PORCINE ASTROVIRUS

The Swine Health Information Center, launched in 2015 with Pork Checkoff funding, protects and enhances the health of the United States swine herd by minimizing the impact of emerging disease threats through preparedness, coordinated communications, global disease monitoring, analysis of swine health data, and targeted research investments.

August 2017 | Updated January 2026

SUMMARY

IMPORTANCE

- The role of porcine astrovirus (PAstV) as a primary pathogen remains unclear. The virus has been linked to gastrointestinal, neurological, and respiratory disease in pigs; however, it is also found in healthy animals, and co-infections are common.

PUBLIC HEALTH

- Astroviruses (AstVs) have a broad and diverse host range.
- Genetic evidence suggests that recombination between human and porcine strains occurs. Clinical illness due to PAstVs has not been documented in people.

INFECTION IN SWINE

- PAstV lineages 1–5 have been found in pigs of all ages with and without clinical disease.
- Experimental infection with PAstVs results in three forms of clinical illness – gastrointestinal, neurological, and respiratory. Asymptomatic infections are very common.

TREATMENT

- There is no treatment for PAstV infection.

CLEANING AND DISINFECTION

- AstVs are stable in the environment.
- Non-enveloped viruses are typically susceptible to aldehydes and chlorine compounds, though some may be resistant to bleach at lower concentrations. Alkalis and peroxygen compounds may also inactivate non-enveloped viruses.

PREVENTION AND CONTROL

- Cleaning and disinfection are critical to prevent enteric disease in pork production facilities.
- Standard biosecurity practices should also be in place.

TRANSMISSION

- Transmission of PAstV is primarily fecal-oral due to ingestion of contaminated feed or water.
- Persistent shedding can continue long after infection.

PATHOGENESIS

- PAstV pathogenesis is not well understood. More information is needed on the tropism of AstVs.

DIAGNOSIS

- PAstVs are difficult to propagate. Reverse transcription polymerase chain reaction (RT-PCR) assays are used to detect viral RNA. Newer multiplex tests detect all five PAstV lineages simultaneously.
- Enzyme-linked immunosorbent assay (ELISA) and serum neutralization have been used to detect antibodies for AstV in pigs.

EPIDEMIOLOGY

- AstVs infect a wide variety of animals and have been detected worldwide.
- The global pooled prevalence of PAstV is approximately 28%, with varying rates across continents. North America has the highest rate (63%), followed by Europe (36%) and Asia (26%). Prevalence is generally highest in nursery pigs.
- PAstVs have been isolated at higher rates in asymptomatic pigs compared to diarrheic pigs and are more likely to be found in non-fecal samples compared to fecal samples.

ETIOLOGY

- There are five distinct PAstV lineages (PAstV-1 to PAstV-5), each of which has been known to circulate in herds in the United States.
- PAstV types 1, 2, and 4 are the most commonly reported in domestic and wild pigs worldwide.
- Different lineages can be associated with different PAstV presentations (gastrointestinal, neurological, or respiratory).

HISTORY IN SWINE

- PAstV was first recognized in the feces of diarrheic pigs in the 1980s and isolated in 1990.
- Research on the various forms of PAstV-related disease is ongoing.

IMMUNITY

- There are no commercially available PAstV vaccines.
- Experimental infection leads to viral shedding in the feces and nasal secretions.
- Little is known of the antigenic relationship among the many strains of AstV.

GAPS IN PREPAREDNESS

- Although PAstVs have been experimentally confirmed as a cause of gastrointestinal, neurological, and respiratory disease, their role as primary swine pathogens remains unclear. PAstVs can be detected in healthy pigs, and co-infection with other pathogens is frequent.
- AstVs are extremely common across a wide range of hosts, including humans, but their pathogenesis is poorly understood.
- There are no commercially available vaccines for PAstV.
- Additional research is needed to better prepare both the producers and veterinarians for future PAstV outbreaks.

LITERATURE REVIEW: PORCINE ASTROVIRUS

IMPORTANCE

The role of PAstV as a primary pathogen remains unclear. The virus has been linked to gastrointestinal, neurological, and respiratory disease in pigs; however, it is also found in healthy animals, and co-infections are common. Recombination occurs frequently between strains. Despite its zoonotic potential, PAstV clinical infection in humans has not been described. Further research is needed across all aspects of the virus to better understand and prevent PAstV infection.

PUBLIC HEALTH

AstVs have a broad and diverse host range. Genetic evidence suggests that recombination between human and porcine strains occurs.[1] In particular, these events can happen in areas where pigs and humans live in close proximity and interact frequently.[2] Recombination of human strains with avian and feline AstVs has also been documented.[3]

Human AstVs cause gastrointestinal and neurological disease, particularly in young, elderly, and immunocompromised individuals.[4] Clinical illness due to PAstVs has not been documented in people. However, the virus's ability to rapidly mutate and the potential for an animal to become co-infected with multiple strains set the stage for a recombination event that could yield a zoonotic strain.

INFECTION IN SWINE

Many PAstV infections are asymptomatic. PAstVs are a cause of gastrointestinal disease, with the highest rates in nursery pigs. They are often found with other diarrhea-causing viruses, such as rotavirus, transmissible gastroenteritis virus, porcine circovirus-2, and porcine hemagglutinating encephalitis virus.[5] Mixed infections can also include porcine kobuvirus, porcine epidemic virus, porcine sapovirus, and porcine deltacoronavirus. Clinical signs include vomiting and diarrhea, which can lead to weight loss and slowed growth. Most cases are self-limiting. Pigs inoculated with PAstV develop mild enteric disease.[6-8] Gross lesions include distended intestines filled with yellow fluid and bloating of the stomach and small intestine.[9] Natural infections can be severe, likely due to viral co-infections contributing to clinical signs.[6] In these instances, PAstVs may play a limited role.[10]

