Impact of human behavior on the spread of African swine fever virus: what every veterinarian should know

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ABSTRACT
African swine fever virus was first identified and characterized in Africa in the early 1900s, but it has spread exponentially in Europe, Asia, and the Caribbean since 2018. While it is a disease that exclusively affects swine, thus posing no infectious risk to human health, the virus’s resiliency and human behavior have facilitated the rapid global dissemination of the virus over the past 4 years. In this Currents in One Health, we will review its epidemiology, viral characteristics, host range, and current prevention strategies; the current perspective on what a response would look like and who would be affected; and if the virus was ever found in the US. Due to the fact that the virus affects all breeds of Sus scrofa, including those used for food and companionship, it is vital for all veterinarians to work together to keep the virus out of the US. It is only through the collaborative efforts of multiple disciplines working locally, nationally, and globally that we can contain the spread of this virus.

One Health Implications

While the infectious impacts of African swine fever (ASF) are limited to swine, the economic impacts are projected to eventually reach people both in and outside of agriculture. Since the US is a net exporter of pork and the immediate response of most trading partners has been to stop importing pork from affected countries, a surplus of domestic supply drives a series of negative impacts throughout the food supply system. For example, long-term projections from an ASF incursion into the US include $50 billion in losses, nationwide employment losses of 140,000 jobs, and downsizing of the swine industry.1 It is important to realize that the life cycle of a market pig is about a year from conception to market, so even swift adjustments to breeding leave a production surplus of live animals that must be managed for at least a year. Further, examination of international disease outbreaks confirms the human impacts of the outbreak and the subsequent response. A longitudinal study2 of the 2001 UK foot-and-mouth disease outbreak illustrated that “distress, feelings of bereavement, fear of a new disaster, loss of trust in authority and systems of control, and the undermining of the value of local knowledge” occurred in diverse groups including those not directly involved in agriculture.

Viral Epidemiology

ASF was first diagnosed as a disease in Kenya in the early 1900s after contact was made between infected warthogs and a European-sourced domestic swine herd (Sus scrofa domesticus) and caused 100% mortality.3 Subsequent detections were limited to Central and Western Africa until it was discovered in Lisbon, Portugal in 1957. The infection was suspected from the feeding of airline waste to domestic pigs near the Lisbon airport from flights originating from Africa.4 From a period of 1960 to 1986, ASF spread was detected in Spain, France, Italy, Sardinia, Belgium, and the Netherlands as well as in the Caribbean and South American countries of Cuba, the Dominican Republic, Haiti, and Brazil. All of those countries, except for the island of Sardinia, were successful in eradicating the disease during that period of time. The viruses in these outbreaks were all classified as genotype I by sequencing of the major capsid protein p72.5

In 2007, ASF was discovered in the Republic of Georgia, presumably by the feeding of infected pork waste from ships coming from East Africa. This viral sequence was identified as a genotype II from East Africa, which tends to be much more virulent than genotype I.5 Poor surveillance and biosecurity allowed infection to become established in feral pig and wild boar populations, facilitating
its spread into domestic herds. Movement and migration patterns of wild boars, as well as the illegal movement and sale of domestic swine, allowed for spread to neighboring countries and the continued migration of ASF to the north and west. Soon, ASF was detected in Russia, Ukraine, and Belarus. In 2014, ASF was first detected in the European Union on the Lithuanian border with Belarus. The virus has subsequently been detected in Estonia, Latvia, Lithuania, and Poland since 2014 and in the Czech Republic, Hungary, Romania, and Bulgaria in 2018. More recent introductions have been found in Germany in 2020 and Italy in 2022. The significant majority of detections are in wild boars, with occasional spillovers into domestic swine herds. Perhaps the most significant recent outbreak occurred in Asia, starting with the first case of ASF confirmed in Liaoning Province in China on August 3, 2018. The virus was identified as a genotype II, very similar to the strain that infected Georgia in 2007. Within the next year, the virus spread to all 32 provinces with 163 reported cases and over 1,192,000 swine culled in an attempt to control the virus. The virus quickly spread throughout the rest of Asia in 2019, including Korea, followed by Vietnam (February), Cambodia (April), Hong Kong and North Korea (May), Laos (June), Myanmar (August), and the Philippines, South Korea, and Timor-Leste (September). The majority of these cases impacted pig producers of all sizes, devastating the swine industries in these countries.

ASF recently made an incursion back into the Americas with an outbreak detected in the Dominican Republic and Haiti in 2020, once again most likely through the feeding of contaminated pork products from ship waste fed to local pigs or through the importation of illegal pork products. Most (98%) of the outbreaks have occurred in backyard pigs while 3 commercial pig operations have been infected as of September 2021.

Viral Characteristics

ASF virus (ASFV) is the lone member of the Asfarviridae family, genus Asfivirus. It is a very large enveloped, double-stranded DNA virus wrapped in an icosahedral complex of approximately 170- to 193-kilobase pairs. The virus codes for approximately 50 structural proteins with the major components of the viral capsid, the protein p72, the 2 structural proteins p30 (p32) and p54, and the polyprotein pp62, being identified as the most antigenic of the proteins that are responsible for the induction of antibodies after a natural infection. These proteins are useful as diagnostic markers but hold no value for antibody-mediated immune protection.

