

Rabbit Hemorrhagic Disease

Viral Hemorrhagic Disease of Rabbits, Rabbit Calicivirus Disease

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Importance

Rabbit hemorrhagic disease is a serious and extremely contagious viral disease of domesticated and wild rabbits. Morbidity and mortality rates are high in unvaccinated animals; on some farms, most or all of the rabbits may die. This disease has also caused dramatic declines in some wild rabbit populations, particularly when it is first introduced. This has had a detrimental effect on some ecosystems in Europe, where wild rabbits are an important food source for certain endangered predators, such as Iberian lynx (*Lynx pardinus*). Conversely, rabbit hemorrhagic disease has been used to help control excessive numbers of wild, non-native European rabbits (*Oryctolagus cuniculus*) in Australia.

The origins of rabbit hemorrhagic disease are not completely understood. The causative virus, rabbit hemorrhagic disease virus (RHDV), may have emerged from avirulent caliciviruses that circulate asymptotically in European rabbits. The first known outbreak occurred in China in 1984, apparently spread by Angora rabbits that had been imported from Europe. Within 9 months, this disease had killed 14 million domesticated rabbits in China. By the late 1990s, outbreaks had been reported from forty countries, and rabbit hemorrhagic disease had become endemic in a number of areas throughout the world. Other regions, including the Americas, have experienced periodic outbreaks in domesticated rabbits. However, the species of wild rabbits found in North America are not susceptible to these RHD viruses, which facilitates eradication.

A new variant called RHDV2 emerged in Europe in 2010, and has spread widely among domesticated and wild rabbits there. This virus has also been found in Australia. RHDV2 affects animals vaccinated against older RHD viruses, as well as unvaccinated rabbits. It can also cause illness in some species of hares. Whether RHDV2 could affect any wild North American lagomorphs is not yet known.

Etiology

Rabbit hemorrhagic disease is caused by rabbit hemorrhagic disease virus (RHDV), a member of the genus *Lagovirus* and family Caliciviridae. There are many strains of RHDV, and three major viral subtypes: RHDV (“classical RHDV”), the antigenic variant RHDVa, and the recently emerged virus RHDV2 (also called RHDVb). Classical RHDV and RHDVa comprise one serotype, while RHDV2 belongs to a different serotype.

Related lagoviruses, called rabbit caliciviruses, circulate in healthy rabbits. These viruses can confer varying degrees of cross-protection to RHDV. While most rabbit caliciviruses do not appear to cause any illness, two potentially pathogenic strains have been reported. One virus identified in the U.S. (proposed name “Michigan rabbit calicivirus”) was isolated from an outbreak that resembled rabbit hemorrhagic disease, although an attempt to reproduce the disease in experimentally infected rabbits resulted in little or no illness. A related strain, the Ashington strain of rabbit calicivirus, was recovered from dead wild rabbits during an outbreak in Europe.

Species Affected

RHDV primarily or exclusively affects wild and domesticated European rabbits (*Oryctolagus cuniculus*). Other lagomorphs generally seem to be unaffected by classical RHDV/RHDVa. Species reported not to be susceptible to these viruses include European brown hares (*Lepus europaeus*), varying (snowshoe) hares (*Lepus americanus*), cottontails (*Sylvilagus floridanus*), black-tailed jackrabbits (*Lepus californicus*) and volcano rabbits (*Romerolagus diazzi*). However, classical RHDV was recently found in dead wild Iberian hares (*Lepus granatensis*) that had been collected during an outbreak in the 1990s. Rodents are the only animals, other than lagomorphs, known to be infected by RHDV; viral RNA was found in the internal organs of wood mice (*Apodemus sylvaticus*) and Algerian mice (*Mus spretus*) collected near warrens that contained infected wild rabbits. There has been no evidence of virus replication in any other mammals examined or tested in the laboratory, including rabbit predators, although some animals did seroconvert.

RHDV2 seems to have a broader host range among lagomorphs. In addition to

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European rabbits, it is known to affect the Cape hare (*Lepus capensis* var. *mediterraneus*) and Italian hare (*Lepus corsicanus*). Epidemiological observations suggest that it probably has little or no effect on European brown hares.

Zoonotic potential

There is no indication that RHDV infects humans.

Geographic Distribution

Rabbit hemorrhagic disease is endemic in Australia, New Zealand, Cuba, parts of Asia and Africa, and most of Europe. The viral subtypes circulating in each region can differ. As of 2016, RHDV2 has been found in a number of European countries and Australia.