Neurological PAstV infection has been documented in pigs.[11,12] Signs associated with CNS infection include hind limb weakness, quadriplegia, and convulsions. Lesions include polioencephalomyelitis and neural necrosis.[12] In one instance, PAstV was associated with congenital tremors; reported lesions included mild to moderate vacuolar changes in the white matter of the cerebrum, brainstem, and cerebellum.[11] PAstV-3 has most commonly been identified in cases of natural infection[13-18] and causes CNS disease in experimentally infected pigs.[19]

PAstV-4 has been detected in the upper respiratory tract of clinically ill pigs,[20] and retrospectively, in lesions consistent with the virus.[21] More recently, an experimental study confirmed that PAstV-4 causes tracheitis and bronchitis in piglets.[22] The lungs may be collapsed and dark pink in color.[22]

INFECTION IN OTHER ANIMALS

Clinical signs of AstV infection vary among other species. AstV has been detected in diarrheic cattle. However, the association between AstV and diarrhea has been questioned, largely because experimental infections in cattle have not consistently produced disease.[23-25] Less commonly, AstV has been associated with respiratory disease in cattle[26] and in at least one case, a human infant.[27] AstV has also been isolated from nasopharyngeal swabs in camels positive for Middle East respiratory syndrome coronavirus.[28]

Neurological disease occurs in mink,[29,30] cattle, sheep,[31] muskox,[32,33] alpacas,[34] and people.[35] Renal and hepatic involvement can accompany enteric disease in avian species.[2,36-38]

TREATMENT

There is no treatment for PAstV infection.

CLEANING AND DISINFECTION

SURVIVAL

As non-enveloped viruses, AstVs are stable in the environment. They can persist in feces and water for weeks to months.[39] Human AstVs have been detected in treated and untreated wastewater, as well as drinking and groundwater.[40]

DISINFECTION

AstVs are not inactivated by acidic pH, heat, many detergents, and lipid solvents.[6] Non-enveloped viruses are typically susceptible to aldehydes and chlorine compounds, though some may be resistant to bleach at lower concentrations.[41] Alkalis and peroxygen compounds may also inactivate non-enveloped viruses (varies by product).[42]

PREVENTION AND CONTROL

Due to the characteristics of AstV, its ubiquity, and its mutability, preventing AstV infections may prove to be difficult. AstVs can survive for an extended period in the environment.[6] The most effective means of preventing infection are immunizing sows to allow passive transfer of antibodies through colostrum to neonates, removing diarrheic pigs from the herd, and implementing strict sanitation standards within the pork production facility. Standard biosecurity practices should also be in place.

TRANSMISSION

PAstV transmission is primarily fecal-oral, due to ingestion of contaminated feed or water. Persistent shedding can continue long after infection, leading to increased transmission in densely housed animals.[3] Vertical transmission may occur in avian species, but there is no evidence of this for mammalian strains.[3] PAstV-2 has been identified in air samples from swine buildings,[43] although it is not known if airborne transmission occurs.

PATHOGENESIS

PAstV pathogenesis is not well understood. Experimentally, infection with PAstV-5 results in the downregulation of beneficial gut bacteria while harmful bacteria are upregulated.[44] There may be more than one cell surface receptor, with different serotypes using different receptors.[3] AstVs enter cells via clathrin-mediated endocytosis, but whether this is the only mechanism of entry is unknown.[3] PAstV was previously thought to localize to the intestine.[38] More information is needed on the tropism of AstVs, particularly the strains that cause neurological disease.[3]

DIAGNOSIS

TESTS TO DETECT NUCLEIC ACIDS, VIRUS, OR ANTIGENS

Previously, only PAstV-1 has been isolated in cell culture.[45] Isolation of PAstV-4[46] and PAstV-5[45,47] has recently been reported. PAstV isolation and propagation require the use of pig kidney cells with trypsin.[6] Direct electron microscopy is often used to confirm PAstV infections clinically.[48]

Reverse transcriptase polymerase chain reaction (RT-PCR) is utilized to diagnose and analyze AstVs. Primer sets specific to porcine strains have been described.[49] Multiplex RT-PCR assays have been developed to detect all five PAstV lineages simultaneously.[50,51] Some assays detect co-infection with gastrointestinal (porcine sapovirus, porcine norovirus, and porcine rotavirus A)[52] and neurotropic PAstVs (sapelovirus and teschovirus).[53]

Due to limited understanding of AstV pathogenesis and its poor growth in cell culture, the development of virus-specific antigen tests has been limited. A recombinant PAstV4 capsid spike protein has been described[54] as well as a monoclonal antibody with neutralizing activity against PAstV-5.[55] Indirect immunofluorescence and immunohistochemistry have been successfully performed for PAstVs.[6,56]

TESTS TO DETECT ANTIBODY

Several enzyme-linked immunosorbent assays (ELISAs) appear to be available for PAstV, although none have been described in the literature. Serum neutralization has been used to detect PAstV.[6]

SAMPLES

PAstV has been isolated most successfully and consistently from the feces of affected animals.[48] However, PAstVs have increasingly been linked to extraintestinal disease.[57] Testing additional samples, such as blood, nasal swabs, and tissues (including CNS), may increase the likelihood of detection, especially in asymptomatic cases.[58,59] PAstV 2, 4, and 5 have been detected in oral fluids.[60]

EPIDEMIOLOGY

SPECIES AFFECTED

AstVs infect a wide variety of animals. Most PAstV studies are in domestic pigs, although the virus has also been detected in wild boar.[61-63] AstVs have also been found in sheep,[64,65] farmed mink,[66] red deer,[67] European roe deer,[68] water buffalo,[69] yaks,[70] camels,[71] dogs,[72,73] a wolf,[74] cats,[75-77] rats,[78] rabbits,[79] marmots,[80] porcupines, shrews, and pikas,[81] cheetahs,[82] chickens,[56] ducks,[36] turkeys,[83] insectivorous bats,[84,85] and marine mammals.[86] More recently, AstVs have been found in reptiles, amphibians, fish[87] and invertebrates.[57]

GEOGRAPHIC DISTRIBUTION

PAstVs have been isolated from pigs worldwide, irrespective of age, season, or climate. This includes North America (United States[88] and Canada,[49]), South America (Chile,[60] Brazil,[89] and Columbia[2]), Asia (Thailand,[90] South Korea,[91] China,[9,92-98] and India[99-102]), Europe (the Czech Republic, Hungary,[2] Croatia,[103] Spain,[104] France,[105] Greece,[106] Slovakia,[107] and Italy[108]), Africa (South Africa,[2] Kenya, and Uganda[109]), and Australia.[110]

There are five recognized lineages (PAstV-1 to PAstV-5), all of which have been found in swine herds in the United States. All five PAstV lineages have also been found in China, Canada, Denmark, Spain, Japan, Croatia, South Korea, and Slovakia.[111]

Human AstV seems to have the highest incidence of infection during the winter temperate climates, but infections have also been reported in spring and summer months.[2] It is unclear whether there is a change in the seasonal incidence of PAstV.

