus isolation, particularly when AlHV-1 is suspected. At necropsy, samples of the spleen, lung, lymph nodes and adrenal glands may be collected for virus isolation. AlHV-1 is inactivated quickly in dead animals, and samples should be taken as soon as possible. The most useful samples are collected immediately after euthanasia of a dying animal. The samples should be refrigerated (not frozen) and shipped on ice.

Samples of lung, liver, lymph nodes, skin (if lesions are present), kidney, adrenal gland, eye, oral epithelium, esophagus, Peyer's patches, urinary bladder, carotid rete, thyroid and heart muscle (and, if practical, brain) should be submitted for histopathology in affected cattle. A wide range of tissues should also be collected from other species; in bison, tissues from the urogenital and intestinal tracts are particularly important to include. Autolysis occurs quickly in this species; the pampiniform plexus may remain diagnostic for longer than some other tissues.

Samples for histopathology should be fixed in 10% neutral buffered formalin.

Paired serum samples, collected 3 to 4 weeks apart, should be taken for serology. Single samples are of limited value; some asymptomatic animals carry antibodies to these viruses.

Recommended actions if malignant catarrhal fever is suspected

Notification of authorities

Malignant catarrhal fever is a reportable disease in many states. State authorities should be consulted for more specific information.

Federal: Area Veterinarians in Charge (AVIC):
http://www.aphis.usda.gov/animal_health/area_offices/

State Veterinarians:
http://www.aphis.usda.gov/vs/sregs/official.html

Control

Malignant catarrhal fever can be prevented by separating susceptible animals from sheep, goats, wildebeest or other suspected reservoir hosts. Wildebeest seem to transmit AlHV-1 readily, and should always be separated from cattle. Cattle should not be allowed on pastures where these animals have recently grazed, particularly near the time wildebeest calve. Wildebeest should also be segregated in zoos. Cattle rarely develop the sheep-associated form of MCF, and separation from sheep is not always necessary. However, an outbreak of sheep-associated MCF was recently reported in cattle exposed to hand-reared lambs in the Netherlands. For this reason, it would be prudent to avoid mixing cattle and sheep, particularly lambs that are actively shedding virus. Bison, some deer and other highly susceptible species should be not be allowed near sheep. Separation by longer distances is particularly important when the host is highly susceptible and the concentration of virus is high (i.e. bison and lambs in feedlots).

Although most infections occur when the carrier host and susceptible animals are in close contact, transmission of AlHV-1 has been reported when animals were separated by a distance of at least 100 meters (328 feet). OvHV-2 was reported in cattle separated from lambs by 70 meters (230 feet). This disease was also reported in bison herds up to 5 km (~3 miles) from a lamb feedlot.

Transmission on fomites must be avoided, particularly when the species is highly susceptible. MCF viruses are susceptible to most commonly available disinfectants. Cell-associated MCFV is very fragile, and infectivity disappears after 72 hours in the environment. Cell-free virus can survive for more than 13 days in humid environments, but disappears quickly when the humidity is low.

In some cases, the production of virus-free hosts may also be considered. OvHV-2 free sheep can be produced by early weaning and isolation, and the production of CpHV-2-free goats has been suggested. Commercial vaccines are not currently available for any species.

During outbreaks, susceptible animals should be separated immediately from the suspected source of the virus. Most incidental hosts are thought to be dead end hosts, and do not need to be culled; however, there is some uncertainty about the possibility of horizontal transmission in some species. Because the incubation period can be very long, cases can continue to occur for months even without horizontal transmission. Stress reduction can help prevent disease in subclinically or mildly affected animals. Antibiotics to control secondary infections and supportive therapy may occasionally help, but many affected animals die.

Public Health

There is no evidence that any of the MCF viruses can infect humans.

Internet Resources

Food and Agriculture Organization of the United Nations. Manual for the Recognition of Exotic Diseases of Livestock. A Reference Guide for Animal Health Staff. http://www.spc.int/rahs/

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

United States Animal Health Association. Foreign Animal Diseases
http://www.vet.uga.edu/vpp/gray_book02/fad/index.php

World Organization for Animal Health (OIE)
http://www.oie.int

OIE Terrestrial Animal Health Code
http://www.oie.int/eng/normes/mcode/A_summry.htm

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals
http://www.oie.int/eng/normes/mmanual/a_summry.htm

References

Albini S, Zimmermann W, Neff F, Ehlers B, Häni H, Li H, Hüssy D, Engels M, Ackermann M. Identification and quantification of ovine gammaherpesvirus 2 DNA in fresh and stored tissues of pigs with symptoms of porcine malignant catarrhal fever. J Clin Microbiol. 2003;41:900-4.