RHDV is not thought to be established in North America, where *O. cuniculus* does not occur in the wild. Outbreaks were reported among domesticated rabbits in the U.S. in 2000 (Iowa), 2001 (Utah, Illinois, New York), 2005 (Indiana), 2008 (Maryland) and 2010 (Minnesota). In some cases, only a single facility or household was affected. The origins of these viruses could not be traced; however, different viruses were involved in each outbreak, and they were thought to have come from outside North America. In 2011, a clinical case occurred in Canada, in one of three rabbits that had been housed indoors for more than a year. The source of this virus is also unknown, although various hypotheses (i.e., reactivation of a persistent infection, emergence from a nonpathogenic calicivirus or transmission from an unknown source on fomites or insects) have been proposed. RHDV was endemic in domesticated rabbits in Mexico from the late 1980s to 1991, but it was eventually eradicated. This disease was also reported from domesticated and wild rabbits in Uruguay in 2004; however, Uruguay ceased vaccination for this disease in 2007, and declared itself free of RHDV to the World Organization for Animal Health (OIE) in 2012.

“Michigan rabbit calicivirus” has been reported in only one outbreak, which occurred in a single Michigan (U.S.) rabbit facility in 2001.

Transmission

RHDV can be transmitted by direct contact with live or dead animals, as well as on fomites. These viruses can enter the body through the oral, nasal or conjunctival routes, although oral transmission is thought to predominate. Most or all secretions and excretions, including urine, feces and respiratory secretions, are thought to contain virus, and RHDV can remain viable in carcasses for long periods. Even rabbit fur alone can be infectious. Surviving animals can continue to shed RHDV for at least a month after they recover. Long-term persistence of viral RNA has been reported in rabbits for at least 15 weeks, but whether this represents true persistence or slow virus clearance is still uncertain. Viral antigens or infectious virus have not been detected in these animals, even in laboratory experiments where they were immunosuppressed.

RHDV is readily spread on fomites including contaminated food, bedding and water. Insects can transmit this virus long distances. Flies are very efficient mechanical vectors; infectious virus can persist in flies for up to 9 days, and only a few virions are needed to infect a rabbit by the conjunctival route. Viruses can also be deposited on vegetation in fly feces or regurgita, then eaten by a rabbit. Fleas and mosquitoes could transmit RHDV mechanically in the laboratory. Mechanical transmission has also been demonstrated in birds and mammals, which can excrete infectious RHDV in feces after eating infected rabbits.

RHDV is very resistant to inactivation when it is protected within tissues. This virus can survive for 7.5 months in tissue suspensions stored at 4°C (39°F), and for more than 3 months in dried organ homogenates at 20°C (68°F). In one study, RHDV remained viable in decomposing rabbit carcasses kept at 22°C (72°F) for up to 20 days, but there was insufficient infectious virus after 26 or 30 days to cause clinical signs in rabbits. However, virus-inoculated bovine liver left to decompose in New Zealand fields (to simulate infected carcasses) remained infectious for at least 3 months. Unprotected viruses shed in excretions are not thought to remain viable for more than a few weeks, and may lose some of their infectivity within one to two weeks. RHDV is also reported to survive exposure to pH 3.0, heat of 50°C (122°F) for an hour, and freeze-thaw cycles.

Disinfection

RHDV can be inactivated with 10% sodium hydroxide or 1-2% formalin. Other disinfectants that have been suggested include 2% One-stroke Environ® (Vestal Lab Inc., St. Louis, MO) and 0.5% sodium hypochlorite (10% household bleach). This virus resists degradation by ether or chloroform.

Incubation Period

The incubation period is reported to be 1-3 days for classical RHDV/RHDVa and 3-9 days for RHDV2 in experimentally infected rabbits.

Clinical Signs

Classical RHDV/ RHDVa

In rabbits less than 4-8 weeks of age, RHDV/ RHDVa infections are usually subclinical. However, some young rabbits may have elevated temperatures, and subclinical signs of liver disease were noted in experimentally infected 4-week-old rabbit kittens. Deaths have also been reported, though rarely. In a recent study, experimentally infected 4-week-old rabbits died rapidly if they were immunosuppressed with corticosteroids.

Peracute and acute disease are the most common syndromes in older rabbits. In peracute cases, infected rabbits develop a fever and die suddenly within 12 to 36 hours of its onset. The only clinical signs may be terminal squeals followed rapidly by collapse and death. Animals with the

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acute form survive somewhat longer, with signs of dullness/apathy, anorexia, congestion of the conjunctiva, and/or prostration. These animals may also develop neurological signs, such as incoordination, excitement, opisthotonos and paddling. Some rabbits turn and flip quickly in their cages; this can resemble convulsions or mania. There may also be respiratory signs (e.g., dyspnea, cyanosis and a terminal, bloodstained, frothy nasal discharge), lacrimation, ocular hemorrhages or epistaxis. Animals that survive longer can develop a subacute form with severe jaundice, accompanied by weight loss and lethargy, and die in a few weeks. These animals may have diarrhea or constipation and abdominal dilatation just before death. A small number of adult rabbits can have milder signs, with a higher survival rate, or are infected subclinically. Rabbits with persistent viral RNA were apparently healthy.