MORBIDITY AND MORTALITY

PAstVs have been found in pigs of all ages with and without diarrhea. A report from Canada found that 80% of healthy pigs tested PAstV-positive by RT-PCR at the time of slaughter.[49] Fecal samples from a high-density farm in North Carolina contained PAstV in 75% of samples taken from both healthy and diarrheic piglets.[112] Seroconversion rates of swine herds have ranged as high as 83% in healthy adult pigs.[6]

In the U.S., pigs with PAstV-associated neurological disease were documented in a multistate swine production system in 2017. Samples from neurologic cases were submitted for testing on three occasions over 9 months. An affected sow farm reported a case-fatality rate of 100%, while two commercial grow-out facilities reported a case-fatality rate of 75%.[13] In Hungary, the index farm had experienced episodes of neurological disease over two years (2015–2017).[12] About 30–40 weaned pigs (1.5–2% of the farm population) were affected each month. A spike in cases (about 80/month, 4% of the farm population) occurred during the autumn months.[12]

A recent meta-analysis found that the global pooled prevalence of PAstV was approximately 28%, with varying rates across continents. North America was the highest (63%), followed by Europe (36%) and Asia (26%).[58] Interestingly, there has been an overall decline in PAstV since 2015.[58] PAstVs were isolated at higher rates in asymptomatic pigs than in diarrheic pigs (36% vs. 28%), and were more likely to be found in non-fecal samples than in fecal samples (43% vs. 23%).[58] Prevalence was highest in nursery pigs (63%), followed by weaners (60%), finishers (50%), sows (35%), and suckling pigs (32%).[58] Another meta-analysis documented a similar trend.[59]

ETIOLOGY

CHARACTERISTICS OF ASTROVIRUSES

AstVs are small, non-enveloped, single-stranded viruses that belong to the family *Astroviridae*. AstVs are named for their star-like morphology.[6] The family is divided into two genera, *Mamastrovirus* and *Avastrovirus,* that affect mammals and avian species, respectively.[6] As of 2025, twenty-two recognized species infect mammals.[113]

The AstV genome ranges in size from about 6000–7700 nt. Three open reading frames encode nonstructural proteins (ORF1a), the RNA-dependent RNA polymerase (ORF1b), and capsid proteins (ORF2).[112] An untranslated region (UTR) is present at the 5´ end. The 3´ end contains both a UTR and a poly (A) tail.[2] There is a highly conserved nucleotide sequence within the RNA-dependent RNA polymerase gene[49] and the 5´UTR.[114]

It was previously accepted that AstVs were host-restricted and species-specific.[83] However, phylogenetic analysis, coupled with the diverse array of species affected and the genetic diversity within *Astroviridae,* suggests that interspecies transmission with virus adaptation is a possibility.[2] For example,

- PAstV detected in U.S. pigs with neurological disease was found to be more closely related to neurotropic AstVs from humans, minks, cows, and sheep than to other porcine isolates.[13]
- Evidence of cross-species AstV transmission exists between sheep and cattle.[31]
- PAstV strain JWH-1 was closely associated with a novel AstV in deer in China.[92]
- Bovine AstV isolated from fecal samples in Japan clustered with PAstV; this isolate also contained an ORF2 region similar to that of ovine AstV.[115]

CHARACTERISTICS OF PORCINE ASTROVIRUS

There are five distinct PAstV lineages, each of which has been known to circulate in swine herds in the United States.[88] PAstV types 1, 2, and 4 are the most commonly reported in domestic and wild pigs worldwide.[111]

Based on phylogenetic analysis, each lineage may have an independent origin, with vast genetic variability evidenced by greater homology between strains of different lineages than within strains of a single lineage.[103] Different lineages are associated with different PAstV presentations. For example,

- PAstV-1: primarily gastrointestinal
- PAstV-2: primarily gastrointestinal

- PAstV-3: primarily neurological
- PAstV-4: gastrointestinal, neurological, and respiratory
- PAstV-5: respiratory, other?

PAstV-3, 4, and 5 seem to occur in pigs only.[111] Co-infection with multiple PAstV strains is possible.[88] There is high genetic diversity among isolates from asymptomatic and pigs with diarrhea.[95]

HISTORY IN SWINE

PAstV was first recognized in the feces of diarrheic pigs in the 1980s[116] and isolated in 1990.[6] The virus has since been linked to gastrointestinal, neurological, and respiratory disease in pigs. See *Morbidity and Mortality* for more details.

IMMUNITY

POST-EXPOSURE

Nursery pigs are highly vulnerable to PAstV due to waning maternal antibody and their weak immune systems.[117] Pigs experimentally infected with PAstV shed infectious virus in their feces seven days post-infection and developed neutralizing antibody titers 14 days post-infection.[49] Pig infected intranasally with PAstV-4 tissue homogenate developed both IgM and IgG antibodies, the latter of which were detectable from 14 to 21 days post-challenge.[22]

Pigs can be infected with multiple PAstVs, and the dominant strains can change over time. In experimentally infected pigs, PAstV-3 and 4 were detected at 2 weeks of age, followed by PAstV-5 at 3.5 weeks of age, just before weaning. One week after weaning, PAstV-1 and 2 were the dominant strains.[118]

VACCINES

There are currently no commercially available PAstV vaccines. Antigenic diversity among PAstV strains[5] presents a challenge for vaccine development and disease prevention.