ASFV is very resilient in the environment, which is one of the main reasons it has been so successful in moving across borders and continents. The virus can be inactivated by heat, but it requires an extreme temperature of 60 °C for 20 minutes or 56 °C for 70 minutes for complete inactivation. It can withstand pH ranges from 3.9 to 11.5 in serum free medium and even wider ranges when placed in serum. The virus can also survive for 70 days in dried blood on wooden boards at 18 to 23 °C, which could serve as a reservoir for other naïve pigs. ASFV has been found in decaying wild boar carcases for at least 15 weeks, which serve as an environmental reservoir and important vector in maintaining the disease in wild boar populations because pigs are omnivorous. ASFV can be inactivated by most common disinfectants that are effective against other enveloped viruses as long as the organic material has first been removed. The most significant concern is the survivability of the virus in undercooked meat, particularly in cured hams and sausages. In Spanish dry-cured meat products, such as Serrano and Iberian ham and shoulders, the virus survives for 140 days, and in loins it survives for 112 days. The virus has also been detected in sausages confiscated from Chinese travelers in South Korea shortly after ASF was detected in China in 2018. These products are often discarded in the garbage or intentionally fed to pigs as uncooked food waste, which can further disseminate the virus. These items are also often carried by travelers and discarded in garbage that wild boars can scavenge and thus become infected, resulting in a new infection, sometimes in another country or continent. Prevention and Control Measures

Currently there are no vaccines or therapeutics that prevent or control ASFV. Due to the complexity of the virus, its large genome, and its numerous genes involved in immune evasion, traditional methods of live and inactivated vaccines have been unrewarding in terms of efficacy. There is evidence that both antibody-mediated and cell-mediated responses are going to be required for vaccine efficacy. Recently, a team from the USDA Plum Island Animal Disease Center developed a gene deletion vaccine candidate of the currently circulating genotype II Georgia 2007 ASFV-G strain. It was found to produce low viremia titers, showed no virus shedding, and developed a strong virus-specific antibody response. Most importantly, it was able to protect the vaccinated pigs when challenged with the virulent parental strain ASFV-G.

Among the biggest risk factors for introduction into the US remains the illegal importation of contaminated food products. With the recent spread of ASF in Europe and Asia since 2018 and 2019, the risk of importation in smuggled pork products in passenger luggage has increased 183%, and 90% of that risk can be centralized to 5 US international airports. The US Customs and Border Protection has responded by increasing the use of trained Beagles at all international airports to inspect luggage from international travelers for illegally smuggled pork products. In 2021, the USDA APHIS issued a federal order to prevent the entry...
or introduction of ASF into the US in association with dogs imported for resale, requiring written documentation verifying completion of disposal of animal bedding, microchip identification, and a postentry bath.\textsuperscript{22}

### Host Range

ASFV is known to infect both wild and domestic species of swine including pigs used for production and those of the species \textit{S. scrofa} kept as companion animals.\textsuperscript{4} In Africa, warthogs and bush pigs infected with ASFV are asymptomatic and involved in a sylvatic life cycle involving soft ticks of the genus \textit{Ornithodoros} that maintain the disease.\textsuperscript{4} ASFV is not infectious to humans,\textsuperscript{23} and pork originating from pigs affected by ASFV is safe to eat.

### Clinical Presentation and Pathology

A wide array of clinical signs can be observed following infection with ASFV, and there are no pathognomonic clinical signs or lesions of the disease. Clinical signs develop following a 2- to 19-day incubation period, with the incubation period being influenced by the strain, inoculation dose, route of transmission, and various host characteristics.\textsuperscript{24} Temperatures will regularly exceed 40 °C and may exceed 41.7 °C as the disease progresses.\textsuperscript{24} Infected animals may become depressed or anorexic and display cyanosis of the ears and hind limbs that may extend over a greater portion of the body, conjunctivitis, watery or bloody diarrhea, increased respiration rate, abortions, and incoordination and paresis of the hind limbs.\textsuperscript{3,24,25} Within a swine herd, mortality rates are often tracked and used as an indicator of disease as well as noninfectious causes.\textsuperscript{26} When ASFV infects a herd, the virus is capable of circulating for several weeks before an increase in mortality is observed in the herd.\textsuperscript{27} With an increase in mortality, postmortem examinations can be performed to gain more insight into the disease process that is occurring. Common gross pathological findings include cyanosis, hemorrhagic gastrohepatic and renal lymph nodes, splenomegaly, renal petechial, and edematous lungs.\textsuperscript{25}