Iberian hares infected with classical RHDV were found dead, but had lesions consistent with a disease caused by a lagovirus (see Postmortem Lesions, below).

RHDV2

RHDV2 affects young rabbits as well as older animals; clinical cases have been reported in rabbits as young as 11 days of age. The clinical signs are similar to the illness caused by RHDV/ RHDVa; however, experimentally infected rabbits generally survived longer, and peracute or acute cases were less common. A captive Italian hare infected with RHDV2 had no clinical signs other than epistaxis before death. Wild Cape hares infected with this virus were found dead.

Michigan rabbit calicivirus

An outbreak caused by Michigan rabbit calicivirus was characterized by acute fatalities over a 3-week period. The initial signs were vulvar hemorrhages in pregnant does, and inappetence in some animals. Additional clinical signs included epistaxis, ataxia, opisthotonos, diarrhea, ocular discharge, vocalizations and death. Clinical signs were rare and mild (transient decreases in activity, inappetence) in rabbits experimentally infected with this virus.

Post Mortem Lesions [Click to view images](#)

RHDV, RHDVa and RHDV2 cause similar lesions in European rabbits. Animals that die are usually in good condition. The primary lesion is hepatic necrosis, and the most consistent post-mortem lesions are hepatic necrosis and splenomegaly. The liver may be pale, with a fine reticular pattern of necrosis outlining each lobule. In cases with extensive necrosis, the liver can be diffusely pale. It may also be yellow, gray, friable or congested. The spleen is usually black and engorged, with rounded edges. The kidneys may be very dark brown. Disseminated intravascular coagulation (DIC) is common in the terminal stages of disease, and results in hemorrhages in a variety of organs and tissues. The trachea is often hyperemic and contains frothy, bloodstained mucus. Congestion and multifocal hemorrhages may be seen in the lungs.

Hemorrhages are also common in the thymus, and petechiae may be found on the serosal membranes or viscera. Infarcts may be seen in most organs. Hemorrhages are not necessarily present in rabbits euthanized before the terminal stage. Catarrhal enteritis of the small intestine and icterus may be evident in subacute cases. Congestion of the meninges has been reported.

The lesions in Cape hares infected with RHDV2 were suggestive of European brown hare syndrome (a rabbit disease caused by a different lagovirus), and included a pale liver (with microscopic lesions of massive necrosis, moderate mononuclear inflammatory infiltrate and little fatty degeneration), an enlarged spleen, and congestion of the other parenchymal organs. The lesions in a single Italian hare were severe pulmonary and tracheal edema with profuse foamy exudate, profuse hemorrhages, and congestion and slight enlargement of the liver. Iberian hares infected with classical RHDV had hemorrhagic lesions and congestion of the liver, lungs and other internal organs.

Rabbits naturally infected with Michigan rabbit calicivirus had hemorrhagic lesions, conjunctival congestion, icterus, and liver lesions consistent with rabbit hemorrhagic disease. Nonspecific signs of hepatic injury were found in the surviving animals. Experimentally infected rabbits did not develop any gross lesions, although rare hepatocellular necrosis was noted in the liver of some animals on histopathologic examination.

Diagnostic Tests

RHDV cannot be grown in cell culture (for virus isolation); however, rabbit hemorrhagic disease can be diagnosed by detecting viral nucleic acids and/or antigens in tissues, secretions/excretions and blood. Electron microscopy may also be helpful. The liver contains the highest viral titers in acute or peracute disease, and is the best organ to submit for virus identification. Viruses may also be abundant in the blood and spleen. When the course of the disease has been prolonged, RHDV (in the form of a virus-like particle) may be easier to find in the spleen than the liver.

Reverse transcription polymerase chain reaction (RT-PCR) tests are used most often for diagnosis. RT-PCR assays have been developed for all of the viral subtypes, although the availability of RHDV2 tests may vary between laboratories. Viral RNA can be found in many organs (especially the liver), as well as in blood, urine and feces. It may be detectable in some convalescent rabbits for a prolonged period. Other methods to detect viral RNA include reverse-transcription loop-mediated isothermal amplification (RT-LAMP) assays, which have been described in the literature, and *in situ* hybridization, which is mainly used in research.

Viral antigens are often detected with enzyme-linked immunosorbent assays (ELISAs), and these assays can also be used to type the virus. Other antigen detection tests include immunostaining, immunoblotting (Western blotting)

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and negative-staining immunoelectron microscopy. A hemagglutination test can also be employed, but it is less sensitive and specific than other assays, and has generally been replaced by ELISAs. Nonpathogenic rabbit caliciviruses may cross-react with RHDV, depending on the specificity of the test.

