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The risk of the introduction of classical swine fever virus at regional level in the European Union: a conceptual framework

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Summary

Recent classical swine fever (CSF) epidemics in the European Union (EU) have clearly shown that preventing the introduction of CSF virus (CSFV) deserves high priority. Insight into all the factors contributing to the risk of CSFV introduction is a prerequisite for deciding which preventive actions are cost-effective. The relations between virus introduction and spread, prevention and control, and economic losses have been described using the conceptual framework presented in this paper. A pathway diagram provides insight into all the pathways contributing to the likelihood of CSFV introduction (LVI_CSF) into regions of the EU. A qualitative assessment based on this pathway diagram shows that regions with high pig densities generally have a higher LVI_CSF, although this cannot be attributed to pig density only. The pathway diagram was also used to qualitatively assess the reduction in LVI_CSF achieved by restructuring the pig production sector. Especially integrated chains of industrialised pig farming reduce the LVI_CSF considerably, but are also difficult and costly to implement. Quantitative assessment of the LVI_CSF on the basis of the pathway diagram is needed to support the results of the qualitative assessments described.

Keywords

Classical swine fever – European Union – Pathway diagram – Prevention – Qualitative risk assessment – Risk – Virus introduction.

Introduction

Recent classical swine fever (CSF) epidemics in the European Union (EU) resulted in high economic losses. In 1993 and 1994, Germany and Belgium were severely affected by a CSF epidemic, with 217 farms infected in Germany (34, 44) and 55 in Belgium (33, 37, 58). Even more disastrous was the 1997/1998 CSF epidemic in the Netherlands, which affected 429 farms and led to the destruction of more than 10 million pigs for preventive and welfare reasons (3). The costs of this epidemic (i.e. direct costs and consequential losses to farms and related industries) were estimated at US$2.3 billion (39). The importation of infected piglets from the Netherlands also resulted in a major epidemic in Spain, with 99 farms being infected in 1997 and 1998 (22, 26).

The introduction of CSF is a continuing threat to the pig production sector of the EU. The disease is still present in some countries of central and eastern Europe (22). Moreover, CSF occurs in an endemic form in wild boar populations in some areas of Germany, France and Italy (35), representing a permanent CSF virus (CSFV) reservoir. Prevention of CSFV introduction should therefore be attributed the highest priority possible.

Most outbreaks in the major CSF epidemics mentioned above occurred in what are referred to as densely populated livestock areas (DPLAs), which have an average pig density of more than 300 pigs/km^2 (40). These areas developed due to economic factors, such as the availability of cheap feedstuff and reasonably priced land and the vicinity of urban markets (19, 30). The concentration of pig production in these areas is supposed to be correlated with the risk of introduction and spread of epidemic diseases (19). Pig and pig farm density are, however, not the only determinants in the risk of virus introduction. Insight into all factors contributing to the risk of virus introduction is a prerequisite for taking preventive actions that are both epidemiologically effective and economically sensible, and is therefore of utmost importance in supporting policy-making. The main aims of this paper were to present a conceptual framework for estimating the overall risk of CSFV introduction into regions within the EU and to explore opportunities to reduce this risk.

Risk of virus introduction is assessed at regional level because operating on a country-by-country basis to prevent disease introduction is no longer in accordance with official EU policy following the establishment of the free internal market in 1993 (2). In that year, veterinary controls at the borders between Member States were abolished, resulting in free movement of livestock and livestock products. In cases of occurrence of certain animal diseases, including CSF, the principle of regionalisation is applied, which consists of implementing disease control measures and restrictions to trade only in the area where the disease occurs (2, 22). The OIE (World organisation for animal health) also recommends this regionalisation principle for the prevention and control of contagious animal diseases (43). A further argument for the use of regions instead of countries for risk assessments lies in the important differences between regions of the EU, even within the same Member State, with regard to pig and pig farm densities and the structure of the pig industry (42).

The paper commences with an overview of definitions and transmission routes for CSFV. A conceptual framework for the risk of CSFV introduction is then presented. In the remainder of the paper, emphasis is placed on the likelihood of CSFV introduction (LVI_CSF). Results of a qualitative assessment of the LVI_CSF for several regions in the EU are presented, after which the possible reduction in the LVI_CSF by structural changes in the pig production sector is explored. The paper concludes with a discussion and prospects for future research.

