

Canine Influenza

Last Full Review: November 2015

Minor Updates: February 2016

Importance

Influenza is a viral disease that has long been known to affect birds and some mammals, but was only recently recognized in dogs. Each influenza virus is maintained in one or more related host species; however, host specificity is not absolute. A virus may occasionally infect other animals, or on rare occasions, become adapted to a new species. No influenza viruses were known to circulate in dogs until 2004-2006, when a virus caused outbreaks of severe and often fatal respiratory disease among racing greyhounds in the U.S. This virus was acquired from horses, and probably entered greyhound populations several years before these outbreaks. Although it has spread to other dogs since this time, the illness in these animals has been more typical of influenza. The most common syndrome is a relatively mild upper respiratory disease with a persistent cough. Pneumonia is possible, generally as the result of secondary infection with bacteria or mycoplasma, but uncommon. At present, infections tend to be seen mainly in animal shelters, kennels, dog day care facilities, or other sites where groups of susceptible dogs are in close contact. This virus does not seem to have spread widely in other pets, and it has not yet been reported outside North America.

A second canine influenza virus was recognized in 2007, when a different virus caused an outbreak of severe respiratory disease in South Korea. This virus seems to have been acquired from birds, and may have entered canine populations around 2005. It was subsequently reported in China and Thailand, and can affect cats as well as dogs. Many reported clinical cases from Asia have been severe, but antibodies have been found in significant numbers of healthy dogs and cats there, suggesting that some animals have milder illnesses. This virus entered North America in 2015. While large numbers of cases have been reported among dogs in the U.S., there have been few deaths, as of November 2015, and most cases appear to be mild.

Other influenza viruses can also affect dogs, without persisting in canine populations. Equine influenza viruses have caused a few small outbreaks, and there are occasionally reports of infections or clinical cases caused by viruses adapted to birds or humans.

Etiology

Canine influenza viruses belong to the species *influenza A virus*, genus *Influenzavirus A*, and family Orthomyxoviridae. Other influenza A viruses circulate in birds (avian influenza viruses), horses and other equids (equine influenza viruses), pigs (swine influenza viruses) or people (human influenza A viruses). Influenza A viruses are classified into subtypes based on two surface proteins, the hemagglutinin (HA) and neuraminidase (NA). The subtype designation consists of the HA and NA found in that virus (e.g., H1N2). While at least 16 types of hemagglutinins (H1 to H16), and 9 neuraminidases (N1 to N9) are known to exist in birds, and two additional HA and NA types occur in bats, only a few avian subtypes (and no bat subtypes) have adapted to circulate in other mammals.

Influenza A viruses are extremely variable, and two viruses that share a subtype may be only distantly related. Nevertheless, all influenza A viruses (except possibly the bat viruses) are similar enough that they can 'reassort,' exchanging gene segments to produce progeny containing elements of both parental viruses – regardless of their original host specificity or subtype. Influenza A viruses can also infect species other than the hosts in which they normally circulate, and on rare occasions, they may adapt to circulate in a new host. [The 'Influenza' factsheet contains a more extensive description of these processes.] Dogs have acquired two influenza viruses since 1999, an H3N8 virus that came from horses, and an H3N2 virus that came from birds.

The North American H3N8 canine influenza virus seems to have jumped directly from horses to dogs, probably in the late 1990s or early 2000s. It is most closely related to the 'Florida lineage' of H3N8 equine influenza viruses, which emerged in the early 1990s. The H3N8 canine influenza virus is maintained in dog populations, and may be evolving into two lineages. It has diverged considerably from equine influenza viruses, and no longer seems to be capable of replicating efficiently in



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horses. The H3N2 canine influenza virus seems to have originated in birds. It is reported to contain gene segments that may have come from several different avian influenza viruses. There is some evidence for its presence among dogs in South Korea as early as 2005, and in China in 2006. H3N2 canine influenza viruses have acquired some diversity in the HA and NA, and appear to be evolving separately in these two countries. There is also evidence of occasional reassortment with avian influenza viruses from poultry. A recent analysis suggested that one canine H3N2 isolate may have acquired a gene from an avian H5N1 HPAI virus. In another case, an H3N2 virus had evidence of reassortment with an avian H9N2 virus.

Other influenza A viruses are also found sporadically in dogs, but are not maintained in canine populations, and are not considered to be canine influenza viruses. They include H3N8 equine influenza viruses, which have caused a few isolated outbreaks in dogs exposed to infected horses, and human influenza viruses including the 2009 pandemic H1N1 influenza virus. An H3N1 virus, which seems to be the result of reassortment between the H3N2 canine influenza virus and the 2009 pandemic H1N1 virus, was recently isolated from a dog with respiratory signs in Korea. A naturally co-infected dog, infected with the latter two 'parental' viruses, has been described. A few dogs have also been affected by some viruses found in birds, such as the Asian lineage H5N1 highly pathogenic avian influenza (HPAI) viruses, an H5N2 HPAI virus that is closely related to this virus, and H9N2 viruses.

Species Affected

As of 2015, the H3N8 canine influenza virus has only been reported in dogs. Its ability to replicate in horses appears to be greatly reduced, with low or absent virus shedding, and inefficient transmission from experimentally infected horses to naive horses. One study reported that horses were not infected when kept in close contact with experimentally infected dogs. One group reported finding viral nucleic acids in two cats, but concluded that the cats were not infected as they never developed measurable antibody (HI) titers to the virus. In laboratory studies, the H3N8 canine influenza virus was not transmitted readily to chickens, turkeys or ducks, and it did not replicate well in pigs.

The H3N2 canine influenza virus has caused clinical cases in dogs and cats in Asia, and antibodies to this virus have been found in both species. Dogs and cats can be infected by contact with experimentally infected dogs, and cats can transmit the virus to other cats. Ferrets can become infected after direct inoculation of the virus in the laboratory, but they seem to be less susceptible: ferrets did not become infected after exposure to experimentally infected dogs, and ferret-to-ferret transmission was limited. Guinea pigs are also susceptible to experimental infection, but there was no evidence for virus replication or shedding in experimentally inoculated chickens, ducks, mice or pigs.

Geographic Distribution

The H3N8 canine influenza virus has been detected, at least sporadically, in most states in the U.S. The distribution of this virus is patchy; in some cases, it caused an outbreak or was detected serologically in an area, but later disappeared. There is no evidence that it currently circulates outside the U.S. As of February 2016, the H3N2 canine influenza virus has been confirmed in Korea, China, Thailand and North America (the U.S.). A serological study found no evidence of its presence in Japan.

Infections with viruses not adapted to dogs can occur wherever these viruses are endemic. Human influenza viruses occur worldwide, and H3N8 equine influenza viruses are widely distributed. Avian influenza viruses are also widely distributed, although different viruses can circulate in different areas.

Transmission

In mammals, influenza viruses are usually transmitted in droplets and aerosols created by coughing and sneezing, and by contact with nasal discharges, either directly or on fomites. Close contact and closed environments favor transmission. The H3N8 and H3N2 canine influenza viruses are both found in respiratory secretions, as is typical of mammalian influenza viruses. Fecal shedding has not been reported for either virus.

The H3N8 canine influenza virus can be detected in the respiratory secretions of both symptomatic and subclinically infected dogs. Overall, virus titers seem to be low, and the H3N8 canine influenza virus does not appear to spread rapidly in the community. However, transmission can occur more efficiently where groups of susceptible dogs are in close contact (e.g., in a kennel). The H3N2 canine influenza virus might be transmitted more efficiently. In addition, treatment with glucocorticoids (prednisolone) was reported to prolong the shedding of the latter virus; in one experiment, the H3N2 canine influenza virus could be detected in the nasal secretions of some treated dogs for as long as 13 days, compared to 8 days in the controls. Experimentally infected cats can shed the H3N2 canine influenza virus, and transmission between cats was reported to be rapid during one outbreak at one animal shelter in South Korea.