Antibodies can be found in convalescent rabbits with ELISAs or hemagglutination inhibition. Nonpathogenic rabbit caliciviruses can complicate serological diagnosis.

Animal inoculation into rabbits may be used occasionally, for instance to help identify cases that have not been definitively diagnosed by other tests.

Treatment

Treatment is currently limited to supportive care. Passively acquired immunity (hyperimmune antiserum) can protect animals that have not yet developed clinical signs, but it is reported to be ineffective in symptomatic rabbits.

Control

Disease reporting

A quick response is vital for containing outbreaks in disease-free regions. Veterinarians who encounter or suspect rabbit hemorrhagic disease should follow their national and/or local guidelines for disease reporting. In the U.S., state or federal veterinary authorities should be informed immediately.

Prevention

Uninfected countries may place restrictions on the importation of live rabbits, meat and other rabbit products (e.g., Angora wool) from endemic areas. Strict quarantines are necessary if an outbreak occurs. RHDV is extremely contagious; it can be transmitted on fomites and by insects, birds and scavenging mammals. Carcasses are infectious, and must be removed immediately and disposed of safely. The virus can sometimes be eradicated by depopulation, disinfection of infected premises, surveillance and quarantines; however, eradication is generally impossible if the virus becomes established in wild rabbit populations. Infected farms should not be restocked immediately, as RHDV can persist for a time in the environment. Sentinel rabbits can be used to monitor premises for persistent viruses.

In regions where RHDV circulates in wild rabbits, domesticated rabbits are protected with biosecurity measures including separation from wild rabbits, sanitation and disinfection, and vaccination. Maintaining closed colonies can help prevent the virus from entering the premises. Where new stock is introduced, quarantining them initially is prudent.

Vaccines are now available for RHDV2 as well as RHDV/ RHDVa; there is limited or no cross-protection between these two groups of viruses. Because the production cycle is short, commercial rabbit farms may only vaccinate breeding animals if rabbit hemorrhagic

disease has not been reported in the area. However, all animals should be vaccinated if an outbreak has occurred, as the likelihood of infection is high even with strict sanitation and other control measures. Vaccination may also be useful as post-exposure prophylaxis, as immunity to RHDV usually develops in approximately 7-10 days. Sentinel animals can be used to monitor vaccinated farms for RHDV.

Morbidity and Mortality

Reported morbidity rates in rabbits infected with classical RHDV/ RHDVa range from 30% to 100%, and the mortality rate is 40-100%. The highest morbidity and mortality rates occur in adult rabbits from naïve populations. Clinical cases may be sporadic in some situations where rabbits are well separated from each other (e.g., some research environments). Rabbit kittens are resistant to illness caused by classical RHDV/RHDVa, and fatalities are rare in animals < 4 weeks of age. Rabbits lose this resistance between 4 and 12 weeks of age.

Variable mortality rates ranging from 5% to 70% have been reported for RHDV2. The average mortality was 20% in experimentally infected rabbits, and in general, this virus is thought to be less virulent than classical RGDV/RHDVa. However, some severe natural outbreaks have been seen. During the initial outbreaks in Australia, which occurred in rabbits vaccinated against RHDVa, the apparent morbidity rate was 44%, with a mortality rate of 37.5%, and case fatality rate of 86%. Young rabbits do not appear to be resistant to RHDV2. Most sources state that clinical cases occur in animals 2-3 weeks of age or older, and 11-day-old kittens were affected in one outbreak. During the initial outbreaks in Spain, mortality rates as high as 50% were seen in young rabbits.

Rabbits that survive rabbit hemorrhagic disease become resistant to related strains. Exposure to nonpathogenic rabbit caliciviruses may also provide some degree of resistance, although cross-protectivity seems to vary depending on the virus. In wild *O. cuniculus* rabbits, outbreaks can be seasonal. In some populations, classical RHDV/RHDVa outbreaks have been associated with the breeding season, with the virus spreading in young rabbits as they lose their age-related protection. In Europe, classical RHDV/RHDVa caused dramatic declines in wild rabbit populations in Spain, Portugal and France, but wild rabbits in the U.K. and some other northern European countries have been less severely affected. In some areas, rabbit populations may recover, and initial high morbidity and mortality rates may be followed by sporadic, less severe outbreaks. RHDV2 has also resulted in extensive outbreaks among wild rabbits in some areas. Epidemics in wild rabbits can lead to outbreaks in domesticated rabbits.

There is relatively little information yet about the effects of RHDV2 on hares. A single case has been reported, to date, in Italian hares. Other nearby hares, including a cage-mate, were unaffected and did not

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seroconvert. This suggests that this species might be relatively resistant to infection. However, fatal illness was confirmed in several wild Cape hares during an outbreak in rabbits.

