African swine fever from Kenya to five continents: the role of wild boar

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Summary

African swine fever is currently the largest threat to world pork production. The complexity of the virus, its persistence in the environment, the particular immune response it elicits without significant neutralising antibodies, its capacity for transmission by several routes and the presentation of different clinical forms, from acute with high mortality to attenuated to chronic, all pose significant challenges.

This article provides an overview the epidemiological situation across five continents, the role of wild boar in virus transmission, the development of new immunological tools that aim to enhance protection against this complicated virus in wild boar, and the protection studies that are currently under way.

Keywords

African swine fever virus – Genotypes – Immunological tools – Neutralising antibodies – Routes of infection.

Introduction

African swine fever virus (ASFV) is a highly complex and intriguing virus affecting only domestic pigs and wild suids. The large virus particle possesses structural complexity that allows it to protect its DNA, to elicit a particular immune response without significant neutralising antibodies and to be transmitted through various routes. Additionally, African swine fever (ASF) can manifest in different clinical forms, ranging from acute to attenuated and even extending to chronic forms in domestic pigs. The development of a safe and effective vaccine has also posed challenges.

ASFV was first described in Kenya [1], where the 24 genotypes described are present and the sylvatic and domestic cycles of ASF coexist. The vectors and reservoirs are wildlife (warthog and bush pig), the tick (*Ornitodorus moubata*) and domestic pigs, making these cycles very active.

ASF has spread outside of Africa on three occasions. The first introduction was in 1957 in Portugal on a small pig farm near the Lisbon airport, due to the introduction of food leftovers from a plane from Africa. The virus belonged to genotype I and had low virulence. In 1960, a second introduction of ASF occurred near Lisbon, this time with a highly virulent virus (Lisbon 60) also belonging to genotype I. This virus spread rapidly to several European countries, the Caribbean and South America [2,3].

The third appearance was the worst that has yet occurred. A highly virulent virus of genotype II left the east coast of Africa by boat in April 2007 and arrived at the harbour of Poti in Georgia. Once again, food leftovers from boats were taken up by local pigs, resulting in infection with ASFV. From there, the virus spread to Armenia in August 2007 and to Russia in November 2007 (in wild boars) and June 2008 (in domestic pigs). It continued to spread to the European Union in 2014, Asia in 2018, Oceania in 2020 and Central America in 2021 [2,4], affecting more than 70 countries across five continents, making it the worst such situation ever recorded.

Two important epidemiological factors were observed. First, the transmission of ASFV through food from infected pigs remains the most significant mechanism of spread, over both long and short distances [5,6]. This has been evidenced in European and Asian countries as well in the Dominican Republic and Haiti. Nevertheless, since 2007, the global risk of ASF spread through undetected infected pork has increased even more due to ASF's geographical expansion, trade globalisation, the co-circulation of attenuated strains and the use of illegal vaccines against ASF. Second, infected wild boars were a crucial factor in the transmission to different areas and countries over short and medium distances. Up to now, the tools to combat the disease have been limited, resulting in significant problems for efficient disease control in several regions. Today, ASF is the biggest threat to the global swine industry. Vaccination arises as a promising and powerful potential tool to effectively decrease ASF spread and help infected countries to better control the disease, including in wildlife (an important factor of disease spread, maintenance and amplification in the current ASF epizootic).

This article reviews the characteristics of ASFV, its persistence in the environment, the epidemiological situation across the five continents, the role of wild boar and, finally, the new immunological tools that aim to enhance protection against ASFV and the research that is being carried out to test them.

What has allowed this virus to advance and persist for so long?

Several factors contribute to the spread and persistence of ASF. Firstly, the virus can remain infectious for a long period [7]. Secondly, it does not elicit a quick and effective immune response. Thirdly, there were failures in obtaining vaccines until very recently. Finally, the lack of adequate biosecurity measures in some ASF-infected regions has facilitated spread of the disease across the five continents.

African swine fever in Asia

Since an outbreak of ASFV began in China in 2018, 23 out of 48 Asian countries have reported infection [4]. Both high-virulence ASF genotype II, introduced by regional spread from 2018, and an attenuated genotype I from an inappropriate Chinese vaccine are circulating [8]. This situation has created important epidemiological implications due to the large amount of contaminated pig meat and pig products in circulation. The presence of both acute and attenuated ASFV isolates, as well as the role of wild boars in the transmission of the disease within the area, created difficulties in the early detection of ASF [8,9]. Finally, Vietnam launched a vaccination programme against ASF in domestic pigs using the vaccine from Navetco.

African swine fever in Europe

Since ASF's introduction into Georgia in 2007, 22 out of 50 European countries have reported infections. However, two different epidemiological scenarios were observed. In Eastern Europe most outbreaks were reported in domestic pigs following virus detection in the wild boar population, while in Western Europe most ASF notifications were reported in wild boars in all types of landscapes (natural, agroforestry and urban areas, with 65.6%, 32.8% and 1.7% of notifications, respectively), with only sporadic outbreaks in domestic pigs [10]. This distribution is related to the biosecurity measures on farms and their localisation, which in some cases is in or near forested areas [11,12]. Among the 22 European countries with reported cases, only the Czech Republic and Belgium eradicated the disease, in 2018 and 2020, respectively. Of these two countries, only Belgium maintains a disease-free status, as wild boar in the Czech Republic again became infected in November 2022. At present, 60 countries are affected, including 12 in Africa, 2 in the Americas, 21 in Asia, 24 in Europe and 1 in Oceania.