Anderson IE, Buxton D, Campbell I, Russell G, Davis WC, Hamilton MJ, Haig DM. Immunohistochemical study of experimental malignant catarrhal fever in rabbits. J Comp Pathol. 2007;136:156-66.

Brenner J, David D. Sheep-associated malignant catarrhal fever in cattle (SA-MCF). Recent clinical and epidemiological aspects in Israel. Isr J Vet Med. 2005;60: 19-22.

Crawford TB, Li H, Rosenburg SR, Norhausen RW, Garner MM. Mural folliculitis and alopecia caused by infection with goat-associated malignant catarrhal fever virus in two sika deer. J Am Vet Med Assoc. 2002 15;221:843-7, 801.

Cunha CW, Traul DL, Taus NS, Oaks JL, O'Toole D, Davitt CM, Li H. Detection of ovine herpesvirus 2 major capsid gene transcripts as an indicator of virus replication in shedding sheep and clinically affected animals. Virus Res. 2008;132:69-75.

Garner G, Saville P, Fediaevsky A. Manual for the recognition of exotic diseases of livestock: A reference guide for animal health staff [online]. Food and Agriculture Organization of the United Nations [FAO]; 2003. B114 – Malignant catarrhal fever. Available at: http://www.spc.int/rahs/Manual/BOVINE/MCFE.htm. Accessed 21 Apr 2008.

Fraser HI, Heide BWJ, Hicks CD, Otto SJG. Malignant catarrhal fever [online]. 2000 Mar. Available at: http://duke.usask.ca/~misra/virology/stud2000/mcf2/mcf.html.* Accessed 11 Sept. 2001.

Heuschele WP. Malignant catarrhal fever. In: Foreign animal diseases. Richmond, VA: United States Animal Health Association, 1998. Available at: http://www.vet.uga.edu/vpp/gray_book02/fad/mcf.php. Accessed 22 Apr 2008.

Jacobsen B, Thies K, von Altrock A, Förster C, König M, Baumgärtner W. Malignant catarrhal fever-like lesions associated with ovine herpesvirus-2 infection in three goats. Vet Microbiol. 2007;124:353-7.

Kahn CM, Line S, editors. The Merck veterinary manual [online]. Whitehouse Station, NJ: Merck and Co; 2003. Malignant catarrhal fever. Available at: . http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/55700.htm. Accessed 22 Apr 2008.

Keel MK, Patterson JG, Noon TH, Bradley GA, Collins JK. Caprine herpesvirus-2 in association with naturally occurring malignant catarrhal fever in captive sika deer (Cervus nippon). J Vet Diagn Invest. 2003;15:179-83.

Kleiboeker SB, Miller MA, Schommer SK, Ramos-Vara JA, Boucher M, Turnquist SE. Detection and multigenic characterization of a herpesvirus associated with malignant catarrhal fever in white-tailed deer (Odocoileus virginianus) from Missouri. J Clin Microbiol. 2002;40:1311-8.

Li H, Dyer N, Keller J, Crawford TB. Newly recognized herpesvirus causing malignant catarrhal fever in white-tailed deer (Odocoileus virginianus). J Clin Microbiol. 2000;38:1313-8.

Li H, Gailbreath K, Bender LC, West K, Keller J, Crawford TB. Evidence of three new members of malignant catarrhal fever virus group in muskox (Ovibos moschatus), Nubian ibex (Capra nubiana), and gemsbok (Oryx gazella). J Wildl Dis. 2003;39:875-80.

Li H, Gailbreath K, Flach EJ, Taus NS, Cooley J, Keller J, Russell GC, Knowles DP, Haig DM, Oaks JL, Traul DL, Crawford TB. A novel subgroup of rhadinoviruses in ruminants. J Gen Virol. 2005;86:3021-6.

Li H, Keller J, Knowles DP, Crawford TB. Recognition of another member of the malignant catarrhal fever virus group: an endemic gammaherpesvirus in domestic goats. J Gen Virol. 2001;82:227-32.