Most rabbit caliciviruses are thought to infect lagomorphs subclinically, but the mortality rate was 32.5% in an outbreak caused by Michigan rabbit calicivirus. All of the affected rabbits were older than 8 weeks. In one study, this virus caused no deaths and few signs of illness in experimentally infected rabbits.

Internet Resources

The Merck Veterinary Manual

<http://www.merckvetmanual.com/mvm/index.jsp>

United States Animal Health Association. Foreign Animal Diseases

http://www.aphis.usda.gov/emergency_response/downloads/nahems/fad.pdf

World Organization for Animal Health (OIE)

<http://www.oie.int>

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals

<http://www.oie.int/international-standard-setting/terrestrial-manual/access-online/>

OIE Terrestrial Animal Health Code

<http://www.oie.int/international-standard-setting/terrestrial-code/access-online/>

References

- Abrantes J, Esteves PJ. Not-so-novel Michigan rabbit calicivirus. *Emerg Infect Dis.* 2010;16(8):1331-2;
- Abrantes J, Lopes AM, Dalton KP, Melo P, Correia JJ, Ramada M, Alves PC, Parra F, Esteves PJ. New variant of rabbit hemorrhagic disease virus, Portugal, 2012-2013. *Emerg Infect Dis.* 2013;19(11):1900-2.
- Abrantes J, Lopes AM, Dalton KP, Parra F, Esteves PJ. Detection of RHDV_a on the Iberian Peninsula: isolation of an RHDV_a strain from a Spanish rabbitry. *Arch Virol.* 2014;159(2):321-6.
- Abrantes J, van der Loo W, Le Pendu J, Esteves PJ. Rabbit haemorrhagic disease (RHD) and rabbit haemorrhagic disease virus (RHDV): a review. *Vet Res.* 2012;43:12.
- Asgari S, Hardy JR, Sinclair RG, Cooke BD. Field evidence for mechanical transmission of rabbit haemorrhagic disease virus (RHDV) by flies (Diptera: Calliphoridae) among wild rabbits in Australia. *Virus Res.* 1998;54:123-32.
- Baily JL, Dagleish MP, Graham M, Maley M, Rocchi MS. RHDV variant 2 presence detected in Scotland. *Vet Rec.* 2014;174(16):411.
- Bárcena J, Guerra B, Angulo I, González J, Valcárcel F, Mata CP, Castón JR, Blanco E, Alejo A. Comparative analysis of rabbit hemorrhagic disease virus (RHDV) and new RHDV2 virus antigenicity, using specific virus-like particles. *Vet Res.* 2015;46:106.
- Bergin IL, Wise AG, Bolin SR, Mullaney TP, Kiupel M, Maes RK. Novel calicivirus identified in rabbits, Michigan, USA. *Emerg Infect Dis.* 2009;15(12):1955-62.
- Brown C. Rabbit hemorrhagic disease. In: Foreign animal diseases. Boca Raton, FL: United States Animal Health Association, 2008. p. 365-8.
- Burmakina G, Malogolovkina N, Lunitsin A, Titov I, Tsybanov S, Malogolovkin A. Comparative analysis of rabbit hemorrhagic disease virus strains originating from outbreaks in the Russian Federation. *Arch Virol.* 2016;161(7):1973-9.
- Camarda A, Pugliese N, Cavadini P, Circella E, Capucci L, Caroli A, Legretto M, Mallia E, Lavazza A. Detection of the new emerging rabbit haemorrhagic disease type 2 virus (RHDV2) in Sicily from rabbit (*Oryctolagus cuniculus*) and Italian hare (*Lepus corsicanus*). *Res Vet Sci.* 2014;97:642-5.
- Campagnolo ER, Ernst MJ, Berninger ML, Gregg DA, Shumaker TJ, Boghossian AM. Outbreak of rabbit hemorrhagic disease in domestic lagomorphs. *J Am Vet Med Assoc.* 2003;223:1151-5, 1128.
- Chasey D. Rabbit haemorrhagic disease: the new scourge of *Oryctolagus cuniculus*. *Lab Anim.* 1997;31:33-44.
- Cooke BD. Rabbit haemorrhagic disease: field epidemiology and the management of wild rabbit populations. *Rev Sci Tech.* 2002;21:347-58.
- Dalton KP, Nicieza I, Abrantes J, Esteves PJ, Parra F. Spread of new variant RHDV in domestic rabbits on the Iberian Peninsula. *Vet Microbiol.* 2014;169(1-2):67-73.
- Dalton KP, Nicieza I, Balseiro A, Muguera MA, Rosell JM, Casais R, Álvarez AL, Parra F. Variant rabbit hemorrhagic disease virus in young rabbits, Spain. *Emerg Infect Dis.* 2012;18(12):2009-12/
- Delibes-Mateos M, Ferreira C, Carro F, Escudero MA, Gortázar C. Ecosystem effects of variant rabbit hemorrhagic disease virus, Iberian Peninsula. *Emerg Infect Dis.* 2014;20(12):2166-8.
- Delibes-Mateos M, Redpath SM, Angulo E, Ferreras P, Villafuerte R. Rabbits as a keystone species in southern Europe. *Biol Conserv.* 2007;137:149-56.
- Donnelly T. Emerging viral diseases of rabbits and rodents: viral hemorrhagic disease and hantavirus infection. *Sem Avian Exotic Pet Med.* 1995;4: 83-91.
- Duarte MD, Carvalho CL, Barros SC, Henriques AM, Ramos F, Fagulha T, Luís T, Duarte EL, Fevereiro M. A real time Taqman RT-PCR for the detection of rabbit hemorrhagic disease virus 2 (RHDV2). *J Virol Methods.* 2015;219:90-5.
- Eden JS, Read AJ, Duckworth JA, Strive T, Holmes EC. Resolving the origin of rabbit hemorrhagic disease virus: Insights from an investigation of the viral stocks released in Australia. *J Virol.* 2015;89(23):12217-20.
- Elsworth P, Cooke BD, Kovaliski J, Sinclair R, Holmes EC, Strive T. Increased virulence of rabbit haemorrhagic disease virus associated with genetic resistance in wild Australian rabbits (*Oryctolagus cuniculus*). *Virology.* 2014;464-465:415-23.
- Embury-Hyatt C, Postey R, Hisanaga T, Burton L, Hooper-McGrevy K, McIntyre L, Millar K, Pasick J. The first reported case of rabbit hemorrhagic disease in Canada. *Can Vet J.* 2012;53(9):998-1002.
- Ferreira PG, Costa-e-Silva A, Aguas AP. Liver disease in young rabbits infected by calicivirus through nasal and oral routes. *Res Vet Sci.* 2006;81(3):362-5.

