Survival and transmission of swine influenza A virus within and between farms

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Summary

Influenza A virus in swine (IAV-S) survives for a short period within the host, and its survival outside the host does not seem to be a significant obstacle to elimination attempts. Virus circulation within sow farms appears to be related mainly to suckling piglets and recently introduced gilts. Three important ways IAV-S is introduced into sow herds are infected pigs, infected humans, and aerosol. Elimination of IAV-S virus in sow herds should be easier than for porcine reproductive and respiratory syndrome virus, and it is possible to remain negative for IAV-S on a long-term basis.

Keywords: swine, influenza, survival, transmission, prevention

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Resumen - Supervivencia y transmisión del virus de la influenza porcina A dentro y entre granjas

El virus de la influenza A en los cerdos (IAV-S) sobrevive durante un breve período dentro del hospedador, y su supervivencia fuera del hospedador no parece ser un obstáculo significativo para los intentos de su eliminación. La circulación del virus dentro de las granjas de cerdas parece estar relacionada principalmente con los lechones lactantes y las primerizas recientemente introducidas. Tres formas importantes de introducir el IAV-S en las granjas de cerdas son cerdos infectados, los seres humanos infectados, y el aerosol. La eliminación del virus IAV-S en las granjas de cerdas debería ser más fácil que para la del virus del síndrome reproductivo y respiratorio del cerdo, y es posible seguir siendo negativo para el IAV-S a largo plazo.

Résumé - Survie et transmission du virus de la grippe porcine A à l'intérieur et entre les fermes

Le virus de l'influenza A chez le porc (IAV-S) survit pendant une courte période au sein de l'hôte, et sa survie à l'extérieur de l'hôte ne semble pas être un obstacle important aux tentatives d'élimination. La circulation du virus dans les fermes de truies semble être principalement associée aux porcelets allaités et aux cochettes récemment introduites. Les porcs infectés, les humains infectés, et les aérosols sont trois façons importantes d'introduire l'IAV-S dans les troupeaux de truies. L'élimination du virus IAV-S dans les troupeaux de truies devrait être plus facile que pour le virus du syndrome reproducteur et respiratoire porcin, et il est possible de rester négatif à long terme pour l'IAV-S.

Influenza A virus in swine (IAV-S) is one of the most common and significant respiratory pathogens of swine. Most swine herds in North America are infected with IAV-S or will become infected at one point in time. Remaining IAV-S negative is a challenge given current ways of raising pigs. This commentary addresses two aspects related to the epidemiology of IAV-S, survival and transmission of the virus and the possibility to become and remain negative for this virus.

Survival inside the host

On an individual basis, pigs do not shed and remain carriers of IAV-S for long. Most studies could only detect the virus from a few days to about a month after infection.[1-3] Compared to other viruses, this is a short carriage period. Porcine reproductive and respiratory syndrome virus (PRRSV), another important pathogen of swine, could be isolated at 157 days and identified by polymerase chain reaction (PCR) up to 251 days after experimental infection.[4,5] On a group basis, all animals do not become infected at the same time. Consequently, the survival within a population of pigs will be longer than for an individual animal. Allerson et al[6] showed that the virus could be detected by PCR in oral fluids up to 42 days after the first day clinical signs of IAV-S were observed. On another farm where pigs were found to be infected 2 days post weaning, the virus was identified in oral fluids up to day 71 post weaning. Since detection was done by PCR and not virus isolation or bioassay, it is not known if the virus detected was infectious. More work is needed to determine how long groups of pigs can remain a source of infection for negative animals in different field situations.

Survival outside the host

The environmental survival of influenza viruses can differ due to differences in temperature, relative humidity, type of matrices, presence or absence of organic matter, and the strain of virus tested.[7-11] The 2009 novel influenza A (H1N1) virus (H1N1pdm09) survived at least 600 days in water at 4°C, but less than 14 days at 35°C.[9] Using a different strain of the same influenza A H1N1pdm09 virus, Greatorex et al[10] reported that live virus recovery had fallen below the detection