Li H, O'Toole D, Kim O, Oaks JL, Crawford TB. Malignant catarrhal fever-like disease in sheep after intranasal inoculation with ovine herpesvirus-2. J Vet Diagn Invest. 2005;17:171-5.

Li H, Taus NS, Lewis GS, Kim O, Traul DL Crawford TB. Shedding of ovine herpesvirus 2 in sheep nasal secretions: the predominant mode for transmission. J Clin Microbiol. 2004;42:5558-64.

Li H, Wunschmann A, Keller J, Hall DG, Crawford TB. Caprine herpesvirus-2-associated malignant catarrhal fever in white-tailed deer (Odocoileus virginianus). J Vet Diagn Invest. 2003;15:46-9.

Munday JS, French AF, Smith A, Wang J, Squires RA. Probable malignant catarrhal fever presented as transient generalised crusting dermatitis in a cow. N Z Vet J. 2008;56:89-93.

Okeson DM, Garner MM, Taus NS, Li H, Coke RL .Ibex-associated malignant catarrhal fever in a bongo antelope (Tragelaphus euryceros). J Zoo Wildl Med. 2007;38:460-4.

O'Toole D, Taus NS, Montgomery DL, Oaks JL, Crawford TB, Li H. Intra-nasal inoculation of American bison (Bison bison) with ovine herpesvirus-2 (OvHV-2) reliably reproduces malignant catarrhal fever. Vet Pathol. 2007;44:655-62.

O'Toole D, Li H, Sourk C, Montgomery DL, Crawford TB. Malignant catarrhal fever in a bison (Bison bison) feedlot, 1993-2000. Vet Diagn Invest. 2002;14:183-93.

Powers JG, VanMetre DC, Collins JK, Dinsmore RP, Carman J, Patterson G, Brahmbhatt D, Callan RJ Evaluation of ovine herpesvirus type 2 infections, as detected by competitive inhibition ELISA and polymerase chain reaction assay, in dairy cattle without clinical signs of malignant catarrhal fever. J Am Vet Med Assoc. 2005;227:606-11.

Schultheiss PC, Van Campen H, Spraker TR, Bishop C, Wolfe L, Podell B. Malignant catarrhal fever associated with ovine herpesvirus-2 in free-ranging mule deer in Colorado. J Wildl Dis. 2007;43:533-7.

Schultheiss PC, Collins JK, Spraker TR, DeMartini JC.Epizootic malignant catarrhal fever in three bison herds: differences from cattle and association with ovine herpesvirus-2. J Vet Diagn Invest. 2000;12:497–502.

Syrjälä P, Saarinen H, Laine T, Kokkonen T, Veijalainen P. Malignant catarrhal fever in pigs and a genetic comparison of porcine and ruminant virus isolates in Finland. Vet Rec. 2006;159:406-9.

Taus NS, Traul DL, Oaks JL, Crawford TB, Lewis GS, Li H. Experimental infection of sheep with ovine herpesvirus 2 via aerosolization of nasal secretions. J Gen Virol. 2005;86:575-9.

United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services [USDA APHIS, VS]. Malignant catarrhal fever [online]. USDA ; 2000. Available at: http://aphisweb.aphis.usda.gov/vs/ep/fad_training/Malivol5/mal5index.htm.* Accessed 10 Sept. 2001.

van Wuijckhuise-Sjouke L, Knibbe GC. [Large outbreak of malignant catarrhal fever in cattle] Tijdschr Diergeneeskd. 2007 1;132:732-4.

Vikøren T, Li H, Lillehaug A, Jonassen CM, Böckerman I, Handeland K. Malignant catarrhal fever in free-ranging cervids associated with OvHV-2 and CpHV-2 DNA. J Wildl Dis. 2006;42:797-807.

Whitaker KA, Wessels ME, Campbell I, Russell GC. Outbreak of wildebeest-associated malignant catarrhal fever in Ankole cattle. Vet Rec. 2007;161:692-5.

World Organization for Animal Health [OIE] . Manual of diagnostic tests and vaccines for terrestrial animals [online]. Paris: OIE; 2004. Malignant catarrhal fever. Available at: http://www.oie.int/eng/normes/mmanual/A_00065.htm. Accessed 22 Apr 2008.

*Link defunct as of 2008