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- Forrester NL, Abubakr MI, Abu Elzein EM, Al-Afaleq AI, Housawi FM, Moss SR, Turner SL, Gould EA. Phylogenetic analysis of rabbit haemorrhagic disease virus strains from the Arabian Peninsula: did RHDV emerge simultaneously in Europe and Asia? *Virology*. 2006;344:277-82.
- Forrester NL, Boag B, Moss SR, Turner SL, Trout RC, White PJ, Hudson PJ, Gould EA. Long-term survival of New Zealand rabbit haemorrhagic disease virus RNA in wild rabbits, revealed by RT-PCR and phylogenetic analysis. *J Gen Virol*. 2003;84:3079-86.
- Forrester NL, Trout RC, Gould EA. Benign circulation of rabbit haemorrhagic disease virus on Lambay Island, Eire. *Virology*. 2007;358:18-22.
- Gall A, Hoffmann B, Teifke JP, Lange B, Schirrneier H. Persistence of viral RNA in rabbits which overcome an experimental RHDV infection detected by a highly sensitive multiplex real-time RT-PCR. *Vet Microbiol*. 2007;120(1-2):17-32.
- Gall A, Schirrneier H. Persistence of rabbit haemorrhagic disease virus genome in vaccinated rabbits after experimental infection. *J Vet Med B Infect Dis Vet Public Health*. 2006;53:358-62.
- Gould EA. First case of rabbit haemorrhagic disease in Canada: contaminated flying insect, vs. long-term infection hypothesis. *Mol Ecol*. 2012;21:1042-7.
- Gregg DA. Viral hemorrhagic disease of rabbits. In: Foreign animal diseases. Richmond, VA: United States Animal Health Association, 1998. Available at: http://www.vet.uga.edu/vpp/gray_book02/fad/vhd.php.* Accessed 2 Sept. 2007.
- Hall RN, Mahar JE, Haboury S, Stevens V, Holmes EC, Strive T. Emerging rabbit hemorrhagic disease virus 2 (RHDVb), Australia. *Emerg Infect Dis*. 2015;21(12):2276-8.
- Henning J, Meers J, Davies PR, Morris RS. Survival of rabbit haemorrhagic disease virus (RHDV) in the environment. *Epidemiol Infect*. 2005;133:719-30.
- International Committee on Taxonomy of Viruses [ICTV]. Virus Taxonomy [online]: 2015 Release EC 47, London, UK, July 2015; Email ratification 2016 (MSL #30) Genus *Lagovirus*. Available at: <http://www.ictvdb.org/>. Accessed 20 Jun 2016.
- Jackson A. The complicated strains of rabbit calicivirus. *Aust Vet J*. 2014;92(11):N22.
- Kerr PJ, Donnelly TM. Viral infections of rabbits. *Vet Clin North Am Exot Anim Pract*. 2013;16(2):437-68.
- Lavazza A, Cavadini P, Barbieri I, Tizzani P, Pinheiro A, Abrantes J, Esteves PJ, Grilli G, Gioia E, Zanoni M, Meneguz P, Guitton JS, Marchandeanu S, Chiari M, Capucci L. Field and experimental data indicate that the eastern cottontail (*Sylvilagus floridanus*) is susceptible to infection with European brown hare syndrome (EBHS) virus and not with rabbit haemorrhagic disease (RHD) virus. *Vet Res*. 2015;46:13.
- Le Gall-Reculé G, Lavazza A, Marchandeanu S, Bertagnoli S, Zwingelstein F, Cavadini P, Martinelli N, Lombardi G, Guérin JL, Lemaitre E, Decors A, Boucher S, Le Normand B, Capucci L. Emergence of a new lagovirus related to rabbit haemorrhagic disease virus. *Vet Res*. 2013;44:81.