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level 24 hours after application to surfaces tested, including glass, plastic, and stainless steel. Bøttner and Belsham[11] were able to recover live IAV-S in slurry kept at 5°C for 9 weeks, for 15 days at 20°C, and for > 24 hours (not specified more in the document) at 35°C. Finally, a study comparing the survival time of various swine viruses in feed ingredients showed that IAV-S could not survive a period of 37 days in any of the ingredients tested. However, PRRSV was found to still be alive at that time in conventional soybean meal, and in dried distillers' grains with solubles.[12] Given the large range in data concerning the survival time of the virus in the environment, there is a need for more information specific to farm conditions. Nevertheless, it is possible to eliminate IAV-S without depopulating the herd, which should suggest that survival of the organism in the environment is not a major obstacle in terms of elimination attempts.

Transmission within the farm

Different studies suggest that recently introduced gilts and suckling piglets are the main reservoirs that allow IAV-S circulation to be maintained in sow herds.[13-17] In the case of piglets, it was shown in an experimental study that cross fostering, a procedure used in virtually all sow herds, was a way by which the virus can be transmitted in farrowing barns.[18] Since the virus can survive for a certain period in the environment, contaminated air or fomites would seem to be other possible ways pigs can become infected. Tests conducted in infected herds have shown that oral fluids and air samples were positive for virus by both PCR and virus isolation, while pen railings and doors were found positive for virus by PCR only.[19] In another study where environmental contamination was evaluated, oral fluids, udder wipes, surface wipes, air, and airborne deposited particle samples were positive for virus by both methods of detection.[20] Similarly, Wright et al[21] detected viral RNA on 75 of 400 (18.75%) inanimate surfaces sampled at agricultural fairs during the summer of 2016, and viable virus was recovered from 7 of 75 (9.33%) positive samples. Allerson et al[22] showed in an experimental model that contaminated fomites could transmit the virus between infected and non-infected pigs. The same was shown in a guinea pig model where transmission was achieved using contaminated fomites, and even more easily by aerosol.[23]

Transmission between farms

Transmission of IAV-S between farms has not been thoroughly evaluated. The main potential or theoretical ways by which the virus may be introduced into swine herds would appear to be infected swine, aerosol, other animal species including humans, transport vehicles, fomites, feed, and water. Semen is not considered to be a way the virus can be introduced in a sow herd.[24] Insects could act as mechanical vectors, but evidence up until now is lacking to suggest that they play a significant role in the epidemiology of IAV-S infection in swine. The possible role of transport vehicles and fomites does not seem to have been critically evaluated either. The 2019 edition of *Diseases of Swine* does not mention them as possible sources of transmission.[25] Considering that the virus can survive in the environment for a while, it can be hypothesized that a truck transporting infected pigs just prior to transporting negative pigs could serve as a source of infection if washing and disinfection are not properly executed. Infected pigs are believed to be the most likely source of infection for swine herds.[25] However, some genetic companies have consistently delivered IAV-S-negative gilts from multiplier herds to commercial sow herds, yet many of these commercial herds have become infected in one way or another over the years (Desrosiers, unpublished information, 2020). So, indirect transmission of this virus is frequent, and it is particularly difficult in hog-dense areas to remain IAV-S negative.[26,27]

Some farms become repeatedly infected with different strains of IAV-S over time. In a study conducted over 5 years in 34 breed-to-wean farms of a commercial system, 41%, 18%, and 21% of the farms had 1, 2, and 3 different strains identified, respectively, over the course of the study.[28] One possible reason for this is that aerosol may be a significant source of transmission and different epidemiological studies point in that direction.[29-32] Species other than swine can serve as potential sources of transmission. The virus can infect feral swine, domestic turkeys, free-ranging waterfowl, and most importantly, humans.[25] The first three are not present in modern swine farms and would thus not constitute direct sources of transmission unless the pigs have outdoor access. Theoretically, pigs may indirectly become infected if something coming from the outside became contaminated by one of these other species and was then introduced into the barn. For example, since there are indications that the virus may survive for long periods in water, farms using surface water could introduce the virus if feral swine or waterfowl also had access to the water source.[9] Karasin et al[33,34] suggested that this is what happened in two cases where pigs from the same Ontario farm became infected with avian influenza strains (H4N6 and H3N3) on two different occasions. The farm occasionally used water from a lake where waterfowl had access. At this time, animal species other than swine are not considered significant factors in influenza virus introduction in North American swine farms. Humans, on the other hand, can be.