Definitions

A brief overview of definitions is provided for key terms used throughout this paper in order to avoid possible confusion.

A generally accepted definition of risk is given by Ahl *et al.* as the likelihood and magnitude of the occurrence of an adverse event (1). Accordingly, risk of virus introduction takes into account the following:

– the likelihood that a virus be introduced into a region and

– the resulting epidemiological consequences and economic losses caused by the primary outbreak and subsequent spread of the disease (62).

Virus introduction is defined as the entrance of a virus into the livestock production sector of a region free of the disease, causing a primary outbreak. (This article focuses on CSFV introduction into the domestic pig population of a region. Virus introduction into the wild boar population has not been considered because the prevention and control strategies used are different [12], as are the economic consequences of such an introduction).

Virus spread is defined as dissemination of virus from one farm to another within the affected region, resulting in secondary outbreaks. The distinction between introduction and spread thus depends on the regional level used, i.e. dissemination of virus between provinces is referred to as spread at country level, but as introduction at the provincial level.

The regional level used in this study was determined by the definition of a primary outbreak derived from EU Council Directive 82/894/EEC: 'an outbreak not epizootiologically linked with a previous outbreak in the same region of a Member State, or the first outbreak in a different region of the same Member State' (13).

The regions referred to in the above definition are areas with a surface area of at least 2,000 km^2, controlled by competent authorities and comprising of at least one member state-dependent, administrative area, e.g. provinces in Belgium, Italy and Spain, counties in the United Kingdom and Ireland and departments in France (11). Based on the EU definition of a primary outbreak, further primary outbreaks can occur within one epidemic if virus is spread from one region to another. This was the case, for example, during the 1997/1998 CSF epidemic in the Netherlands, in which four primary outbreaks were recorded.

Both introduction and spread of virus occur by so-called transmission routes (TRs). These are the carriers and mechanisms which may lead to virus transmission from infected to susceptible animals. In this paper, TRs for virus introduction will be referred to as pathways and TRs for virus spread as spread mechanisms.

Transmission routes for classical swine fever virus

General overview

Table I presents an overview of the most important TRs for CSFV, based on published scientific literature.

The movement of pigs which are incubating the disease, or are persistently infected, is the most common mode of CSFV transmission (23, 54). Other important TRs are indirect spread of virus through transport vehicles and human contacts (23) and feeding swill which has not been properly heated (56). Classical swine fever virus can survive in pork and pork products beyond processing (10, 24). Survival can be prolonged for months if the meat is stored at a cool

Table I
Transmission routes for classical swine fever virus

Transmission route	References [(a)]	Importance for introduction	Importance for spread
Animal movements	15, 21, 23, 25, 27, 34, 54, 56	++	++
Transport vehicles	21, 23, 25, 27, 34, 56	+	++
Human contacts	21, 23, 25, 27, 34, 54, 56	+/–	++
Swill-feeding	15, 21, 22, 25, 27, 34, 54, 56, 59	++	+/–
Wild boar	15, 25, 34, 35, 36, 42, 54, 56	++	–
Air currents	18, 23, 54, 56	–	+/–
Rodents, birds, arthropods, pets	23, 27, 52, 53, 56	–	+/–
Manure	23, 53	–	+/–
Genetic material	16, 23	+/–	+

– : unimportant
+/–: might be important
\+ : important
++ : very important

a) A selection of references has been made. An extensive overview of references can be obtained from the corresponding author

temperature, or even years if stored frozen (54, 57). The presence of virus in infected wild boar also constitutes an important TR, either by direct or indirect contact, for example, through the food chain (42, 54).

Other TRs include airborne transmission through air currents (18, 52), mechanical transmission by arthropod vectors, birds, pet animals and rodents (23, 52), transmission by manure (23) and transmission by genetic material, i.e. artificial insemination (16, 23).

So-called neighbourhood infection has been ascribed an important role in the spread of CSFV, especially during recent CSF epidemics in the EU (23, 44, 49). Neighbourhood infection is considered to be the TR for those farms for which the origin of infection is unknown and which are situated in the immediate vicinity of another herd, infected at an earlier date. Neighbourhood infection is not a TR in itself, but refers to a number of possible TRs that account for virus spread over a short distance, including spread by human contacts, air currents, rodents and birds, all of which are included in Table I.