Knowing normal anatomy is the key to identifying abnormalities when they arise. Cyanosis or hyperemia can be easily identified on pigs with lighter pigmentation compared with darker pigmented swine. A normal spleen should be pliable, narrow, ovoid, and dark red in color with thin, crisp edges. When removed from the abdomen, a normal spleen will be approximately the length from the thoracic inlet to the mandibular symphysis. ASFV-affected spleens may be very enlarged, dark blue to purple in color, and friable. Normal lymph nodes are pale, small, pea- to grape-sized structures. Abnormal lymph nodes from pigs affected with ASFV are often enlarged and may become hemorrhagic. Normal swine kidneys are the traditional kidney bean shape and reddish brown in color. Kidneys affected by ASFV may have petechial hemorrhages that may coalesce and are often referred to as “turkey egg” kidneys due to the resemblance of a turkey’s egg. Images of abnormal findings from ASFV-positive pigs are shown (Figure 1). A good overview of lesions and images has been reported by Salguero.\textsuperscript{28}

Figure 1—Sharply demarcated hyperemia on the hind end (A), an enlarged and hemorrhagic gastrohepatic lymph node (B), and coalescing petechia and ecchymosis of the renal cortex (C) of a pig. Images sourced from the USDA Plum Island Animal Disease Center.

It is of critical importance that caretakers and practitioners be vigilant in monitoring not only mortality data but also clinical signs to be able to rapidly identify when ASFV may have infected a herd.
Although there are no pathognomonic lesions for ASFV, it can present similarly to porcine reproductive and respiratory syndrome virus, porcine circovirus type 2, or salmonellosis. Reporting suspicious cases in which ASFV is a differential will lead to more timely detection and help to minimize the impacts on animal health, welfare, and the economy.

**Outbreak Response**

ASF is considered to be a foreign animal disease in the US and is a notifiable disease to the World Organization for Animal Health. The US has never had ASF, and incursion of the virus would have ramifications on our ability to export pork. This would have a dramatic impact on our economy as the US exports approximately 25% of its pork. If ASFV is suspected to be present, the first step will be to contact a state animal health official to initiate a foreign animal disease investigation. This will involve a foreign animal disease diagnostician visiting the premises to collect diagnostic samples for confirmation during a foreign animal disease investigation. Often, samples are collected in duplicate, with 1 set being sent to a National Veterinary Services Laboratory (NVSL). The NVSL has 2 laboratories: 1 laboratory located in Ames, Iowa, and the Foreign Animal Disease Diagnostic Laboratory on Plum Island, New York. Samples suspected to be positive for ASFV are sent to the Foreign Animal Disease Diagnostic Laboratory, which will be moving to the National Bio and Agro-Defense Facility in Manhattan, Kansas in the near future. The second set of samples is sent to the local National Animal Health Laboratory Network diagnostic laboratory certified by the USDA to conduct testing. USDA-approved sample types for ASFV include whole-blood and tissue samples including the tonsil, spleen, and gastrohepatic, renal, and inguinal lymph nodes.

If ASFV is confirmed by the NVSL, the USDA APHIS has developed disease response plans known as “The Red Books.” Following ASFV detection, the goal will be to control and quickly eradicate the disease. This is based on 4 epidemiological principles as outlined in the “ASF Response Plan: The Red Book”:

1. Prevent contact between ASFV and swine.
2. Stop the production of ASFV by infected or exposed swine.
3. Stop the transmission of ASFV by vectors.
4. Prevent ASFV from becoming established in feral swine populations.

To prevent contact between ASFV and other susceptible swine, a national movement standstill of all swine for at least 72 hours will be implemented and control areas will be established around the infected site(s) consisting of a 3-km infected zone and 2-km buffer zone. Additionally, a 5-km surveillance zone will be set around the control area. During the 72-hour movement standstill, an epidemiological investigation will be conducted to determine if any other premises are linked to the infected premises. Linked premises may also be tested, and if positive, new control areas will be established. Enhanced biosecurity practices may be implemented to further reduce the potential for exposure to ASFV, particularly for sites that are located within the control zone. Enhanced biosecurity practices, as outlined by the Secure Pork Supply Plan, may include restricted premises entry, a clearly designated parking area, a perimeter buffer area and line of separation with access points, and cleaning and disinfection stations.

To stop the production of ASFV by infected or exposed swine, animals will be mass depopulated following AVMA-approved methods for mass depopulation. Following depopulation, animals must be disposed of properly in alignment with federal, state, and local regulations. Because of the resiliency of ASFV, depopulation and disposal must be conducted in a biosecure manner to prevent disease spread.

Early detection, depopulation, and disposal are key in the prevention of ASFV spread by vectors and establishment of the virus in feral swine populations. Current surveillance is dependent on caretakers and veterinarians reporting case-compatible clinical signs to state and federal animal health officials to have a foreign animal disease investigation generated and animals tested for ASFV. Recently, a new surveillance stream has been opened that allows diagnosticists at Veterinary Diagnostic Laboratories to test case-compatible sick pig submissions in which ASF lesions are suspected.

**Conclusion**

ASFV represents one of the greatest threats to pigs around the world. Although ASF does not infect humans, our behaviors have contributed to the spread of this virus globally, where it has created disease and welfare concerns for the animals, distress for their caretakers, and economic hardships for the nations affected. The economic and psychological impacts are devastating in the agriculture community and eventually spread to the rest of the society with lasting impact. It is incumbent on everyone to be vigilant in doing our part to ensure that we do everything possible to avoid the introduction of ASFV into the US.

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