Performing a comprehensive phylogenetic analysis of 1404 whole-genome sequences from IAV-S collected from 1931 to 2013, Nelson et al[35] concluded that human-to-swine transmission occurred frequently over this period. However, it is really since 2009 with the emergence of the influenza A H1N1pdm09 virus that this situation has become much more obvious. Soon after the initial spread of this virus in the human population, the virus was detected in pigs and since then transmitted from humans to pigs throughout the world.[36] Norway has adopted an ongoing annual serosurveillance of IAV-S since 1997, and all results had been negative prior to the incursion of the influenza A H1N1pdm09 virus in October 2009. Cases of influenza A H1N1pdm09 virus in swine occurred soon after the first human cases caused by the same virus were diagnosed in the country.[27] Within a few months, more than one third of the herds had antibodies against the virus. The results of an epidemiological study showed that the most important risk factor associated with introduction of influenza A H1N1pdm09 virus to swine herds in the initial phase of the outbreak was the presence of farm staff with influenza-like illness before the pigs became infected. This was the case in 12 of 14 nucleus and multiplier herds. The authors concluded that the rapid and widespread seroconversion against the virus could be explained by the emergence of a novel virus that is readily transmitted between people and swine in a largely susceptible population of humans and an entirely naïve population of pigs.[37]

While this still needs to be scientifically quantified, the information currently available suggests the 3 important ways IAV-S is introduced into hog barns are infected swine, infected humans, and aerosol. As with several other significant swine pathogens, the relative importance of the various ways swine farms are becoming infected with IAV-S has not been evaluated.[38] Without quantification of the different possible transmission routes, it is difficult to know how to prioritize control efforts.

Discussion

In North America, remaining negative to IAV-S is difficult. The virus can be introduced into swine farms by infected pigs, infected humans, and by different indirect ways.[22,25] Nevertheless, some Canadian herds in Quebec have remained negative to this virus for long periods, some many years or decades. Most if not all these farms are in areas with very few pigs, so location and distance to infected pigs appear to be critical factors to consider. Table 1 shows characteristics associated with some of these herds that have remained free of the virus for many years. (R. Boutin, DVM, email, July 2020; B. Boucher, DVM, email, July 2020; and M. St-Hilaire, DVM, email, July 2020).

Farm A was a single site, farrow-to-finish multiplier. Blood samples were taken at the end of finishing twice a year between 1990 and 2008 and had always been IAV-S negative. It became a commercial herd in 2008 and remained as such until 2015. Blood samples were not taken during this period but based on absence of clinical signs and diagnosis of the condition, both the producer and practitioner believe the negative status was maintained. The farm was changed again in 2015 to a 6000-head finishing site and began introducing pigs from outside sources. The IAV-S status from 2015 to the present is unknown. When sows were present on site, this herd purchased gilts from a nucleus herd 6 times a year, and IAV-S-negative blood samples were requested before the gilts were introduced into the multiplier.

Similarly, farms B to F tested gilts in quarantine before introducing them into the sow herds. On the two occasions where gilts were found to be seropositive, they were kept in quarantine for an extra month to ensure that they would not be infectious at the time of introduction. The IAV-S-negative status of the sow herds was based on absence of clinical signs in the sow herds and progeny, absence of influenza diagnoses from submissions made to the laboratory when health problems occurred, as well as PCR tests in oral fluids, serological tests conducted in late nursery aged piglets, or both.

Farms G to N belong to the same organization, which had a routine IAV-S monitoring program up until 2015 but discontinued the program given the consistent negative results and for cost reasons. From 2015 to the present, the IAV-S-negative status was based on absence of clinical signs in the sow herds and progeny and absence of influenza diagnoses from submissions made to the laboratories when health problems occurred. In the few instances where clinical signs suggestive of IAV-S were observed in the sow herds, serological results confirmed that the farms had remained negative for IAV-S.