Dogs infected with other influenza viruses (i.e., those not adapted to dogs) may or may not transmit them to others in close contact. There seems to be no significant dog-to-dog transmission of H3N8 equine influenza viruses.

There is no specific information on the persistence of canine influenza viruses in the environment; however, it is likely to be similar to other mammalian influenza viruses. Human influenza A viruses seem to remain viable for less than 24-48 hours on most surfaces, with recovery from porous surfaces sometimes lasting less than 8-12 hours. Nevertheless, some data indicate that they might survive longer on some fomites or in some conditions. Low

temperatures and protection from sunlight enhance virus survival. Swine influenza viruses and avian influenza viruses can persist in feces from <1 day to 2 weeks or longer, depending on environmental factors including desiccation. Avian influenza viruses and human influenza A viruses may be found for weeks or months in some types of water (e.g., distilled), although they might be inactivated faster in aquatic environments that contain normal microbial flora.

Disinfection

Influenza A viruses are susceptible to a wide variety of disinfectants including sodium hypochlorite, 60% to 95% ethanol, quaternary ammonium compounds, aldehydes (glutaraldehyde, formaldehyde), phenols, acids, povidone-iodine and other agents. Common household agents including 1% bleach, 10% malt vinegar or 0.01-0.1% dishwashing liquid (washing up liquid), as well as antimicrobial wipes, were found to destroy the viability of human influenza viruses, although hot water alone (55°C; 131°F) did not eliminate these viruses rapidly. Influenza A viruses can also be inactivated by heat of 56-60°C (133-140°F) for a minimum of 60 minutes (or higher temperatures for shorter periods), as well as by ionizing radiation or extremes of pH (pH 1-3 or pH 10-14).

Incubation Period

The incubation period for H3N8 canine influenza is thought to be one to 5 days, with most cases appearing in 2 to 3 days.

Fever has been reported as soon as one to 3 days in dogs inoculated with the H3N2 canine influenza virus, with respiratory signs developing 2 to 8 days after inoculation. In experimentally infected cats, clinical signs first appeared after 2 to 7 days.

Clinical Signs

Canine influenza (H3N8)

The most common presentation in H3N8 canine influenza is a mild illness that resembles infectious tracheobronchitis (kennel cough) or other upper respiratory diseases. An initial (usually low grade) fever may be followed by a persistent cough, which tends to be nonproductive and dry (in cases not complicated by co-infections), but may also be soft and moist. The cough can last for up to 3 weeks regardless of treatment. Other common clinical signs include nasal discharge, sneezing, ocular discharge, lethargy and anorexia. The nasal discharge can start clear but may quickly become mucopurulent. Purulent discharges seem to resolve with antibiotics, suggesting the involvement of secondary bacterial infections. Some dogs have only a low fever, without respiratory signs, and asymptomatic seroconversion has been reported.

More severely affected dogs exhibit a high fever with an increased respiratory rate and other signs of pneumonia

or bronchopneumonia. Severe lung involvement seems to occur mainly in cases with secondary bacterial or mycoplasmal infections. During the initial outbreaks among racing greyhounds, some dogs were found dead peracutely with evidence of hemorrhages in the respiratory tract. This syndrome does not seem to be prominent in pets.

Experimentally infected horses had mild clinical signs compared to horses inoculated with equine influenza viruses, or remained asymptomatic.

Canine influenza (H3N2)

Clinical cases reported in dogs have been characterized by fever (which may be low) and respiratory signs including nasal discharge, sneezing, coughing and anorexia. The nasal discharge was described as copious in one report. Dogs affected in early reports from South Korea and China were severely ill, and although few cases were reported, a number of them were fatal. Affected dogs developed mild to severe respiratory signs during two outbreaks at animal shelters in South Korea, with significant numbers of deaths. Similar respiratory signs were described during a recent outbreak at a veterinary hospital in Thailand. The severity of the clinical signs was not described in this report, but no deaths are mentioned. Some of these dogs were ill for as long as 7-10 days. In Asia, some dogs without a history of severe respiratory disease are seropositive, suggesting that subclinical infections may also occur. There are currently no published articles describing the outbreaks in the U.S.; however, informal reports suggest that most cases have been characterized by relatively mild upper respiratory signs, with few deaths.

The H3N2 canine influenza virus also seems to cause illness in cats. This virus has been found in cats during outbreaks of respiratory disease among dogs and cats at two animal shelters in South Korea. The clinical signs in the cats included coughing, dyspnea, tachypnea and lethargy, and a significant number of infections were fatal. Co-infections might have played some role in at least one of these outbreaks, as *Bordetella bronchiseptica* was also found in at least one cat. Cats that were experimentally infected with the H3N2 canine influenza virus had elevated temperatures, lethargy and respiratory signs including coughing, sneezing, ocular and nasal discharge, conjunctivitis and abdominal breathing. Antibodies to the H3N2 canine influenza virus have also been reported in apparently healthy cats.

Although ferrets were not very susceptible to this virus, some experimentally infected animals developed clinical signs. Sneezing was seen most often, and some animals were lethargic and anorectic. Experimentally infected guinea pigs remained asymptomatic, but developed lung lesions.

Other influenza viruses in dogs

In the U.K., an H3N8 equine influenza virus caused a limited outbreak among foxhounds in 2002. The disease was characterized by coughing, lethargy and weakness,

sometimes progressing to loss of consciousness, and was diagnosed as bronchointerstitial pneumonia. One dog died and several were euthanized. Clinical signs in dogs infected with H3N8 equine influenza viruses in Australia included anorexia, depression, slight nasal discharge, and in some cases, a cough that persisted for several weeks. All of these dogs recovered. Dogs that were experimentally infected with H3N8 equine influenza viruses remained asymptomatic or had very mild clinical signs (e.g., periodic anorexia and sneezing).

An H3N1 virus, which appears to be a reassortant between the canine H3N2 virus and the human 2009 pandemic H1N1 virus, was isolated from a dog with respiratory signs in Korea. Dogs inoculated with this virus remained asymptomatic and had only mild lung lesions.

There are only a few descriptions of human influenza virus infections in dogs. Some viruses, such as the 2009 pandemic H1N1 virus, are capable of causing severe respiratory signs, with radiological evidence of pneumonia, but milder signs have also been reported, and several studies have detected antibodies to human influenza viruses in healthy dogs that had no history of severe respiratory illness. Natural or experimental avian influenza virus infections in dogs have, likewise, ranged from asymptomatic or mild (e.g., transient fever, conjunctivitis or mild respiratory signs) to severe illnesses with respiratory signs, fever, and in some cases, systemic signs such as diarrhea. As with human influenza viruses, antibodies to various avian influenza viruses have been detected in healthy dogs in some locations (e.g., China). Additional details are available in the 'Influenza' factsheet.

Post Mortem Lesions

Canine influenza (H3N8)

Fatal H3N8 canine influenza cases in racing greyhounds were often characterized by hemorrhages in the lungs, mediastinum and pleural cavity. The lungs also exhibited signs of severe pneumonia, and were dark red to black. Fibrinous pleuritis was seen in some cases. In other dogs, fatal cases seem to be characterized mainly by suppurative secondary bacterial pneumonia, and hemorrhagic pneumonia does not appear to be common. Bronchitis and tracheitis were the only significant lesions in 5 shelter dogs that were euthanized primarily for a chronic cough unresponsive to antibiotics.

Based on studies in experimentally infected dogs, the early lesions are thought to be tracheitis and bronchitis, with some extension to the bronchioles. Variable lower respiratory tract lesions may be seen, especially later in the illness, and may include petechiae, areas of consolidation and other lesions consistent with viral pneumonia.