Indication of importance

Information from historical outbreaks was used to classify TRs according to their importance for introduction and spread (Table I). Only a qualitative classification can be provided, because the ultimate importance of a specific TR depends on the extent of presence (e.g. number of animal contacts) and its specific risk (e.g. probability of virus transmission per animal contact) and can therefore differ per region.

The major routes for CSFV introduction into regions of the EU since the prohibition of mass vaccination in 1992 include feeding improperly heated swill, direct or indirect contact with wild boar and animal movements (17, 25). These TRs were therefore considered of great importance in CSFV introduction. The most important TRs for virus spread during recent epidemics were animal movements, transport vehicles, human contacts and neighbourhood infections (23, 25, 34, 44, 60). These TRs were therefore considered as very important in CSFV spread.

The origin of disease was obtained from the Animal Disease Notification System (ADNS) of the EU for 28.2% of all primary CSF outbreaks (n = 206) and 35.0% of all secondary CSF outbreaks (n = 1,247) between January 1990 and April 1999 (Fig. 1). Although the classification of TRs used in the ADNS differs from that used in Table I, the main TRs responsible for the outbreaks in the ADNS correspond to a large extent to those derived from scientific literature. Most primary CSF outbreaks (about 85%) were caused by the purchase of animals, feeding waste food and spread by fomites (spread by fomites is all virus spread caused by objects contaminated with the disease agent and, hence, covers those indirect contacts between animals that are not included in other TRs distinguished by the ADNS [A. Laddomada, personal communication], including spread by wild boar [44]). More than 95% of all secondary outbreaks for which the origin of disease is provided by the ADNS were caused by neighbourhood contacts, purchase of animals or spread by fomites, humans and transport vehicles.

A conceptual framework for assessing the risk of classical swine fever virus introduction

Although the use of import risk analysis has increased significantly in recent years, most analyses focused only on a single pathway for virus introduction (9, 28, 51). However, comprehensive understanding of all the factors which contribute to the risk of virus introduction, including their interactions, is required to support epidemiologically and economically sound decisions concerning preventive actions. This is illustrated in Figure 2. Pathways determine the likelihood of virus introduction (LVI), whereas spread mechanisms determine the extent of virus spread. Long-term economic losses due to virus introduction in a region are determined by both the likelihood of introduction and the extent of virus spread. The presence of both pathways and spread mechanisms is, to a large extent, determined by the structure of the livestock production sector in a given region,