- Le Gall-Reculé G, Zwingelstein F, Boucher S, Le Normand B, Plassiart G, Portejoie Y, Decors A, Bertagnoli S, Guérin J.L., Marchandeanu S. Detection of a new variant of rabbit haemorrhagic disease virus in France. *Vet. Rec*. 2011;168:137-8.
- Le Gall-Reculé G, Zwingelstein F, Fages MP, Bertagnoli S, Gelfi J, Aubineau J, Roobrouck A, Botti G, Lavazza A, Marchandeanu S. Characterisation of a non-pathogenic and non-protective infectious rabbit lagovirus related to RHDV. *Virology*. 2011;410(2):395-402.
- Liu J, Kerr PJ, Wright JD, Strive T. Serological assays to discriminate rabbit haemorrhagic disease virus from Australian non-pathogenic rabbit calicivirus. *Vet Microbiol*. 2012;157(3-4):345-54.
- Lopes AM, Correia J, Abrantes J, Melo P, Ramada M, Magalhães MJ, Alves PC, Esteves PJ. Is the new variant RHDV replacing genogroup 1 in Portuguese wild rabbit populations? *Viruses*. 2014;7:27-36.
- Lopes AM, Marques S, Silva E, Magalhães MJ, Pinheiro A, Alves PC, Le Pendu J, Esteves PJ, Thompson G, Abrantes J. Detection of RHDV strains in the Iberian hare (*Lepus granatensis*): earliest evidence of rabbit lagovirus cross-species infection. *Vet Res*. 2014;45:94.
- Marchandeanu S, Le Gall-Reculé G, Bertagnoli S, Aubineau J, Botti G, Lavazza A. Serological evidence for a non-protective RHDV-like virus. *Vet Res*. 2005;36:53-62.
- Marques RM, Teixeira L, Aguas AP, Ribeiro JC, Costa-e-Silva A, Ferreira PG. Immunosuppression abrogates resistance of young rabbits to rabbit haemorrhagic disease (RHD). *Vet Res*. 2014;45:14.
- Matthaei M, Kerr PJ, Read AJ, Hick P, Haboury S, Wright JD, Strive T. Comparative quantitative monitoring of rabbit haemorrhagic disease viruses in rabbit kittens. *Virology*. 2014;11:109.
- Mayer J. Rabbit calicivirus disease (viral hemorrhagic disease). In: Kahn CM, Line S, Aiello SE, editors. The Merck veterinary manual [online]. Whitehouse Station, NJ: Merck and Co; 2015. Available at: http://www.merckvetmanual.com/mvm/exotic_and_laboratory_animals/rabbits/viral_diseases_of_rabbits.html. Accessed 2 Jun 2016.
- Merchán T, Rocha G, Alda F, Silva E, Thompson G, de Trucios SH, Pagés A. Detection of rabbit haemorrhagic disease virus (RHDV) in nonspecific vertebrate hosts sympatric to the European wild rabbit (*Oryctolagus cuniculus*). *Infect Genet Evol*. 2011;11(6):1469-74.
- McColl KA, Merchant JC, Hardy J, Cooke BD, Robinson A, Westbury HA. Evidence for insect transmission of rabbit haemorrhagic disease virus. *Epidemiol Infect*. 2002;129:655-63.
- McColl KA, Morrissy CJ, Collins BJ, Westbury HA. Persistence of rabbit haemorrhagic disease virus in decomposing rabbit carcasses. *Aust Vet J*. 2002;80:298-9.
- McIntosh MT, Behan SC, Mohamed FM, Lu Z, Moran KE, Burrage TG, Neilan JG, Ward GB, Botti G, Capucci L, Metwally SA. A pandemic strain of calicivirus threatens rabbit industries in the Americas. *Virology*. 2007;4:96.