The tests used to evaluate the IAV-S status of these farms varied over time. Initially, the serological tests available were inhibition hemagglutination (IHA) or enzyme-linked immunosorbent assay (ELISA) tests specifically targeting H1N1 or H3N2 strains. The practitioners responsible for supervision of the herds in Table 1 switched the test to an ELISA reported to cover all strains of influenza A virus (IDEXX AI Multi-Screen Ab Test; IDEXX) after it became available in Canada in 2011. The exception was farm A, for which H1N1 and H3N2 IHA tests were used during the whole period. As for identification of the organism or its genetic material, virus isolation was replaced by PCR tests when local laboratories began to offer them towards the end of the 2000s.

Table 1: Characteristics of some swine farms in Quebec, Canada that have remained IAV-S-negative for many years

Practitioner	Farm	Type of farm	# sows	Distance to pigs*	IAV-S-negative period
1	A	Farrow-to-finish	500	8 km	1990-2015
2	B	Farrow-to-wean	600	3 km	2005-2017
	C	Farrow-to-wean	600	6 km	2012-2020
	D	Farrow-to-wean	780	4 km	2012-2020
	E	Farrow-to-wean	1200	10 km	2014-2020
	F	Farrow-to-wean	2375	12 km	2016-2020
3	G	Farrow-to-wean	550	> 10 km	2016-2020
	H	Farrow-to-wean	550	> 10 km	2003-2020
	I	Farrow-to-wean	550	> 10 km	2003-2020
	J	Farrow-to-wean	600	> 10 km	2003-2020
	K	Farrow-to-wean	1100	5.4 km	2017-2020
	L	Farrow-to-wean	450	> 10 km	2016-2020
	M	Farrow-to-wean	550	> 10 km	2017-2020
	N	Farrow-to-wean	800	> 10 km	2015-2020

* Distance of the sow herd to the closest positive pigs or pigs of unknown IAV-S status as estimated by the practitioner.

Based on the experience of the individual farms reported in Table 1, it is possible to remain negative for IAV-S on a long-term basis. Remaining IAV-S negative has also been possible on a regional or country basis. Although no active surveillance program is used to prove absence of the virus, no cases of IAV-S have been diagnosed in herds on Prince Edward Island, Canada for several years (D. Hurnik, DVM, email, December 2019). However, it must be acknowledged that the province has fewer than 20 swine production sites and distance between farms is greater than what is observed in hog-dense areas. Norway does not have a large swine industry, but its 85,000 sows remained negative for IAV-S for 12 years (1997-2009).

Remaining negative to IAV-S is possible. While other possibilities for introduction, like transport vehicles, exist and may eventually be shown to be significant, three important ways the virus can be introduced into sow herds would appear to be infected gilts, aerial spread, and infected people. Controlling these sources of infection is feasible. For sow herds considering maintaining an IAV-S-negative status, the three main criteria to consider given the current knowledge are introduction of only non-infected gilts; locating these herds away from hog-dense areas or using efficient air filtration systems; and ensuring that personnel or visitor entrance policies reduce the risk of infected people entering the premises, understanding that subclinically infected people may introduce the virus.

Even if a herd is or becomes IAV-S positive, it should theoretically be easier to eliminate this virus in sow herds than it is to eliminate PRRSV. Pigs can remain carriers of the latter much longer than for IAV-S, so a shorter period of herd closure should be needed to eliminate IAV-S than would be needed for PRRSV elimination. Unlike PRRSV, IAV-S rarely crosses the placental barrier, so pigs do not usually become infected *in utero*. Van Reeth and Vincent[25] stated that IAV-S is unlikely to spread outside the respiratory tract. In a few studies, feces, intestines, or spleen occasionally tested positive by PCR, but virus-positive cells have reportedly not been demonstrated outside the respiratory tract.[25] If virus circulation can be stopped in farrowing, and if a herd closure is implemented, the two main sources of viral maintenance of IAV-S in sow herds would seemingly be addressed.