Canine influenza (H3N2)

Severe hemorrhagic, cranioventral bronchointerstitial pneumonia was reported in most fatal cases of canine H3N2 influenza in naturally infected dogs from Asia; however,

only partial necropsies were available and only for a limited number of cases. Experimentally infected dogs also had signs of pneumonia with multifocal to coalescing reddish consolidation, edema and hemorrhages in the lungs. No lesions were found outside the respiratory tract.

During one outbreak of severe respiratory disease in cats, the lesions included severe bronchopneumonia with consolidation in large areas of the lung, and pulmonary edema in some cats. Some cats were coinfecting with other respiratory pathogens.

Some experimentally infected ferrets and guinea pigs had areas of consolidation in the lungs.

Diagnostic Tests

Canine influenza (H3N8)

Serology and reverse transcription polymerase chain reaction (RT-PCR) assays are the most reliable methods for detecting H3N8 canine influenza. Hemagglutination inhibition is considered the serological test of choice. Virus neutralization (microneutralization test) can also be done, but this test is usually too cumbersome for routine use. Antibodies usually develop 7-10 days after infection and continue to rise to high levels around 14 days. Although acute and convalescent titers are ideal, many dogs do not have pre-existing titers to this virus, and a single sample collected more than 7 days after the onset of clinical signs may be useful.

RT-PCR is the most reliable method to detect the virus directly, due to its sensitivity. Nasal swabs are the preferred sample from live dogs, and were more likely to yield virus than nasopharyngeal swabs in experimentally infected dogs. Lung tissue samples are collected at necropsy. Virus isolation may also be done, but it is unlikely to be successful in a dog that has had clinical signs for more than 3 days. The H3N8 canine influenza virus has been isolated in both embryonated eggs and cell cultures (MDCK cells); some viruses have been recovered in only eggs or cells, while others can be isolated in both systems. Both virus isolation and RT-PCR can fail to detect the virus in infected dogs if the samples are collected too late.

Antigen-capture ELISA tests do not seem to be reliable in individual dogs, probably because virus shedding is low, and the timing of sample collection is not always optimal. A recent study suggested that the sensitivity of these tests is much lower than RT-PCR and lower than virus isolation, and false positives were also common. However, they may be useful during investigations of outbreaks at kennels or other facilities housing groups of dogs.

Canine influenza (H3N2)

Little has been published about diagnostic testing for H3N2 canine influenza, but virus isolation and RT-PCR were used in some outbreaks, and a multiplex PCR assay developed in South Korea has been published. Respiratory samples (e.g., nasal swabs) are collected. Serological tests

may also be helpful, and at least one test is now available in the U.S. It should be noted that the H3N8 and H3N2 canine influenza viruses differ significantly; RT-PCR and serological tests used to detect the H3N8 canine influenza virus will not detect infections with the H3N2 virus.

Treatment

Treatment is supportive, and often includes antibiotics to control secondary bacterial infections. Although antiviral drugs (e.g., neuraminidase inhibitors) are sometimes used in cases of human influenza, these drugs have not been tested in canine influenza. They are most useful during the first 48 hours after the onset of clinical signs, and in many cases, this period is likely to have passed by the time the dog is seen by a veterinarian. The risk that viruses might become resistant to these drugs is also a concern.

Control

Disease reporting

Official reporting requirements for canine influenza differ between areas, and this disease is currently reportable in some U.S. states, but not others. However, information about outbreaks is often disseminated even in locations with no formal requirement to report this disease.

Prevention

Vaccines for canine influenza are available in some areas. A licensed vaccine for the H3N8 canine influenza virus is commercially available in the U.S. An H3N2 canine influenza virus has been approved in South Korea. The degree of cross-protection between these viruses, if any, is currently unclear.

Influenza viruses usually spread most readily when susceptible animals are in close contact. Infection control measures are similar to those used for other contagious respiratory diseases, and include isolation of infected animals; cleaning and disinfection of cages, bowls and other fomites; and hygiene measures including hand washing. Clothing can be cleaned by washing it with detergent at normal laundry temperatures.

Veterinarians should be alert to announcements of canine influenza outbreaks in an area. Clients should also be advised to consult a veterinarian if their dog develops signs of a respiratory illness, and should be questioned about potential exposures to other dogs (e.g., recent boarding). When outbreaks occur at establishments, quarantines and the isolation of infected animals can reduce virus dissemination to the community and within the facility.

Morbidity and Mortality

In mammals, the severity of the clinical signs can differ with the virus, and is also influenced by host factors such as immunity, age and concurrent diseases. Uncomplicated infections with influenza viruses adapted to that host tend to be associated with high morbidity rates, low mortality rates

and rapid recovery. More severe disease and higher mortality rates may be seen in young, old or debilitated animals. Secondary bacterial infections can exacerbate the clinical signs, prolong recovery and result in complications such as pneumonia. Infections with viruses not adapted to that host vary widely in severity; some viruses typically cause asymptomatic infections and mild illnesses, while others tend to cause severe disease.

Canine influenza (H3N8)

Although H3N8 canine influenza was first reported in racing greyhounds, all breeds are now considered to be susceptible. The greatest risk of infection is among dogs that reside in kennels or are exposed to transient groups of dogs, as in animal shelters or dog day care facilities. In some facilities, more than 40% of the dogs may be seropositive. Infected dogs from these high risk populations may introduce the virus into new areas. Currently, the H3N8 canine influenza virus does not appear to be common among household pets in the U.S., with studies reporting seroprevalence rates less than 5%. In some areas, exposure rates have been low even in pets that participate in some types of gatherings (e.g., flyball tournaments). One study suggested that canine influenza is rare, if it exists at all, in Canada. In the province of Ontario, a survey found antibodies to the H3N8 virus in only one of 225 dogs in 2006. This dog was a greyhound that had come from a racetrack in Florida, and may have been infected there. More recently, no seropositive dogs were found among Canadian and U.S. dogs that participated in the 2010 Iditarod race.

During outbreaks among fully susceptible dogs in close contact (e.g., in kennels), the infection rate may approach 100%, and clinical signs in 60-80% of the dogs is not unusual. Most dogs are expected to develop the less severe form of the disease and recover; however, a more severe form with pneumonia occurs in a minority. The overall mortality rate is thought to be 1-5%, although some sources suggest that it might be as high as 8%. Secondary bacterial infections appear to contribute significantly to these deaths. Higher case fatality rates have been reported in small groups of greyhounds. At one Florida greyhound racetrack, the case fatality rate was 36%. More severe illness would also be expected in debilitated animals.

Canine influenza (H3N2)

Illnesses caused by the H3N2 canine influenza virus have been reported from veterinary hospitals, kennels and animal shelters in South Korea, China and Thailand, and recently, from dogs in the U.S. There is no known breed predilection; cases have been described in various species of dogs, as well as cats. Many of the reported clinical cases from Asia have been severe. In the initial report from Korea, only one of the 5 dogs seen at 3 veterinary clinics survived. Similarly, 2 of 4 cases in pet dogs diagnosed in China were fatal. During one explosive, severe outbreak at a Korean animal shelter, approximately 200 dogs and 50

cats showed signs of respiratory disease. The morbidity rate in this outbreak was 100% in cats, while the case fatality rate was 25% in affected dogs, and 40% in cats. It is possible that other pathogens also contributed to this outbreak. At least one cat that died was co-infected with *Bordetella bronchiseptica*. During another outbreak in a South Korean animal shelter, the morbidity and mortality rates were reported to be 77% and 23%, respectively, in dogs, and 47% and 22%, respectively, in cats. Currently, signs among dogs in the U.S. generally appear to be mild, and the case fatality rate is reported to be low; news reports indicated that there were approximately 8 confirmed deaths due to this virus, among more than 1500 cases as of May, 2015.