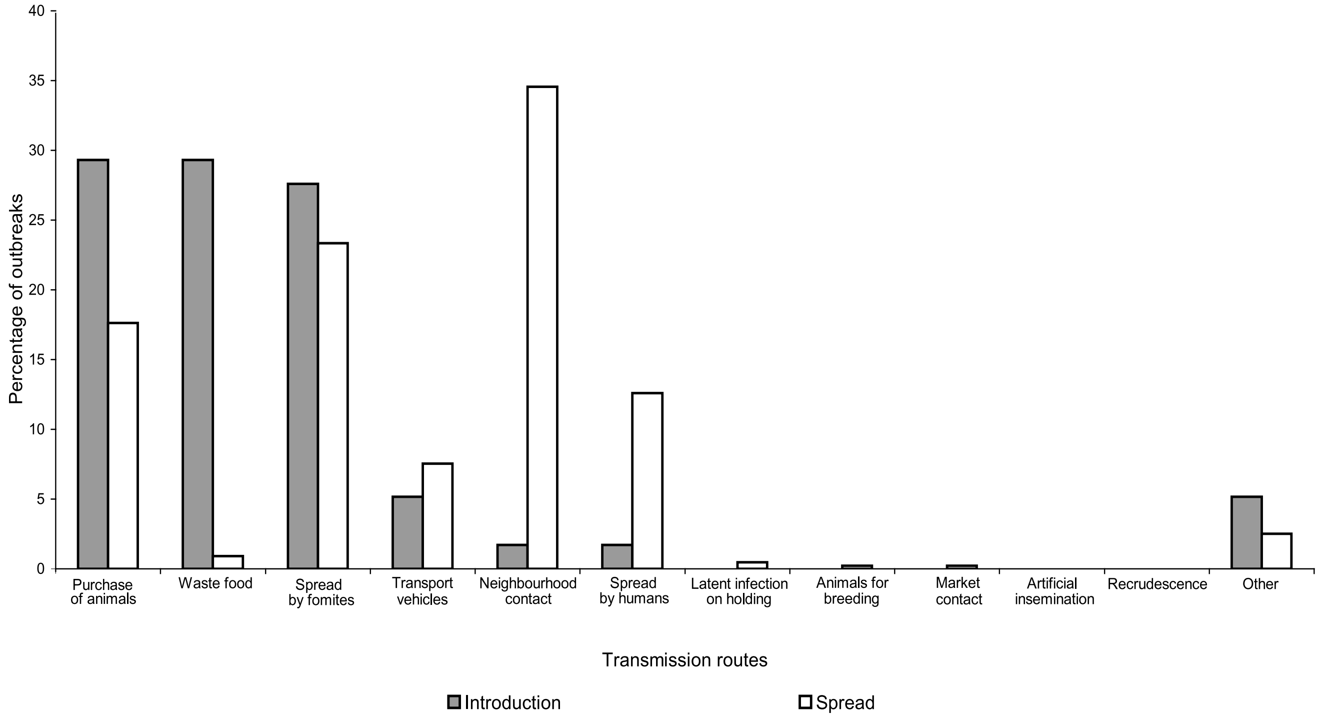


Fig. 1
Transmission routes responsible for classical swine fever outbreaks in the European Union between January 1990 and April 1999, for which the origin of disease is registered in the Animal Disease Notification System, i.e. about 34% of all outbreaks

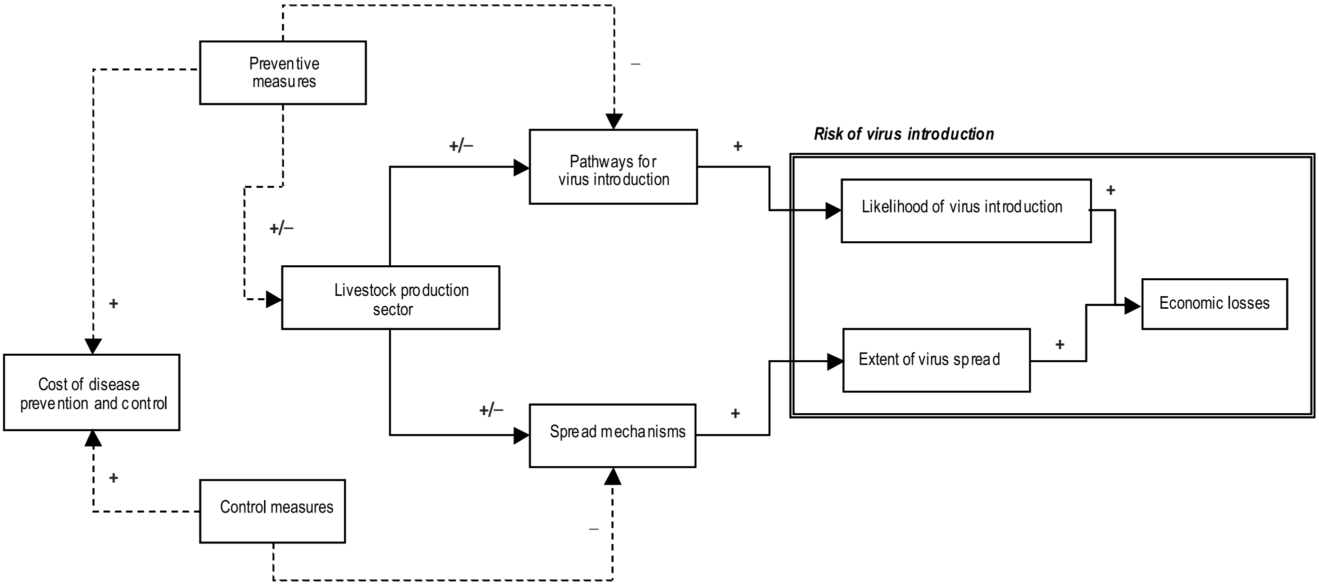
e.g. farm and animal densities, farm types (mixed or specialised, open or closed, extensive or intensive), and contact patterns. Preventive measures aim at reducing the LVI, whereas control measures are applied to decrease disease spread and eventually eradicate the virus. Both types of measures aim at reducing the economic losses of virus introduction, although their implementation also results in expenses. From an economic point of view, measures should only be taken if the reduction in economic losses outweighs the cost of disease prevention and control.