CROSS-PROTECTION

Antibodies appear to be specific to their respective capsid proteins.[83] Little is known of the antigenic relationship among the many strains of AstV. Antibodies to PAstV do not react with bovine AstV.[116]

GAPS IN PREPAREDNESS

Although PAstVs have been experimentally confirmed as causes of gastrointestinal, neurological, and respiratory diseases, their role as primary swine pathogens remains unclear. PAstVs can be detected in healthy pigs, and co-infection with other pathogens is frequent. Although AstVs are extremely common across a wide range of hosts, including humans, their pathogenesis is poorly understood. There are no commercially available vaccines for PAstV. Additional research is needed to better prepare both the producers and veterinarians for future PAstV outbreaks.

REFERENCES

1. Ulloa JC, Gutiérrez MF. Genomic analysis of two ORF2 segments of new porcine astrovirus isolates and their close relationship with human astroviruses. *Can J Microbiol*. 2010;56(7):569-77. doi:10.1139/w10-042
2. De Benedictis P, Schultz-Cherry S, Burnham A, Cattoli G. Astrovirus infections in humans and animals - molecular biology, genetic diversity, and interspecies transmissions. *Infect Genet Evol*. 2011;11(7):1529-44. doi:10.1016/j.meegid.2011.07.024
3. Roach SN, Langlois RA. Intra- and cross-species transmission of astroviruses. *Viruses*. 2021;13(6). doi:10.3390/v13061127
4. Johnson C, Hargest V, Cortez V, Meliopoulos VA, Schultz-Cherry S. Astrovirus pathogenesis. *Viruses*. Jan 22 2017;9(1). doi:10.3390/v9010022
5. Mor SK, Chander Y, Marthaler D, Patnayak DP, Goyal SM. Detection and molecular characterization of Porcine astrovirus strains associated with swine diarrhea. *J Vet Diagn Invest*. 2012;24(6):1064-7. doi:10.1177/1040638712458781
6. Shimizu M, Shirai J, Narita M, Yamane T. Cytopathic astrovirus isolated from porcine acute gastroenteritis in an established cell line derived from porcine embryonic kidney. *J Clin Microbiol*. 1990;28(2):201-6.
7. Ulloa JC, Olarte-Aponte AM, Ospina JC, Rincon MA. Experimental infection of conventional newly-weaned piglets with porcine astrovirus. *Acta Virol*. 2019;63(1):96-102. doi:10.4149/av_2019_112
8. Opriessnig T, Xiao CT, Halbur PG. Porcine astrovirus type 5-associated enteritis in pigs. *J Comp Pathol*. 2020;181:38-46. doi:10.1016/j.jcpa.2020.09.014
9. Fang Q, Wang C, Liu H, et al. Pathogenic characteristics of a porcine astrovirus strain isolated in China. *Viruses*. 2019;11(12). doi:10.3390/v11121156
10. Qiu M, Li S, Xiao Y, et al. Pathogenic and metagenomic evaluations reveal the correlations of porcine epidemic diarrhea virus, porcine kobuvirus and porcine astroviruses with neonatal piglet diarrhea. *Microb Pathog*. 022;170:105703. doi:10.1016/j.micpath.2022.105703
11. Blomström AL, Ley C, Jacobson M. Astrovirus as a possible cause of congenital tremor type AII in piglets? *Acta Vet Scand*. 2014;56(1):82. doi:10.1186/s13028-014-0082-y
12. Boros A, Albert M, Pankovics P, et al. Outbreaks of neuroinvasive astrovirus associated with encephalomyelitis, weakness, and paralysis among weaned pigs, Hungary. *Emerg Infect Dis*. 2017;23(12):1982-1993. doi:10.3201/eid2312.170804
13. Arruda B, Arruda P, Hensch M, et al. Porcine astrovirus type 3 in central nervous system of swine with polioencephalomyelitis. *Emerg Infect Dis*. 2017;23(12):2097-2100. doi:10.3201/eid2312.170703
14. Park JS, Jeong CG, Chae SB, et al. Porcine astrovirus infection in brains of pigs in Korea. *Viruses*. 2024;16(9). doi:10.3390/v16091372
15. Yasumitsu CY, Dall Agnol AM, Xavier AAC, et al. Porcine astrovirus 3 RNA in the central nervous system of weaned pigs with neurologic disease and polioencephalomyelitis in Brazil. *Microb Pathog*. 2024;196:106917. doi:10.1016/j.micpath.2024.106917
16. Matias Ferreyra FS, Bradner LK, Burrough ER, et al. Polioencephalomyelitis in domestic swine associated with porcine astrovirus type 3. *Vet Pathol*. 2020;57(1):82-89. doi:10.1177/0300985819875741
17. Rawal G, Matias Ferreyra F, N RM, et al. Detection and cellular tropism of porcine astrovirus type 3 on breeding farms. *Viruses*. 2019;11(11). doi:10.3390/v11111051
18. Rawal G, Ferreyra FM, Macedo NR, et al. Ecology of porcine astrovirus type 3 in a herd with associated neurologic disease. *Viruses*. 2020;12(9). doi:10.3390/v12090992
19. Ferreyra FM, Arruda PEH, Bradner LK, et al. Experimental porcine astrovirus type 3-associated polioencephalomyelitis in swine. *Vet Pathol*. 2021;58(6):1064-1074. doi:10.1177/03009858211025794