Studies from Asia have reported antibodies to the H3N2 canine influenza virus among cats and dogs with or without respiratory signs. One study found that 3.5% of serum samples collected from dogs in South Korea between 2005 and 2009 were seropositive. Approximately 3% of pet cats and cats in colonies in South Korea also had antibodies to this virus. Studies from China have reported seroprevalence rates ranging from 3.5% to 33% in dogs, and 1% to 10% in cats. Some of these studies reported relatively high seroprevalence rates among stray dogs in animal shelters (20%), dogs raised for food (12%), and dogs living on poultry farms and near poultry markets (5-14% or 16-33%, depending on the assay); however, one study also reported antibodies in 33% of pet dogs. While cross-reactivity with other influenza viruses can complicate serological studies, some of these studies reported a pattern of reactivity that is higher to the H3N2 canine influenza virus than to H3 influenza viruses from other species.

Public Health

There are no reports of human infections with canine influenza viruses, although such infections are theoretically possible. As a precaution, physicians, veterinarians and others have been asked to report any cases of human influenza that seem to be linked to exposure to canine influenza. As a general practice, it is prudent for immunocompromised people, the elderly, young children and pregnant women to avoid contact with animals that are ill.

Internet Resources

American Animal Hospital Association (AAHA). Canine influenza.
<https://www.avma.org/KB/Resources/Reference/Pages/Canine-Influenza-Backgrounder.aspx>

American Animal Hospital Association (AAHA) Client Fact Sheet
http://secure.aahanet.org/eweb/dynamicpage.aspx?site=resources&webcode=CI_clientfactsheet

Cornell University College of Veterinary Medicine. Canine Influenza Virus (including testing, sample submission).

<https://ahdc.vet.cornell.edu/news/civ.cfm>

The Merck Veterinary Manual

<http://www.merckmanuals.com/vet/index.html>

Public Health Agency of Canada. Pathogen Safety Data Sheets

<http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/index-eng.php>

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References

- Acha PN, Szyfres B (Pan American Health Organization [PAHO]). Zoonoses and communicable diseases common to man and animals. Volume 2. Chlamydiosis, rickettsioses and viroses. 3rd ed. Washington DC: PAHO; 2003. Scientific and Technical Publication No. 580. Influenza; p. 155-172.
- American Animal Hospital Association [AAHA]. Canine influenza – background for professionals. AAHA; 2005 Oct. Available at: http://www.aahanet.org/index_adds/canine_flu_background.html.* Accessed 6 Mar 2007.
- American Veterinary Medical Association. Canine influenza virus emerges in Florida [online]. J Am Vet Med Assoc News Express. Sept. 22, 2005. Available at: <http://www.avma.org/onlnews/javma/oct05/x051015b.asp>.* Accessed 7 Mar 2005.
- American Veterinary Medical Association [AVMA]. Control of canine influenza in dogs. AVMA; 2005 Dec. Available at: http://www.avma.org/public_health/influenza/canine_guidelines.asp.* Accessed 6 Mar 2007.
- Anderson TC, Bromfield CR, Crawford PC, Dodds WJ, Gibbs EP, Hernandez JA. Serological evidence of H3N8 canine influenza-like virus circulation in USA dogs prior to 2004. Vet J. 2012;191(3):312-6.
- Anderson TC, Crawford PC, Dubovi EJ, Gibbs EP, Hernandez JA. Prevalence of and exposure factors for seropositivity to H3N8 canine influenza virus in dogs with influenza-like illness in the United States. J Am Vet Med Assoc. 2013;242(2):209-16.

- Anderson TC, Crawford PC, Katz JM, Dubovi EJ, Landolt G, Gibbs EP. Diagnostic performance of the canine influenza A virus subtype H3N8 hemagglutination inhibition assay. *J Vet Diagn Invest.* 2012 May;24(3):499-508.
- Barrell EA, Pecoraro HL, Torres-Henderson C, Morley PS, Lunn KF, Landolt GA. Seroprevalence and risk factors for canine influenza virus (H3N8) exposure in household dogs in Colorado. *J Vet Intern Med.* 2010;24:1524-7.
- Bean B, Moore BM, Sterner B, Peterson LR, Gerding DN, Balfour HH, Jr. Survival of influenza viruses on environmental surfaces. *J Infect Dis.* 1982;146(1):47-51.
- Brown IH. (OIE/FAO/EU International Reference Laboratory for Avian Influenza). Influenza virus infections of pigs. Part 1: swine, avian & human influenza viruses [monograph online]. Available at: <http://www.pighealth.com/influenza.htm>. * Accessed 31 Dec 2006.
- Brown JD, Swayne DE, Cooper RJ, Burns RE, Stallknecht DE. Persistence of H5 and H7 avian influenza viruses in water. *Avian Dis.* 2007;51(1 Suppl):285-9.
- Bunpapong N, Nonthabenjawan N, Chaiwong S, Tangwangvivat R, Boonyapisitsopa S, Jairak W, Tuanudom R, Prakairungnamthip D, Suradhat S, Thanawongnuwech R, Amonsin A. Genetic characterization of canine influenza A virus (H3N2) in Thailand. *Virus Genes.* 2014;48(1):56-63.
- Buonavoglia C, Martella V. Canine respiratory viruses. *Vet Res.* 2007;38:355-373.
- Carey S. UF researchers: equine influenza virus likely cause of Jacksonville greyhound deaths [online]. News Releases, University of Florida College of Veterinary Medicine. Available at: http://www.vetmed.ufl.edu/pr/nw_story/greyhds.htm. * Accessed 7 Mar 2005.
- Castleman WL, Powe JR, Crawford PC, Gibbs EP, Dubovi EJ, Donis RO, Hanshaw D. Canine H3N8 influenza virus infection in dogs and mice. *Vet Pathol.* 2010;47(3):507-17.
- Chen Y, Mo YN, Zhou HB, Wei ZZ, Wang GJ, Yu QX, Xiao X, Yang WJ, Huang WJ. Emergence of human-like H3N2 influenza viruses in pet dogs in Guangxi, China. *Virology.* 2015;12:10.
- Chen Y, Zhong G, Wang G, Deng G, Li Y, Shi J, Zhang Z, Guan Y, Jiang Y, Bu Z, Kawaoka Y, Chen H. Dogs are highly susceptible to H5N1 avian influenza virus. *Virology.* 2010;405(1):15-9.
- Cheng K, Yu Z, Gao Y, Xia X, He H, Hua Y, Chai H. Experimental infection of dogs with H6N1 avian influenza A virus. *Arch Virol.* 2014;159(9):2275-82.
- Chumpolbanchorn K, Suemanotham N, Siripara N, Puyati B, Chaichoune K. The effect of temperature and UV light on infectivity of avian influenza virus (H5N1, Thai field strain) in chicken fecal manure. *Southeast Asian J Trop Med Public Health.* 2006;37(1):102-5.
- Cornell University College of Veterinary Medicine. Canine influenza virus. Appropriate samples for detection [online]. Animal Health Diagnostic Center – Emerging Issues. Available at: <http://www.diaglab.vet.cornell.edu/issues/civ.asp#samp>. * Accessed 7 Mar 2007.
- Cornell University College of Veterinary Medicine. Canine influenza virus detected [online]. Animal Health Diagnostic Center Announcements. Sept 21, 2005. Available at <http://www.diaglab.vet.cornell.edu/issues/civ-dect.asp>. * Accessed 27 Sept 2005.
- Cornell University College of Veterinary Medicine. Midwest canine influenza outbreak caused by new strain of virus. Available at: <http://mediarelations.cornell.edu/2015/04/12/midwest-canine-influenza-outbreak-caused-by-new-strain-of-virus/>. Accessed 28 Nov 2015.
- Cornell University College of Veterinary Medicine. News: H3N2 influenza: how to protect your dog. Available at: <http://www.vet.cornell.edu/Baker/News/H3N2canineinfluenza.cfm>. Accessed 28 Nov 2015.
- Cornell University College of Veterinary Medicine. Cornell Animal Health Diagnostic Center develops test for H3N2. Available at: <http://www.vet.cornell.edu/news/H3N2CanineInfluenzaConfirm.cfm>. Accessed 28 Nov 2015.
- Cornell University College of Veterinary Medicine. Canine influenza H3N2 updates. Available at: <https://ahdc.vet.cornell.edu/news/civchicago.cfm>. Accessed 28 Nov 2015.
- Couch RB. Orthomyxoviruses [monograph online]. In: Baron S, editor. *Medical microbiology*. 4th ed. New York: Churchill Livingstone; 1996. Available at: <http://www.gsbs.utmb.edu/microbook/>. * Accessed 7 Mar 2007.
- Crawford PC, Dubovi EJ, Castleman WL, Stephenson I, Gibbs EPJ, Chen L, Smith C, Hill RC, Ferro P, Pompey J, Bright RA, Medina M-J, Johnson CM, Olsen CW, Cox NJ, Klimov AI, Katz JM, Donis RO. Transmission of equine influenza virus to dogs. *Science.* 2005;310:482-485.
- Crispe E, Finlaison DS, Hurt AC, Kirkland PD. Infection of dogs with equine influenza virus: evidence for transmission from horses during the Australian outbreak. *Aust Vet J.* 2011;89 Suppl 1:27-8.
- Daly JM, Blunden AS, Macrae S, Miller J, Bowman SJ, Kolodziejek J, Nowotny N, Smith KC. Transmission of equine influenza virus to English foxhounds. *Emerg Infect Dis.* 2008;14(3):461-4.
- Daly JM, Cullinane. Influenza infections [online]. In: Lekeux P, editor. *Equine respiratory diseases*. Ithaca NY: International Veterinary Information Service 189; 2013. Available at: http://www.ivis.org/special_books/Lekeux/daly/chapter.asp?LA=1. Accessed 16 June 2014.
- Damiani AM, Kalthoff D, Beer M, Müller E, Osterrieder N. Serological survey in dogs and cats for influenza A(H1N1)pdm09 in Germany. *Zoonoses Public Health.* 2012;59(8):549-52.
- Davidson I, Nagar S, Haddas R, Ben-Shabat M, Golender N, Lapin E, Altory A, Simanov L, Ribshtein I, Panshin A, Perk S. Avian influenza virus H9N2 survival at different temperatures and pHs. *Avian Dis.* 2010;54(1 Suppl):725-8.
- De Benedictis P., Beato MS, Capua I. Inactivation of avian influenza viruses by chemical agents and physical conditions: a review. *Zoonoses Public Health.* 2007;54(2):51-68.