The situation in Caribbean countries: Haiti and the Dominican Republic

Both Haiti and the Dominican Republic were infected with ASF genotype I by the entry of infected swine products and food leftovers used for feeding backyard pigs – the Dominican Republic in 1978 and Haiti in 1979. In 2021, a new ASF infection caused by a high-virulence genotype II was declared in both countries. Currently, the virus is affecting both countries [4], and the Dominican Republic has initiated an ASF vaccination programme using the Navetco vaccine.

The main risk factors contributing to spread of African swine fever

Several risk factors are strongly associated with the spread of ASF.

- More countries than ever have reported infection with ASF across five continents.
- Subsequently, there is an increase in the circulation of ASF-contaminated food and pig products from ASF-infected pigs worldwide. This is the main source of ASF spread in affected countries and introduction into ASF-free countries.
- ASFV can persist in the environment and in frozen pork products for years [7].
- The wild boar population is increasing, as is its distribution in natural areas, agroforestry areas and even urban environments.
- The expansion of urban areas and the overpopulation of wild boar increase direct and indirect contact between wild boar and domestic pigs, due to wild boar's need to find food outside natural areas, causing interaction and conflicts with humans and livestock.
- A considerable number of backyard pig farms are still in contact with wild boar, sharing a habitat and environment.
- There is a lack of adequate biosecurity on some commercial pig farms.
- There is a knowledge gap about the mechanisms of ASF transmission in rural areas.
- Detection of ASF is often delayed. Very few people want to be the first to declare ASF for several reasons: potential administrative problems, the possibility of a thorough farm inspection, etc.

Why is the wild boar population increasing?

The wild boar (*Sus scrofa*) is a species with great ecological plasticity, exhibiting a high capacity for adaptation and survival in environments that have been altered by humans [13,14].

Several factors are contributing to the global increase in the wild boar population: i) the disappearance of traditional agriculture in parallel with the intensification of crop production, increasing the availability of feed; ii) reforestation and increase in shelter areas (scrub and wooded areas); iii) supplementary or artificial feeding, as well as compensatory population responses to hunting pressure [15]; iv) inefficient hunting and management [16]; v) the remarkable ability of wild boar to adapt to diverse environments and their varied trophic diet [17]; vi) wild boar's high reproductive rate [18]; vii) warmer winter temperatures; and viii) an absence of or decrease in predators in many areas [19].

During the last century, the wild boar population grew exponentially and continuously in Europe, in many parts of the Palearctic and in other regions of the world [14], resulting in increased populations in many regions. Further growth can be expected, not only in Europe but also at the global level [20]. All these facts have led to numerous conflicts due to agricultural damage, problems in the conservation of natural areas, and threats to animal health [11,15].

A vaccine for wild boar

A safe vaccine for ASF has been a dream for many years, but until very recently effective and safe vaccine prototypes were not available.

For domestic pigs, a vaccine recently appeared on the market, produced by the company Navetco and developed in collaboration with the United States Department of Agriculture. It contains a genetically modified ASFV with a deletion of gene I177L [21]. As previously mentioned, the vaccine has been used in Asia (Vietnam) and more recently in the Dominican Republic, but several problems have been observed. So far, no matching DIVA assay to differentiate infected from vaccinated animals is commercially available.

There have been few studies on ASF vaccination in wild boar. Preliminary work [22] has demonstrated the successful oral immunisation of wild boar with a non-hemadsorbing, attenuated genotype II ASFV that was isolated in Latvia in 2017 (Lv17/WB/Rie1). That immunisation conferred 92% protection against challenge with a high-virulence ASFV isolate (Arm07). This is, to the author's knowledge, the first report of a potential vaccine against ASF in wild boar.

The European Union-funded VACDIVA (https://www.vacdiva.eu) project is working to obtain an ASFV DIVA vaccine for wild boar. Several mutants from Lv17/WB/Rie1 have been produced by Zadori Zoltan *et al*. (European Patent Application No. EP22462011.2) and have been evaluated as potential vaccine prototypes for wild boar in several *in vivo* experimental studies. Mutant selection is ongoing in an extended experiment in wild boar. Currently, these candidates are being analysed for potential side effects to determine the level of protection by oral immunisation after challenge, overdosing and shedding in laboratory conditions. A field trial of the VACDIVA prototype vaccine is being conducted in Uganda in warthogs. The vaccine has also been evaluated in six different groups of wild boar with good results. A field trial with vaccination and challenge is in preparation. Additionally, one adapted DIVA enzyme-linked immunosorbent assay kit (European Patent Application No. EP22462010) for differentiating infected animals from naive or vaccinated ones has been developed as part of the VACDIVA project.

Conclusions

To date, six *in vivo* studies in wild boar have been conducted to evaluate both the vaccine alone and vaccination and challenge together, in laboratory conditions, for a period of three to four months, revealing good results in protection and no side effects. An *in vivo* vaccine and virus challenge is currently under evaluation in warthogs in Africa. A new study with vaccine and challenge in wild boar involving high numbers of animals and for a longer period of time, under controlled conditions, is in preparation. This study will enable observations of the animals for an extended period and assessment of the duration of the immune response induced by the vaccine prototype (delta CD), the duration of protection and the absence of side effects. The VACDIVA project aims to gather as much information as possible to prove, with this study, that the vaccine is safe, effective and DIVA compatible. Thus, there is finally hope for an ASF vaccine for wild boar that can meet the needs of the current epizootic.

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