20. Padmanabhan A, Hause BM. Detection and characterization of a novel genotype of porcine astrovirus 4 from nasal swabs from pigs with acute respiratory disease. *Arch Virol*. 2016;161(9):2575-9. doi:10.1007/s00705-016-2937-1
21. Rahe MC, Michael A, Piñeyro PE, Groeltz-Thrush J, Derscheid RJ. Porcine astrovirus 4 detection in lesions of epitheliotropic viral infection in the porcine respiratory tract. *Transbound Emerg Dis*. 2023;2023:9113355. doi:10.1155/2023/9113355
22. Rahe MC. Project # 23-077: Reproduction of clinical respiratory disease and respiratory epitheliotropic viral infection lesions with porcine astrovirus 4. Swine Health Information Center (SHIC); 2025.
23. Woode GN, Bridger JC. Isolation of small viruses resembling astroviruses and caliciviruses from acute enteritis of calves. *J Med Microbiol*. 1978;11(4):441-52. doi:10.1099/00222615-11-4-441
24. Bridger JC, Hall GA, Brown JF. Characterization of a calici-like virus (Newbury agent) found in association with astrovirus in bovine diarrhea. *Infect Immun*. 1984;43(1):133-8.
25. Woode GN, Pohlenz JF, Gourley NE, Fagerland JA. Astrovirus and Breda virus infections of dome cell epithelium of bovine ileum. *J Clin Microbiol*. 1984;19(5):623-30.
26. Ng TF, Kondov NO, Deng X, Van Eenennaam A, Neibergs HL, Delwart E. A metagenomics and case-control study to identify viruses associated with bovine respiratory disease. *J Virol*. 2015;89(10):5340-9. doi:10.1128/jvi.00064-15
27. Cordey S, Brito F, Vu DL, et al. Astrovirus VA1 identified by next-generation sequencing in a nasopharyngeal specimen of a febrile Tanzanian child with acute respiratory disease of unknown etiology. *Emerg Microbes Infect*. 2016;5:e67. doi:10.1038/emi.2016.67
28. Li Y, Khalafalla AI, Paden CR, et al. Identification of diverse viruses in upper respiratory samples in dromedary camels from United Arab Emirates. *PLoS One*. 2017;12(9):e0184718. doi:10.1371/journal.pone.0184718
29. Blomstrom AL, Widen F, Hammer AS, Belak S, Berg M. Detection of a novel astrovirus in brain tissue of mink suffering from shaking mink syndrome by use of viral metagenomics. *J Clin Microbiol*. 2010;48(12):4392-6. doi:10.1128/jcm.01040-10
30. Gavier-Widén D, Bröjer C, Dietz HH, et al. Investigations into shaking mink syndrome: an encephalomyelitis of unknown cause in farmed mink (*Mustela vison*) kits in Scandinavia. *J Vet Diagn Invest*. 2004;16(4):305-12. doi:10.1177/104063870401600408
31. Boujon CL, Koch MC, Wuthrich D, et al. Indication of cross-species transmission of astrovirus associated with encephalitis in sheep and cattle. *Emerg Infect Dis*. 2017;23(9):1604-1608. doi:10.3201/eid2309.170168
32. Boujon CL, Koch MC, Kauer RV, et al. Novel encephalomyelitis-associated astrovirus in a muskox (*Ovibos moschatus*): a surprise from the archives. *Acta Vet Scand*. 2019;61(1):31. doi:10.1186/s13028-019-0466-0
33. Fang Q, Li M, Liu H, et al. Detection and genetic diversity of a novel water buffalo astrovirus species found in the Guangxi Province of China. *Front Vet Sci*. 2021;8:692193. doi:10.3389/fvets.2021.692193
34. Küchler L, Rüfli I, Koch MC, et al. Astrovirus-associated polioencephalomyelitis in an alpaca. *Viruses*. 2020;13(1). doi:10.3390/v13010050
35. Quan PL, Wagner TA, Briese T, et al. Astrovirus encephalitis in boy with X-linked agammaglobulinemia. *Emerg Infect Dis*. 2010;16(6):918-25. doi:10.3201/eid1606.091536
36. Liu N, Wang F, Shi J, Zheng L, Wang X, Zhang D. Molecular characterization of a duck hepatitis virus 3-like astrovirus. *Vet Microbiol*. 2014;170(1-2):39-47. doi:10.1016/j.vetmic.2014.01.026
37. Pankovics P, Boros A, Kiss T, Delwart E, Reuter G. Detection of a mammalian-like astrovirus in bird, European roller (*Coracias garrulus*). *Infect Genet Evol*. 2015;doi:10.1016/j.meegid.2015.06.020
38. Koci MD, Moser LA, Kelley LA, Larsen D, Brown CC, Schultz-Cherry S. Astrovirus induces diarrhea in the absence of inflammation and cell death. *J Virol*. 2003;77(21):11798-808.
39. Espinosa AC, Mazari-Hiriart M, Espinosa R, Maruri-Avidal L, Méndez E, Arias CF. Infectivity

and genome persistence of rotavirus and astrovirus in groundwater and surface water. *Water Res*. 2008;42(10-11):2618-28. doi:10.1016/j.watres.2008.01.018