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- Moss SR, Turner SL, Trout RC, White PJ, Hudson PJ, Desai A, Armesto M, Forrester NL, Gould EA. Molecular epidemiology of rabbit haemorrhagic disease virus. *J Gen Virol.* 2002;83:2461-7.
- Peacock D, Mutze G, Sinclair R, Kovaliski J, Cooke B. Rabbit haemorrhagic disease: applying Occam's razor to competing hypotheses. *Mol Ecol.* 2012;21(5):1038-41.
- Puggioni G, Cavadini P, Maestrone C, Scivoli R, Botti G, Ligios C, Le Gall-Reculé G, Lavazza A, Capucci L. The new French 2010 rabbit hemorrhagic disease virus causes an RHD-like disease in the Sardinian Cape hare (*Lepus capensis mediterraneus*). *Vet Res.* 2013;44:96.
- Saunders R. Vaccinating rabbits against RVHD-2. *Vet Rec.* 2016;178(4):100-1.
- Schwensow NI, Cooke B, Kovaliski J, Sinclair R, Peacock D, Fickel J, Sommer S. Rabbit haemorrhagic disease: virus persistence and adaptation in Australia. *Evol Appl.* 2014;7(9):1056-67.
- Shien JH, Shieh HK, Lee LH. Experimental infections of rabbits with rabbit haemorrhagic disease virus monitored by polymerase chain reaction. *Res Vet Sci.* 2000;68:255-9.
- U.S. Department of Agriculture, Animal and Plant Health Inspection Service [USDA APHIS], Centers for Epidemiology and Animal Health [CEI]. Rabbit calicivirus disease, Iowa, April 2000. Impact worksheet. USDA APHIS, VS CEI; 2000 Apr. Available at: <http://www.aphis.usda.gov:80/vs/ceah/cei/rabbitcal.htm>.*
- U.S. Department of Agriculture, Animal and Plant Health Inspection Service [USDA APHIS], Centers for Epidemiology and Animal Health [CEI]. Rabbit hemorrhagic disease, Indiana. Impact worksheet. USDA APHIS, VS CEI; 2005 Jun. Available at: http://www.aphis.usda.gov/vs/ceah/cei/IW_2005_files/RHD_Indiana_061505_files/RHD_Indiana_061505.htm.* Accessed 25 Jan 2006.
- Van de Bildt MW, van Bolhuis GH, van Zijderveld F, van Riel D, Drees JM, Osterhaus AD, Kuiken T. Confirmation and phylogenetic analysis of rabbit hemorrhagic disease virus in free-living rabbits from the Netherlands. *J Wildl Dis.* 2006;42:808-12.
- Wang X, Hao H, Qiu L, Dang R, Du E, Zhang S, Yang Z. Phylogenetic analysis of rabbit hemorrhagic disease virus in China and the antigenic variation of new strains. *Arch Virol.* 2012;157(8):1523-30.
- Westcott DG, Choudhury B. Rabbit haemorrhagic disease virus 2-like variant in Great Britain. *Vet Rec.* 2015;176(3):74.
- White PJ, Trout RC, Moss SR, Desai A, Armesto M, Forrester NL, Gould EA, Hudson PJ. Epidemiology of rabbit haemorrhagic disease virus in the United Kingdom: evidence for seasonal transmission by both virulent and avirulent modes of infection. *Epidemiol Infect.* 2004;132:555-67.
- World Organization for Animal Health [OIE] Handistatus II [database online]. OIE; 2004. Available at: <http://www.oie.int/hs2/report.asp?lang=en>. Accessed 4 Sept 2007.
- World Organization for Animal Health [OIE] . Manual of diagnostic tests and vaccines for terrestrial animals [online]. Paris: OIE; 2016. Rabbit haemorrhagic disease. Available at: http://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/2.06.02_RHD.pdf. Accessed 21 Jun 2016.
- World Organization for Animal Health [OIE]. News from member nations. Self-declaration by Uruguay of freedom from rabbit hemorrhagic disease. Available at: www.oie.int/doc/ged/D12729.PDF. Accessed 29 Jun 2016.
- World Organization for Animal Health (OIE). World animal health information database (WAHID) [online]. Rabbit haemorrhagic disease: January 2005 – 2016. Paris:OIE;2016. Available at: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home. Accessed 27 Jun 2016.
- Yuan D, Guo D, Liu J, Si C, Jiang Q, Lin H, Yang T, Qu L. Development of a reverse-transcription loop-mediated isothermal amplification method for detection of rabbit hemorrhagic disease virus. *J Virol Methods.* 2013;187(2):274-7.
- Zheng T, Lu G, Napier AM, Lockyer SJ. No virus replication in domestic cats fed with RHDV-infected rabbit livers. *Vet Microbiol.* 2003;95:61-73.

*Link defunct as of 2016