- Deshpande M, Abdelmagid O, Tubbs A, Jayappa H, Wasmoen T. Experimental reproduction of canine influenza virus H3N8 infection in young puppies. *Vet Ther*. 2009;10(1-2):29-39.
- Domanska-Blicharz K, Minta Z, Smietanka K, Marche S, van den Berg T. H5N1 high pathogenicity avian influenza virus survival in different types of water. *Avian Dis*. 2010;54(1 Suppl):734-7.
- Dublineau A, Batejat C, Pinon A, Burguiere AM, Leclercq I, Manuguerra JC. Persistence of the 2009 pandemic influenza A (H1N1) virus in water and on non-porous surface. *PLoS One*. 2011;6(11):e28043.
- Dubovi EJ. Canine influenza. *Vet Clin North Am Small Anim Pract*. 2010;40(6):1063-71.
- Dubovi EJ, Njaa BL. Canine influenza. *Vet Clin North Am Small Anim Pract*. 2008;38:827-35, viii.
- Dundon WG, De BP, Viale E, Capua I. Serologic evidence of pandemic (H1N1) 2009 infection in dogs, Italy. *Emerg Infect Dis*. 2010;16(12):2019-21.
- Enserink M. Flu virus jumps from horses to dogs [online]. *Science Now*. American Association for the Advancement of Science; 26 September 2005. Available at: <http://sciencenow.sciencemag.org/cgi/content/full/2005/926/2>. Accessed 6 Mar 2007.
- Fenner F, Bachmann PA, Gibbs EPJ, Murphy FA, Studdert MJ, White DO. *Veterinary virology*. San Diego, CA: Academic Press Inc.; 1987. Orthomyxoviridae; p. 473-484.
- Giese M, Harder TC, Teifke JP, Klopfleisch R, Breithaupt A, Mettenleiter TC, Vahlenkamp TW. Experimental infection and natural contact exposure of dogs with avian influenza virus (H5N1). *Emerg Infect Dis*. 2008;14:308-10.
- Greatorex JS, Digard P, Curran MD, Moynihan R, Wensley H, Wreghitt T, Varsani H, Garcia F, Enstone J, Nguyen-Van-Tam JS. Survival of influenza A (H1N1) on materials found in households: implications for infection control. *PLoS One*. 2011;6(11):e27932.
- Greatorex JS, Page RF, Curran MD, Digard P, Enstone JE, Wreghitt T, Powell PP, Sexton DW, Vivancos R, Nguyen-Van-Tam JS. Effectiveness of common household cleaning agents in reducing the viability of human influenza A/H1N1. *PLoS One*. 2010;5(2):e8987.
- Haas B, Ahl R, Bohm R, Strauch D. Inactivation of viruses in liquid manure. *Rev Sci Tech*. 1995;14(2):435-45.
- Hai-Xia F, Yuan-Yuan L, Qian-Qian S, Zong-Shuai L, Feng-Xia Z, Yan-Li Z, Shi-Jin J, Zhi-Jing X. Interspecies transmission of canine influenza virus H5N2 to cats and chickens by close contact with experimentally infected dogs. *Vet Microbiol*. 2014;170(3-4):414-7.
- Hayward JJ, Dubovi EJ, Scarlett JM, Janeczko S, Holmes EC, Parrish CR. Microevolution of canine influenza virus in shelters and its molecular epidemiology in the United States. *J Virol*. 2010;84(24):12636-45.
- Hong M, Kang B, Na W, An D, Moon H, Kim DJ, Oh J, Park SJ, Poo H, Kim JK, Kim J, Song D. Prolonged shedding of the canine influenza H3N2 virus in nasal swabs of experimentally immunocompromised dogs. *Clin Exp Vaccine Res*. 2013;2(1):66-8.
- Horimoto T, Gen F, Murakami S, Iwatsuki-Horimoto K, Kato K, Akashi H, Hisasue M, Sakaguchi M, Kawaoka Y, Maeda K. Serological evidence of infection of dogs with human influenza viruses in Japan. *Vet Rec*. 2014;174(4):96.
- International Committee on Taxonomy of Viruses 133. Universal virus database, version 3. 00.046. Orthomyxoviridae [online]. Available at: <http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB>. Accessed 15 Dec 2009.
- Jeoung HY, Lim SI, Shin BH, Lim JA, Song JY, Song DS, Kang BK, Moon HJ, An DJ. A novel canine influenza H3N2 virus isolated from cats in an animal shelter. *Vet Microbiol*. 2013;165(3-4):281-6.
- Jeoung HY, Shin BH, Lee WH, Song DS, Choi YK, Jeong W, Song JY, An DJ. Seroprevalence of subtype H3 influenza A virus in South Korean cats. *J Feline Med Surg*. 2012;14(10):746-50.
- Jirjis FF, Deshpande MS, Tubbs AL, Jayappa H, Lakshmanan N, Wasmoen TL. Transmission of canine influenza virus (H3N8) among susceptible dogs. *Vet Microbiol*. 2010;144(3-4):303-9.
- Kang YM, Kim HM, Ku KB, Park EH, Yum J, Seo SH. H3N2 canine influenza virus causes severe morbidity in dogs with induction of genes related to inflammation and apoptosis. *Vet Res*. 2013;44:92.
- Kim H, Song D, Moon H, Yeom M, Park S, Hong M, Na W, Webby RJ, Webster RG, Park B, Kim JK, Kang B. Inter- and intraspecies transmission of canine influenza virus (H3N2) in dogs, cats, and ferrets. *Influenza Other Respir Viruses*. 2013;7(3):265-70.
- Kirkland PD, Finlaison DS, Crispe E, Hurt AC. Influenza virus transmission from horses to dogs, Australia. *Emerg Infect Dis*. 2010;16(4):699-702.
- Kruth SA, Carman S, Weese JS. Seroprevalence of antibodies to canine influenza virus in dogs in Ontario. *Can Vet J*. 2008;49:800-2.
- Lamb S, McElroy T. Bronson alerts public to newly emerging canine flu. Florida Department of Agriculture and Consumer Services; 2005 Sept. Available at: <http://doacs.state.fl.us/press/2005/09202005.html>. * Accessed 7 Mar 2005.
- Larson LJ, Henningson J, Sharp P, Thiel B, Deshpande MS, Davis T, Jayappa H, Wasmoen T, Lakshmanan N, Schultz RD. Efficacy of the canine influenza virus H3N8 vaccine to decrease severity of clinical disease after cochallenge with canine influenza virus and *Streptococcus equi* subsp. *zooepidemicus*. *Clin Vaccine Immunol*. 2011;18(4):559-64.
- Lee E, Kim EJ, Kim BH, Song JY, Cho IS, Shin YK. Molecular analyses of H3N2 canine influenza viruses isolated from Korea during 2013-2014. *Virus Genes*. 2016;52(2):204-17.
- Lee E, Kim EJ, Kim BH, Song JY, Cho IS, Shin YK. Multiplex RT-PCR detection of H3N2 influenza A virus in dogs. *Mol Cell Probes*. 2015;30(1):56-60.
- Lee IH, Le TB, Kim HS, Seo SH. Isolation of a novel H3N2 influenza virus containing a gene of H9N2 avian influenza in a dog in South Korea in 2015. *Virus Genes*. 2016 Jan 12. [Epub ahead of print].
- Lee YN, Lee DH, Lee HJ, Park JK, Yuk SS, Sung HJ, Park HM, Lee JB, Park SY, Choi IS, Song CS. Evidence of H3N2 canine influenza virus infection before 2007. *Vet Rec*. 2012;171(19):477.
- Lee YN, Lee DH, Park JK, Yuk SS, Kwon JH, Nahm SS, Lee JB, Park SY, Choi IS, Song CS. Experimental infection and natural contact exposure of ferrets with canine influenza virus (H3N2). *J Gen Virol*. 2013;94(Pt 9):2140.