40. Takuissu GR, Kenmoe S, Ebogo-Belobo JT, et al. Assessing the prevalence of astroviruses in water environments: A systematic review and meta-analysis. *ACS ES T Water*. 2023;3(12):3782-3789. doi:10.1021/acsestwater.3c00415
41. Abad FX, Pinto RM, Villena C, Gajardo R, Bosch A. Astrovirus survival in drinking water. *Appl Environ Microbiol*. 1997;63(8):3119-22.
42. Center for Food Security and Public Health (CFSPH). The Antimicrobial Spectrum of Disinfectants. Accessed March 28, 2016. http://www.cfsph.iastate.edu/Disinfection/Assets/AntimicrobialSpectrumDisinfectants.pdf
43. Létourneau V, Gagné MJ, Vyskocil JM, et al. Hunting for a viral proxy in bioaerosols of swine buildings using molecular detection and metagenomics. *J Environ Sci (China)*. 2025;148:69-78. doi:10.1016/j.jes.2023.08.017
44. Li Z, Wu X, Zhang Y, et al. Isolation and pathogenicity of a Chinese porcine astrovirus type 5 strain HNPDS-01 and its influence on cecum microbiota in piglets. *Transbound Emerg Dis*. 2024;2024:5777097. doi:10.1155/2024/5777097
45. Mi S, Guo S, Xing C, et al. Isolation and characterization of porcine astrovirus 5 from a classical swine fever virus-infected specimen. *J Virol*. 2020;95(2). doi:10.1128/jvi.01513-20
46. Tao J, Li B, Cheng J, et al. Genomic divergence characterization and quantitative proteomics exploration of type 4 porcine astrovirus. *Viruses*. 2022;14(7). doi:10.3390/v14071383
47. Du Y, Qin Y, Feng X, et al. Isolation and identification of a new porcine astrovirus 5 demonstrated that oxidative stress enhances porcine astrovirus replication. *BMC Vet Res*. 2025;21(1):518. doi:10.1186/s12917-025-04939-x
48. Indik S, Valicek L, Smid B, Dvorakova H, Rodak L. Isolation and partial characterization of a novel porcine astrovirus. *Vet Microbiol*. 2006;117(2-4):276-83. doi:10.1016/j.vetmic.2006.06.020
49. Luo Z, Roi S, Dastor M, Gallice E, Laurin MA, L'homme Y. Multiple novel and prevalent astroviruses in pigs. *Vet Microbiol*. 2011;149(3-4):316-23. doi:10.1016/j.vetmic.2010.11.026
50. Zhang Q, Wen D, Liu Q, Opriessnig T, Yu X, Jiang Y. Universal primer multiplex PCR assay for detection and genotyping of porcine astroviruses. *J Virol Methods*. 2023;322:114822. doi:10.1016/j.jviromet.2023.114822
51. Zhang Q, Liu Q, Opriessnig T, Wen D, Gu K, Jiang Y. Multiplex gel-based PCR assay for the simultaneous detection of 5 genotypes of porcine astroviruses. *J Vet Diagn Invest*. 2023;35(2):132-138. doi:10.1177/10406387221145329
52. He J, Shi K, Shi Y, et al. Development of a quadruplex RT-qPCR for the detection of porcine astrovirus, porcine sapovirus, porcine norovirus, and porcine rotavirus A. *Pathogens*. 2024;13(12). doi:10.3390/pathogens13121052
53. László Z, Pankovics P, Reuter G, et al. Development and large-scale testing of a novel one-step triplex RT-qPCR assay for simultaneous detection of "Neurotropic" porcine sapeloviruses, teschoviruses (Picornaviridae) and type 3 porcine astroviruses (Astroviridae) in various samples including nasal swabs. *Viruses*. 2022;14(3). doi:10.3390/v14030513
54. Haley DJ, Lanning S, Henricson KE, et al. Structure and antigenicity of the porcine astrovirus 4 capsid spike. *Viruses*. 024;16(10). doi:10.3390/v16101596
55. Hu Y, Li Z, Hao C, et al. Identification of an immunodominant neutralizing epitope of porcine astrovirus type 5 capsid protein. *Virol Sin*. 2025;40(2):296-299. doi:10.1016/j.virs.2025.03.003
56. Lee A, Wylie M, Smyth VJ, et al. Chicken astrovirus capsid proteins produced by recombinant baculoviruses: potential use for diagnosis and vaccination. *Avian Pathol*. 2013;42(5):434-42. doi:10.1080/03079457.2013.822467
57. Janowski AB. Beyond the gastrointestinal tract: The emerging and diverse tissue tropisms of astroviruses. *Viruses*. 2021;13(5). doi:10.3390/v13050732
58. Ge X, Li Y, Zhao F, et al. Global prevalence of porcine astrovirus: A systematic review and meta-analysis. *Prev Vet Med*. 2025;238:106465. doi:10.1016/j.prevetmed.2025.106465

59. Rawal G, Linhares DCL. Scoping review on the epidemiology, diagnostics and clinical significance of porcine astroviruses. *Transbound Emerg Dis*. 2022;69(3):974-985. doi:10.1111/tbed.14123
60. Flores C, Ariyama N, Bennett B, et al. Case report: First report and phylogenetic analysis of porcine astroviruses in Chile. *Front Vet Sci*. 2021;8:764837. doi:10.3389/fvets.2021.764837
61. Mizuno S, Teshima N, Yokota T, et al. Genetic diversity and evolutionary relationships of porcine astroviruses from wild boars and domestic pigs in Japan. *Infect Genet Evol*. 2026;137:105875. doi:10.1016/j.meegid.2025.105875
62. Vilcek S, Salamunova S, Jackova A. Genetic identification of astroviruses in wild boars. *J Vet Sci*. 2019;20(1):91-94. doi:10.4142/jvs.2019.20.1.91
63. Shin J, Choe S, Hyun BH, An DJ. Phylogenetic analysis of kobuviruses and astroviruses from Korean wild boars: 2016-2018. *Arch Virol*. 2021;166(9):2591-2596. doi:10.1007/s00705-021-05164-1
64. Snodgrass DR, Angus KW, Gray EW, Menzies JD, Paul G. Pathogenesis of diarrhoea caused by astrovirus infections in lambs. *Arch Virol*. 1979;60(3-4):217-26.
65. Reuter G, Pankovics P, Delwart E, Boros A. Identification of a novel astrovirus in domestic sheep in Hungary. *Arch Virol*. 2012;157(2):323-7. doi:10.1007/s00705-011-1151-4
66. Englund L, Chriel M, Dietz HH, Hedlund KO. Astrovirus epidemiologically linked to pre-weaning diarrhoea in mink. *Vet Microbiol*. 2002;85(1):1-11.
67. Tzipori S, Menzies JD, Gray EW. Detection of astrovirus in the faeces of red deer. *Vet Rec*. 1981;108(13):286.
68. Smits SL, van Leeuwen M, Kuiken T, Hammer AS, Simon JH, Osterhaus AD. Identification and characterization of deer astroviruses. *J Gen Virol*. 2010;91(Pt11):2719-22. doi:10.1099/vir.0.024067-0
69. Alfred N, Liu H, Li ML, et al. Molecular epidemiology and phylogenetic analysis of diverse bovine astroviruses associated with diarrhea in cattle and water buffalo calves in China. *J Vet Med Sci*. 2015;77(6):643-51. doi:10.1292/jvms.14-0252
70. Chen X, Zhang B, Yue H, et al. A novel astrovirus species in the gut of yaks with diarrhoea in the Qinghai-Tibetan Plateau, 2013. *J Gen Virol*. 2015;96(12):3672-80. doi:10.1099/jgv.0.000303
71. Woo PC, Lau SK, Teng JL, et al. A novel astrovirus from dromedaries in the Middle East. *J Gen Virol*. 2015;96(9):2697-707. doi:10.1099/jgv.0.000233
72. Martella V, Moschidou P, Lorusso E, et al. Detection and characterization of canine astroviruses. *J Gen Virol*. 2011;92(Pt 8):1880-7. doi:10.1099/vir.0.029025-0
73. Martella V, Moschidou P, Buonavoglia C. Astroviruses in dogs. *Vet Clin North Am Small Anim Pract*. 2011;41(6):1087-95. doi:10.1016/j.cvsm.2011.09.001
74. Sarchese V, Fruci P, Palombieri A, et al. Molecular identification and characterization of a genotype 3 hepatitis E virus (HEV) strain detected in a wolf faecal sample, Italy. *Animals (Basel)*. 2021;11(12). doi:10.3390/ani11123465
75. Sabshin SJ, Levy JK, Tupler T, Tucker SJ, Greiner EC, Leutenegger CM. Enteropathogens identified in cats entering a Florida animal shelter with normal feces or diarrhea. *J Am Vet Med Assoc*. 2012;241(3):331-7. doi:10.2460/javma.241.3.331
76. Zhang W, Li L, Deng X, Kapusinszky B, Pesavento PA, Delwart E. Faecal virome of cats in an animal shelter. *J Gen Virol*. 2014;95(Pt 11):2553-64. doi:10.1099/vir.0.069674-0
77. Wang Y, Guo X, Cui Y, et al. Genetic characterization and phylogenetic analysis of feline astrovirus from Anhui province in eastern China. *3 Biotech*. 2020;10(8):354. doi:10.1007/s13205-020-02308-z
78. Chu DK, Chin AW, Smith GJ, et al. Detection of novel astroviruses in urban brown rats and previously known astroviruses in humans. *J Gen Virol*. 2010;91(Pt10):2457-62. doi:10.1099/vir.0.022764-0
79. Martella V, Moschidou P, Pinto P, et al. Astroviruses in rabbits. *Emerg Infect Dis*. 2011;17(12):2287-93. doi:10.3201/eid1712.110967
80. Ao YY, Yu JM, Li LL, et al. Diverse novel astroviruses identified in wild Himalayan marmots. *J*