There are situations where the virus was eliminated from sow herds and from single site, farrow-to-finish operations without using any special strategies. In one such operation, the previously naïve herd became infected. It was closed to any introductions from the outside, but sows farrowing each week were producing piglets that were eventually susceptible to infection. Yet, the virus was eliminated from this single site, farrow-to-finish farm in that particular case and on two other occasions involving different IAV-S strains (R. Boutin, DVM, email, November 2019). This was done without vaccines or any significant changes in management. A similar situation was reported by Mueller and Theis[39] where another small, single site, farrow-to-finish operation that was previously negative became infected in November 2012. Viral circulation stopped in 2013 without any special interventions, and the farm has remained negative since then. In another study, elimination of both porcine respiratory coronavirus and IAV-S was achieved when two sow herds adopted a 4-week batch farrowing system, which allowed having no suckling piglets in the farrowing barn every month, and the use of an autogenous vaccine.[40] Thomson et al[41] were able to eliminate IAV-S in three 5000-sow herds using a program based on whole herd vaccination, herd closure, and partial depopulation. Torremorell et al[42] went from introducing gilts monthly or bimonthly to every four months and, coupled with a partial depopulation program, eliminated IAV-S from a 1200-sow three-site system. Finally, Lower[43,44] described a protocol to eliminate IAV-S from sow herds that included herd closure (12-16 weeks) and management strategies to prevent infection of piglets in farrowing barns. This protocol is reported to have produced good and repeatable results for 8 years.

While both theoretical and practical data suggest that eliminating IAV-S is easier than eliminating PRRSV, more information is needed before conclusions can be reached on the best ways to eliminate the virus, the success rates obtained, the time it takes, and the cost it incurs. Similarly, more data is needed to confirm and quantify the factors, other than location, that may allow some farms to remain negative on a long-term basis.

A last point to consider is the potential for IAV-S to become a significant issue in human health because of mutations or reassortments. Therefore, producing pigs that are not infected with this virus would seem to be a sensible objective not only for performance, but also for public health.

Implications

- Survival and transmission of IAV-S are not insurmountable obstacles.
- It is possible to maintain IAV-S-negative sow herds.
- More consideration should be put on the production of IAV-S-negative pigs.

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Conflicts of interest

None reported.

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* Non-refereed references.

Conversion tables

Weights and measures conversions

Common (US)	Metric	To convert	Multiply by
1 oz	28.35 g	oz to g	28.35
1 lb (16 oz)	0.45 kg	lb to kg	0.45
2.2 lb	1 kg	kg to lb	2.2
1 in	2.54 cm	in to cm	2.54
0.39 in	1 cm	cm to in	0.39
1 ft (12 in)	0.3 m	ft to m	0.3
3.28 ft	1 m	m to ft	3.28
1 mi	1.6 km	mi to km	1.6
0.62 mi	1 km	km to mi	0.62
1 in^2	6.45 cm^2	in^2 to cm^2	6.45
0.16 in^2	1 cm^2	cm^2 to in^2	0.16
1 ft^2	0.09 m^2	ft^2 to m^2	0.09
10.76 ft^2	1 m^2	m^2 to ft^2	10.8
1 ft^3	0.03 m^3	ft^3 to m^3	0.03
35.3 ft^3	1 m^3	m^3 to ft^3	35.3
1 gal (128 fl oz)	3.8 L	gal to L	3.8
0.26 gal	1 L	L to gal	0.26
1 qt (32 fl oz)	0.95 L	qt to L	0.95
1.06 qt	1 L	L to qt	1.06

Temperature equivalents (approx)

°F	°C
32	0
50	10.0
60	15.5
61	16.1
65	18.3
70	21.1
75	23.8
80	26.6
82	27.7
85	29.4
90	32.2
102	38.8
103	39.4
104	40.0
105	40.5
106	41.1
212	100.0

°F = (°C × 9/5) + 32
°C = (°F - 32) × 5/9

Conversion calculator available at: amamanualofstyle.com/page/si-conversion-calculator

Conversion chart, kg to lb (approx)

Pig size	Lb	Kg
Birth	3.3-4.4	1.5-2.0
Weaning	7.7	3.5
	11	5
	22	10
Nursery	33	15
	44	20
	55	25
	66	30
Grower	99	45
	110	50
	132	60
Finisher	198	90
	220	100
	231	105
	242	110
	253	115
Sow	300	136
	661	300
Boar	794	360
	800	363

1 tonne = 1000 kg
1 ppm = 0.0001% = 1 mg/kg = 1 g/tonne
1 ppm = 1 mg/L