- Lei N, Yuan ZG, Huang SF, Zhang DW, Zhang AG, Huang BH, Zhang GH, Li SJ. Transmission of avian-origin canine influenza viruses A (H3N2) in cats. *Vet Microbiol.* 2012;160(3-4):481-3.
- Li S, Shi Z, Jiao P, Zhang G, Zhong Z, Tian W, Long LP, Cai Z, Zhu X, Liao M, Wan XF. Avian-origin H3N2 canine influenza A viruses in southern China. *Infect Genet Evol.* 2010;10(8):1286-8.
- Lin D, Sun S, Du L, Ma J, Fan L, Pu J, Sun Y, Zhao J, Sun H, Liu J. Natural and experimental infection of dogs with pandemic H1N1/2009 influenza virus. *J Gen Virol.* 2012;93(Pt 1):119-23.
- Lu H, Castro AE, Pennick K, Liu J, Yang Q, Dunn P, Weinstock D, Henzler D. Survival of avian influenza virus H7N2 in SPF chickens and their environments. *Avian Dis.* 2003;47(3 Suppl):1015-21.
- Lyoo KS, Kim JK, Kang B, Moon H, Kim J, Song M, Park B, Kim SH, Webster RG, Song D. Comparative analysis of virulence of a novel, avian-origin H3N2 canine influenza virus in various host species. *Virus Res.* 2015;195:135-40. doi:
- Maas R, Tacke M, Ruuls L, Koch G, van RE, Stockhofe-Zurwieden N. Avian influenza (H5N1) susceptibility and receptors in dogs. *Emerg Infect Dis.* 2007;13(8):1219-21.
- McKinley ET, Spackman E, Pantin-Jackwood MJ. The pathogenesis of H3N8 canine influenza virus in chickens, turkeys and ducks. *Influenza Other Respir Viruses.* 2010;4(6):353-6.
- McManus CM, Levy JK, Andersen LA, McGorray SP, Leutenegger CM, Gray LK, Hilligass J, Tucker SJ. Prevalence of upper respiratory pathogens in four management models for unowned cats in the Southeast United States. *Vet J.* 2014;201(2):196-201.
- Na W, Lyoo KS, Song EJ, Hong M, Yeom M, Moon H, Kang BK, Kim DJ, Kim JK, Song D. Viral dominance of reassortants between canine influenza H3N2 and pandemic (2009) H1N1 viruses from a naturally co-infected dog. *Virol J.* 2015;12:134
- Newton R, Cooke A, Elton D, Bryant N, Rash A, Bowman S, Blunden T, Miller J, Hammond TA, Camm I, Day M. Canine influenza virus: cross-species transmission from horses. *Vet Rec.* 2007;161:142-143.
- Nielsen AA, Jensen TH, Stockmarr A, Jorgensen PH. Persistence of low-pathogenic H5N7 and H7N1 avian influenza subtypes in filtered natural waters. *Vet Microbiol.* 2013 October 25;166(3-4):419-28.
- Oxford J, Berezin EN, Courvalin P, Dwyer DE, Exner M, Jana LA, Kaku M, Lee C, Letlape K, Low DE, Madani TA, Rubino JR, Saini N, Schoub BD, Signorelli C, Tierno PM, Zhong X. The survival of influenza A(H1N1)pdm09 virus on 4 household surfaces. *Am J Infect Control.* 2014;42(4):423-5.
- Payungporn S, Crawford PC, Kouo TS, Chen LM, Pompey J, Castleman WL, Dubovi EJ, Katz JM, Donis RO. Influenza A virus (H3N8) in dogs with respiratory disease, Florida. *Emerg Infect Dis.* 2008;14:902-8.
- Pecoraro HL, Bennett S, Garretson K, Quintana AM, Lunn KF, Landolt GA. Comparison of the infectivity and transmission of contemporary canine and equine H3N8 influenza viruses in dogs. *Vet Med Int.* 2013;2013:874521.
- Pecoraro HL, Bennett S, Spindel ME, Landolt GA. Evolution of the hemagglutinin gene of H3N8 canine influenza virus in dogs. *Virus Genes.* 2014; 49(3): 393-9.
- Pecoraro HL, Lee JS, Achenbach J, Nelson S Jr, Landolt GA. Seroprevalence of canine influenza virus (H3N8) in Iditarod racing sled dogs. *Can Vet J.* 2012 Oct;53(10):1091-4.
- Pratelli A, Colao V. A population prevalence study on influenza infection in dogs in southern Italy. *New Microbiol.* 2014;37(3):277-83.
- Promed Mail. Influenza, canine-USA (Florida). June 20, 2006. Archive Number 20060620.1703. Available at <http://www.promedmail.org>. Accessed 10 Jan 2007.
- Promed Mail. Influenza, canine-USA (multistate). March 25, 2006. Archive Number 20060325.0921. Available at <http://www.promedmail.org>. Accessed 10 Jan 2007.
- Promed Mail. Influenza, canine-USA (multistate). October 2, 2005. Archive Number 20051002.2883. Available at <http://www.promedmail.org>. Accessed 10 Jan 2007.
- Promed Mail. Influenza, canine-USA (Wyoming). May 3, 2006. Archive Number 20060503.1279. Available at <http://www.promedmail.org>. Accessed 10 Jan 2007.
- Promed Mail. PRO/AH/EDR> Influenza pandemic (H1N1) 2009, animal (40): USA (NY) canine. Dec 22, 2009. Archive Number 20091222.4305. Available at: <http://www.promedmail.org>. Accessed Dec 2009.
- Promed Mail. PRO/AH> Influenza, canine - USA (09): (MA) multistate, H3N2, May 24, 2015. Archive Number: 20150524.3382637. Available at: <http://www.promedmail.org>. Accessed Nov 2015.
- Public Health Agency of Canada. Pathogen Safety Data Sheet – Influenza A virus type A. Pathogen Regulation Directorate, Public Health Agency of Canada; 2012 Feb. Available at: <http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/influenza-a-eng.php>. Accessed 16 June 2014.
- Public Health Agency of Canada. Pathogen Safety Data Sheet – Influenza A virus subtypes H5, H7 and H9. Pathogen Regulation Directorate, Public Health Agency of Canada; 2012 Apr. Available at: <http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/influenza-grippe-a-eng.php>. Accessed 16 June 2014.
- Quintana AM, Hussey SB, Burr EC, Pecoraro HL, Annis KM, Rao S, Landolt GA. Evaluation of infectivity of a canine lineage H3N8 influenza A virus in ponies and in primary equine respiratory epithelial cells. *Am J Vet Res.* 2011;72(8):1071-8.
- Ramirez-Martinez LA, Contreras-Luna M, De la Luz J, Manjarrez ME, Rosete DP, Rivera-Benitez JF, Saavedra-Montanez M, Ramirez-Mendoza H. Evidence of transmission and risk factors for influenza A virus in household dogs and their owners. *Influenza Other Respir Viruses.* 2013;7(6):1292-6.
- Romvary J, Rozsa J, Farkas E. Infection of dogs and cats with the Hong Kong influenza A (H3N2) virus during an epidemic period in Hungary. *Acta Vet Hung.* 2014;25:255-9.
- Rush BR. Equine influenza. In: Aiello SE, Moses MA, editors. *The Merck veterinary manual* [online]. Whitehouse Station, NJ: Merck and Co; 2014. Available at: http://www.merckmanuals.com/vet/respiratory_system/respiratory_diseases_of_horses/equine_influenza.html. Accessed 16 June 2014.
- Said AW, Usui T, Shinya K, Ono E, Ito T, Hikasa Y, Matsuu A, Takeuchi T, Sugiyama A, Nishii N, Yamaguchi T. A serosurvey of subtype H3 influenza A virus infection in dogs and cats in Japan. *J Vet Med Sci.* 2011;73(4):541-4.