Gen Virol. 2017;98(4):612-623. doi:10.1099/jgv.0.000709
81. Hu B, Chmura AA, Li J, et al. Detection of diverse novel astroviruses from small mammals in China. *J Gen Virol*. 2014;95(Pt 11):2442-9. doi:10.1099/vir.0.067686-0
82. Atkins A, Wellehan JF, Jr., Childress AL, Archer LL, Fraser WA, Citino SB. Characterization of an outbreak of astroviral diarrhea in a group of cheetahs (*Acinonyx jubatus*). *Vet Microbiol*. 2009;136(1-2):160-5. doi:10.1016/j.vetmic.2008.10.035
83. Meliopoulos VA, Kayali G, Burnham A, et al. Detection of antibodies against Turkey astrovirus in humans. *PLoS One*. 2014;9(5):e96934. doi:10.1371/journal.pone.0096934
84. Chu DK, Poon LL, Guan Y, Peiris JS. Novel astroviruses in insectivorous bats. *J Virol*. 2008;82(18):9107-14. doi:10.1128/jvi.00857-08
85. Zhu HC, Chu DK, Liu W, et al. Detection of diverse astroviruses from bats in China. *J Gen Virol*. 2009;90(Pt 4):883-7. doi:10.1099/vir.0.007732-0
86. Rivera R, Nollens HH, Venn-Watson S, Gulland FM, Wellehan JF, Jr. Characterization of phylogenetically diverse astroviruses of marine mammals. *J Gen Virol*. 2010;91(Pt1):166-73. doi:10.1099/vir.0.015222-0
87. Geoghegan JL, Di Giallonardo F, Wille M, et al. Virome composition in marine fish revealed by meta-transcriptomics. *Virus Evol*. 2021;7(1):veab005. doi:10.1093/ve/veab005
88. Xiao CT, Gimenez-Lirola LG, Gerber PF, Jiang YH, Halbur PG, Opriessnig T. Identification and characterization of novel porcine astroviruses (PAstVs) with high prevalence and frequent co-infection of individual pigs with multiple PAstV types. *J Gen Virol*. 2013;94(Pt 3):570-82. doi:10.1099/vir.0.048744-0
89. Hammerschmitt ME, de Almeida PR, de Cecco BS, et al. Swine polioencephalomyelitis in Brazil: identification of teschovirus A, sapelovirus A, and enterovirus G in a farm from Southern Brazil. *Braz J Microbiol*. 2021;doi:10.1007/s42770-021-00509-z
90. Kumthip K, Khamrin P, Saikruang W, et al. Detection and genetic characterization of porcine astroviruses in piglets with and without diarrhea in Thailand. *Arch Virol*. 2018;163(7):1823-1829. doi:10.1007/s00705-018-3806-x
91. Lee S, Jang G, Lee C. Complete genome sequence of a porcine astrovirus from South Korea. *Arch Virol*. 2015;160(7):1819-21. doi:10.1007/s00705-015-2436-9
92. Lan D, Ji W, Shan T, et al. Molecular characterization of a porcine astrovirus strain in China. *Arch Virol*. 2011;156(10):1869-75. doi:10.1007/s00705-011-1050-8
93. Ren K, Wang R, Liu X, et al. Epidemiological investigation and genetic characterization of porcine astrovirus genotypes 2 and 5 in Yunnan province, China. *Arch Virol*. 2022;167(2):355-366. doi:10.1007/s00705-021-05311-8
94. Zhao C, Chen C, Li Y, et al. Genomic characterization of a novel recombinant porcine astrovirus isolated in northeastern China. *Arch Virol*. 2019;164(5):1469-1473. doi:10.1007/s00705-019-04162-8
95. Lv SL, Zhang HH, Li JY, et al. High genetic diversity and recombination events of porcine astrovirus strains identified from ill and asymptomatic pigs in 2017, Hunan Province, China. *Virus Genes*. 2019;55(5):673-681. doi:10.1007/s11262-019-01692-w
96. Qin Y, Fang Q, Li X, et al. Molecular epidemiology and viremia of porcine astrovirus in pigs from Guangxi province of China. *BMC Vet Res*. 2019;15(1):471. doi:10.1186/s12917-019-2217-x
97. Su M, Qi S, Yang D, Guo D, Yin B, Sun D. Coinfection and genetic characterization of porcine astrovirus in diarrheic piglets in China from 2015 to 2018. *Front Vet Sci*. 2020;7:462. doi:10.3389/fvets.2020.00462
98. Chen XU, He Y, Li W, et al. Identification and characterization of a novel recombinant porcine astrovirus from pigs in Anhui, China. *Pol J Microbiol*. 2020;69(4):471-478. doi:10.33073/pjm-2020-051
99. Rajkhowa S, Sonowal J, Pegu SR, Deb R, Gupta VK. Epidemiology and emerging trends of zoonotic viral diseases of pigs in India. *Viruses*.2025;17(3). doi:10.3390/v17030381
100. Vaishali, Gupta R, Kumar M, et al. Coinfection of porcine astrovirus and other porcine viruses in