- Sliwa J. American Society for Microbiology [ASM]. Canine influenza was around as early as 1999. Press Release, International Conference on Emerging Infectious Diseases; 2008 Mar 16-19; Atlanta, GA. Available at: <http://www.asm.org/Media/index.asp?bid=57269>.* Accessed 13 Jan 2009.
- Sakaguchi H, Wada K, Kajioka J, Watanabe M, Nakano R, Hirose T, Ohta H, Aizawa Y. Maintenance of influenza virus infectivity on the surfaces of personal protective equipment and clothing used in healthcare settings. *Environ Health Prev Med.* 2010;15(6):344-9.
- Schulz B, Klinkenberg C, Fux R, Anderson T, de Benedictis P, Hartmann K. Prevalence of canine influenza virus A (H3N8) in dogs in Germany. *Vet J.* 2014;202(1):184-5.
- Seiler BM, Yoon KJ, Andreasen CB, Block SM, Marsden S, Blitvich BJ. Antibodies to influenza A virus (H1 and H3) in companion animals in Iowa, USA. *Vet Rec.* 2010;167(18):705-7.
- Serra VF, Stanzani G, Smith G, Otto CM. Point seroprevalence of canine influenza virus H3N8 in dogs participating in a flyball tournament in Pennsylvania. *J Am Vet Med Assoc.* 2011;238:726-30.
- Shortridge KF, Zhou NN, Guan Y, Gao P, Ito T, Kawaoka Y, Kodihaili S, Krauss S, Markwell D, Murti KG, Norwood M, Senne D, Sims L, Takada A, Webster RG. Characterization of avian H5N1 influenza viruses from poultry in Hong Kong. *Virology.* 1998;252(2):331-42.
- Smith KC, Daly JM, Blunden AS, Laurence CJ. Canine influenza virus. *Vet Rec.* 2005;157:599.
- Solorzano A, Foni E, Cordoba L, Baratelli M, Razzuoli E, Bilato D et al. Cross-species infectivity of H3N8 influenza virus in an experimental infection in swine. *J Virol.* 2015;89(22):11190-202.
- Song D, Kim H, Na W, Hong M, Park SJ, Moon H, Kang B, Lyoo KS, Yeom M, Jeong DG, An DJ, Kim JK. Canine susceptibility to human influenza viruses (A/pdm 09H1N1, A/H3N2 and B). *J Gen Virol.* 2015;96(Pt 2):254-8.
- Song D, Kang B, Lee C, Jung K, Ha G, Kang D, Park S, Park B, Oh J. Transmission of avian influenza virus (H3N2) to dogs. *Emerg Infect Dis.* 2008;14:741-6.
- Song D, Lee C, Kang B, Jung K, Oh T, Kim H, Park B, Oh J. Experimental infection of dogs with avian-origin canine influenza A virus (H3N2). *Emerg Infect Dis.* 2009;15:56-8.
- Song D, Moon HJ, An DJ, Jeoung HY, Kim H, Yeom MJ, Hong M, Nam JH, Park SJ, Park BK, Oh JS, Song M, Webster RG, Kim JK, Kang BK. A novel reassortant canine H3N1 influenza virus between pandemic H1N1 and canine H3N2 influenza viruses in Korea. *J Gen Virol.* 2012;93(Pt 3):551-4.
- Song DS, An DJ, Moon HJ, Yeom MJ, Jeong HY, Jeong WS, Park SJ, Kim HK, Han SY, Oh JS, Park BK, Kim JK, Poo H, Webster RG, Jung K, Kang BK. Interspecies transmission of the canine influenza H3N2 virus to domestic cats in South Korea, 2010. *J Gen Virol.* 2011;92(Pt 10):2350-5.
- Song QQ, Zhang FX, Liu JJ, Ling ZS, Zhu YL, Jiang SJ, Xie ZJ. Dog to dog transmission of a novel influenza virus (H5N2) isolated from a canine. *Vet Microbiol.* 2013;161(3-4):331-3.
- Songserm T, Amonsin A, Jam-on R, Sae-Heng N, Pariyothorn N, Payungporn S, Theamboonlers A, Chutinimitkul S, Thanawongnuwech R, Poovorawan Y. Fatal avian influenza A H5N1 in a dog. *Emerg Infect Dis.* 2006;12:1744-7.
- Songserm T, Jam-On R, Sae-Heng N, Meemak N. Survival and stability of HPAI H5N1 in different environments and susceptibility to disinfectants. *Dev Biol (Basel).* 2006;124:254.
- Su S, Chen J, Jia K, Khan SU, He S, Fu X, Hong M, Sun L, Qi W, Gray GC, Li S. Evidence for subclinical influenza A(H1N1)pdm09 virus infection among dogs in Guangdong province, China. *J Clin Microbiol.* 2014;52(5):1762-5.
- Su S, Li HT, Zhao FR, Chen JD, Xie JX, Chen ZM, Huang Z, Hu YM, Zhang MZ, Tan LK, Zhang GH, Li SJ. Avian-origin H3N2 canine influenza virus circulating in farmed dogs in Guangdong, China. *Infect Genet Evol.* 2013;14:444-9.
- Su S, Qi W, Zhou P, Xiao C, Yan Z, Cui J, Jia K, Zhang G, Gray GC, Liao M, Li S. First evidence of H10N8 avian influenza virus infections among feral dogs in live poultry markets in Guangdong province, China. *Clin Infect Dis.* 2014;59(5):748-50.
- Su S, Yuan Z, Chen J, Xie J, Li H, Huang Z, Zhang M, Du G, Chen Z, Tu L, Zou Y, Miao J, Wang H, Jia K, Li S. Short communication: isolation and phylogenetic analysis of an avian-origin H3N2 canine influenza virus in dog shelter, China. *Virus Genes.* 2013;46(3):554-7. .
- Su S, Zhou P, Fu X, Wang L, Hong M, Lu G Sun L, Qi W, Ning Z, Jia K, Yuan Z, Wang H, Ke C, Wu J, Zhang G, Gray GC, Li S. Virological and epidemiological evidence of avian influenza virus infections among feral dogs in live poultry markets, China: A threat to human health? *Clin Infect Dis.* 2014;58(11):1644-6.
- Sun X, Xu X, Liu Q, Liang D, Li C, He Q, Jiang J, Cui Y, Li J, Zheng L, Guo J, Xiong Y, Yan J. Evidence of avian-like H9N2 influenza A virus among dogs in Guangxi, China. *Infect Genet Evol.* 2013;20:471-5.
- Sun Y, Shen Y, Zhang X, Wang Q, Liu L, Han X, Jiang B, Wang R, Sun H, Pu J, Lin D, Xia Z, Liu J. A serological survey of canine H3N2, pandemic H1N1/09 and human seasonal H3N2 influenza viruses in dogs in China. *Vet Microbiol.* 2014;168(1):193-6.
- Sweet C, Smith H. Pathogenicity of influenza virus. *Microbiol Rev.* 1980;44: 303-330.
- Teng Q, Zhang X, Xu D, Zhou J, Dai X, Chen Z, Li Z. Characterization of an H3N2 canine influenza virus isolated from Tibetan mastiffs in China. *Vet Microbiol.* 2013;162(2-4):345-52.
- Thomas Y, Vogel G, Wunderli W, Suter P, Witschi M, Koch D, Tapparel C, Kaiser L. Survival of influenza virus on banknotes. *Appl Environ Microbiol.* 2008;74(10):3002-7.
- U.S. Centers for Disease Control and Prevention [CDC]. Media briefing on canine influenza. CDC; 2005 September. Available at: <http://www.cdc.gov/od/oc/media/transcripts/t050926.htm>.* Accessed 6 Mar 2007.
- von Grotthuss M, Rychlewski L. Influenza mutation from equine to canine. *Science.* 2006;311:1241-2.
- Webster RG, Yakhno M, Hinshaw VS, Bean WJ, Murti KG. Intestinal influenza: replication and characterization of influenza viruses in ducks. *Virology.* 1978;84(2):268-78.
- Wiley CA, Ottoson MC, Garcia MM, Wiley LE, Otto CM. The seroprevalence of canine influenza virus H3N8 in dogs participating in a flyball tournament in Pennsylvania in 2010: A follow-up study. *J Vet Intern Med.* 2013;27(2):367-70.

- Wood JP, Choi YW, Chappie DJ, Rogers JV, Kaye JZ. Environmental persistence of a highly pathogenic avian influenza (H5N1) virus. *Environ Sci Technol*. 2010;44(19):7515-20.
- Yamamoto Y, Nakamura K, Yamada M, Mase M. Persistence of avian influenza virus (H5N1) in feathers detached from bodies of infected domestic ducks. *Appl Environ Microbiol*. 2010;76(16):5496-9.
- Yamanaka T, Nemoto M, Tsujimura K, Kondo T, Matsumura T. Interspecies transmission of equine influenza virus (H3N8) to dogs by close contact with experimentally infected horses. *Vet Microbiol*. 2009;139(3-4):351-5.
- Yamanaka T, Tsujimura K, Kondo T, Matsumura T, Ishida H, Kiso M, Hidari KI, Suzuki T. Infectivity and pathogenicity of canine H3N8 influenza A virus in horses. *Influenza Other Respi Viruses*. 2010;4(6):345-51.
- Yang X, Liu C, Liu F, Liu D, Chen Y, Zhang H, Qu L, Li Y, Xia D, Liu M. Identification and genetic characterization of avian-origin H3N2 canine influenza viruses isolated from the Liaoning province of China in 2012. *Virus Genes*. 2014;49(2):342-7.
- Yoon KJ, Cooper VL, Schwartz KJ, Harmon KM, Kim WI, Janke BH, Strohbehn J, Butts D, Troutman J. Influenza virus infection in racing greyhounds. *Emerg Infect Dis*. 2005;11:1974-1976.
- Zhan GJ, Ling ZS, Zhu YL, Jiang SJ, Xie ZJ. Genetic characterization of a novel influenza A virus H5N2 isolated from a dog in China. *Vet Microbiol*. 2012;155(2-4):409-16.
- Zhang K, Zhang Z, Yu Z, Li L, Cheng K, Wang T, Huang G, Yang S, Zhao Y, Feng N, Fu J, Qin C, Gao Y, Xia X. Domestic cats and dogs are susceptible to H9N2 avian influenza virus. *Virus Res*. 2013;175(1):52-7.
- Zhang X, Shen Y, Du L, Wang R, Jiang B, Sun H, Pu J, Lin D, Wang M, Liu J, Sun Y. Serological survey of canine H3N2, pandemic H1N1/09, and human seasonal H3N2 influenza viruses in cats in northern China, 2010-2014. *Virol J*. 2015;12:50.
- Zhang YB, Chen JD, Xie JX, Zhu WJ, Wei CY, Tan LK, Cao N, Chen Y, Zhang MZ, Zhang GH, Li SJ. Serologic reports of H3N2 canine influenza virus infection in dogs in Northeast China. *J Vet Med Sci*. 2013;75(8):1061-2.
- Zhao FR, Li SJ, Zhou DH, Chen N, Zhang YZ, Qi WB, Jiao PR, Liao M, Tong GZ, Zhang GH. Seroprevalence of avian origin H3N2 canine influenza virus infection in pet dogs in Shenzhen, China. *Afr J Microbiol Res*. 2011;6:5960-3.
- Zhao FR, Liu CG, Yin X, Zhou DH, Wei P, Chang HY. Serological report of pandemic (H1N1) 2009 infection among cats in northeastern China in 2012-02 and 2013-03. *Virol J*. 2014;11:49.
- Zhou H, He SY, Sun L, He H, Ji F, Sun Y, Jia K, Ning Z, Wang H, Yuan L, Zhou P, Zhang G, Li S. Serological evidence of avian influenza virus and canine influenza virus infections among stray cats in live poultry markets, China. *Vet Microbiol*. 2015;175(2-4):369-73.
- Zhu H, Hughes J, Murcia PR. Origins and evolutionary dynamics of H3N2 canine influenza virus. *J Virol*. 2015;89(10):5406-18.

*Link is defunct