diarrheic pigs in Haryana, India. *Arch Virol*. 2023;168(10):246. doi:10.1007/s00705-023-05865-9

101. Kattoor JJ, Malik YS, Saurabh S, et al. First report and genetic characterization of porcine astroviruses of lineage 4 and 2 in diarrhoeic pigs in India. *Transbound Emerg Dis*. 2019;66(1):47-53. doi:10.1111/tbed.13058
102. Kour R, Kumar P, Jindal N, et al. Molecular detection and characterization reveals circulation of multiple genotypes of porcine astrovirus in Haryana, India. *Arch Virol*. 2021;166(10):2847-2852. doi:10.1007/s00705-021-05195-8
103. Brnic D, Jemersic L, Keros T, Prpic J. High prevalence and genetic heterogeneity of porcine astroviruses in domestic pigs. *Vet J*. 2014;202(2):390-2. doi:10.1016/j.tvjl.2014.08.015
104. Puente H, Arguello H, Cortey M, et al. Detection and genetic characterization of enteric viruses in diarrhoea outbreaks from swine farms in Spain. *Porcine Health Manag*. 2023;9(1):29. doi:10.1186/s40813-023-00326-w
105. Capai L, Piorkowski G, Maestrini O, et al. Detection of porcine enteric viruses (Kobuvirus, Mamastrovirus and Sapelovirus) in domestic pigs in Corsica, France. *PLoS One*. 2022;17(1):e0260161. doi:10.1371/journal.pone.0260161
106. Stamelou E, Giantsis IA, Papageorgiou KV, et al. Epidemiology of astrovirus, norovirus and sapovirus in Greek pig farms indicates high prevalence of Mamastrovirus suggesting the potential need for systematic surveillance. *Porcine Health Manag*. J2022;8(1):5. doi:10.1186/s40813-021-00245-8
107. Salamunova S, Jackova A, Mandelik R, Novotny J, Vlasakova M, Vilcek S. Molecular detection of enteric viruses and the genetic characterization of porcine astroviruses and sapoviruses in domestic pigs from Slovakian farms. *BMC Vet Res*. 2018;14(1):313. doi:10.1186/s12917-018-1640-8
108. Tassoni L, Zamperin G, Schiavon E, et al. First whole genome characterization of porcine astrovirus detected in swine faeces in Italy. *Vet Ital*. 2019;55(3):221-229. doi:10.12834/VetIt.1873.9956.1
109. Amimo JO, Machuka EM, Abworo EO, Vlasova AN, Pelle R. Whole genome sequence analysis of porcine astroviruses reveals novel genetically diverse strains circulating in East African smallholder pig farms. *Viruses*. 2020;12(11). doi:10.3390/v12111262
110. Bhatta TR, Chamings A, Alexandersen S. Exploring the cause of diarrhoea and poor growth in 8-11-week-old pigs from an Australian pig herd using metagenomic sequencing. *Viruses*. 2021;13(8). doi:10.3390/v13081608
111. Kumar P, Panghal R, Minhas SK, et al. Porcine astrovirus: a review. *Arch Virol*. 2026;171(3):77. doi:10.1007/s00705-026-06535-2
112. Shan T, Li L, Simmonds P, Wang C, Moeser A, Delwart E. The fecal virome of pigs on a high-density farm. *J Virol*. 2011;85(22):11697-708. doi:10.1128/jvi.05217-11
113. International Committee on the Taxonomy of Viruses (ICTV). Current Taxonomy Release. 2025.
114. Matias Ferreyra F, Harmon K, Bradner L, et al. Comparative analysis of novel strains of porcine astrovirus type 3 in the USA. *Viruses*. 2021;13(9). doi:10.3390/v13091859
115. Nagai M, Omatsu T, Aoki H, et al. Full genome analysis of bovine astrovirus from fecal samples of cattle in Japan: identification of possible interspecies transmission of bovine astrovirus. *Arch Virol*. 2015;160(10):2491-501. doi:10.1007/s00705-015-2543-7
116. Bridger JC. Detection by electron microscopy of caliciviruses, astroviruses and rotavirus-like particles in the faeces of piglets with diarrhoea. *Vet Rec*. 1980;107(23):532-3.
117. Upadhaya SD, Kim IH. The impact of weaning stress on gut health and the mechanistic aspects of several feed additives contributing to improved gut health function in weanling piglets-A review. *Animals (Basel)*. 2021;11(8). doi:10.3390/ani11082418
118. Schyns MAR, van den Braak R, Peijnenborg J, et al. Characterization of the enteric virome of clinically healthy pigs around weaning on commercial farms in the Netherlands using next generation sequencing and qPCR. *Porcine Health Manag*. 2025;11(1):41. doi:10.1186/s40813-025-00446-5