Preventive measures are usually taken to reduce the impact of pathways, e.g. by quarantine of imported animals. Most control measures aim at reducing the presence of spread mechanisms, e.g. by movement standstills and stamping-out of infected premises. These types of measures are of a technical character and can be implemented and lifted rapidly, thus providing ad-hoc solutions. An alternative approach to prevention is restructuring the livestock production sector of a region. This is an irreversible and often expensive process which impacts the risk of virus introduction in the long-term, not only changing the LVI, but also the opportunities for disease spread once the virus has been introduced. The Netherlands provides an example of how the livestock production sector can be restructured at regional level. In an attempt to solve two major problems of DPLAs, i.e. manure surpluses and contagious animal disease epidemics (19), the legislation aims at reducing total pig populations (4) and relocating the national pig production in clustered areas, separated by so-called pig-free corridors (5).

Pathway diagram to estimate the likelihood of classical swine fever virus introduction

To obtain more insight into the regional LVI_CSF in the EU, a pathway diagram was designed to show all the possible pathways for CSFV introduction, including their main events and inter-relations (Fig. 3). A pathway diagram uses a tree-like approach to provide insight into all the possible causes of an adverse event. For the adverse event to occur, all the events of a certain pathway have to take place. Estimating the probability of occurrence of the adverse event is made possible by adding probabilities to all the events in the diagram.

The pathway diagram comprises four levels. At the top of the diagram, the first level shows the pathways for virus introduction into a region, including both exogenous and endogenous pathways. Exogenous pathways are linked with virus sources outside the region where they might cause a primary outbreak, whereas endogenous pathways reside within the affected region. The pathways were derived from the TRs presented in Table I. Some TRs were, however, broken down into more specific sub-TRs to account for all the possible routes of virus introduction at regional level.



+ : positive connection (e.g. if more pathways for virus introduction are present, the likelihood of virus introduction will increase)
– : negative connection (e.g. if more preventive measures are installed, the [risk of] pathways for virus introduction will decrease)
+/– : unpredictable connection (e.g. a change in the livestock production sector might either increase or decrease the spread mechanisms present)

Fig. 2
The relation between the risk of virus introduction and preventive and control measures

A pathway can only contribute to the LVI if present. The extent of presence is expressed in pathway-units. These are the logical units in which a pathway is usually measured, e.g. an animal, one kilogram of animal product or a returning livestock truck. Exogenous pathways only constitute a risk if they originate from an area where the disease is prevalent, whereas endogenous pathways only pose a risk if they contain a virus reservoir. Some exogenous pathways only contribute to the LVI if they originate in a neighbouring area, e.g. air currents and birds, pets, arthropods and rodents. These pathways play a minor role in virus introduction because they only transport the virus over short distances.

At the second level, it is determined whether any infected or contaminated pathway-units are present. Only in such cases will a pathway contribute to the overall LVI.

The third level is used to evaluate whether preventive actions may detect and/or inactivate the virus. Only a selection of preventive measures is given in the diagram, but most additional measures that can be taken by a region, e.g. testing or quarantine, can be introduced at this level.

If the virus is still present after passing the third level, virus transfer to susceptible domestic animals can occur by two main routes, i.e. swill-feeding or direct or indirect contact with susceptible animals. Which route is relevant depends on the pathway for virus introduction. Virus transfer will only result in an outbreak if the virus conveyed constitutes an infective dose. There is, however, one exception to this general pattern, i.e. the legal or illegal importation of an infected live animal will always lead to an outbreak if the animal survives and infection is not detected sufficiently early. In such cases, swill-feeding or contact with susceptible animals is not needed to cause a primary outbreak since the imported animals become part of the livestock population.

For each pathway, the main events leading to a primary outbreak of CSF are shown in the pathway diagram. Theoretically, each event in the diagram can be assigned a probability that the event will occur. These are all conditional probabilities, i.e. the probability of occurrence of a certain event given that all previous events have occurred. For example, virus introduction by the pathway 'returning livestock trucks' will only occur if a livestock truck returns to the region after visiting an infected region, if this truck is contaminated with virus, if the truck is not disinfected properly, if the truck comes into contact with susceptible animals and if the virus dose conveyed is at least the minimum infective dose.

Interventions to reduce the likelihood of classical swine fever virus introduction

The pathway diagram can be used to explore opportunities for reducing the LVI_CSF for regions in the EU. Interventions can take place at all levels of the diagram, except the second one.

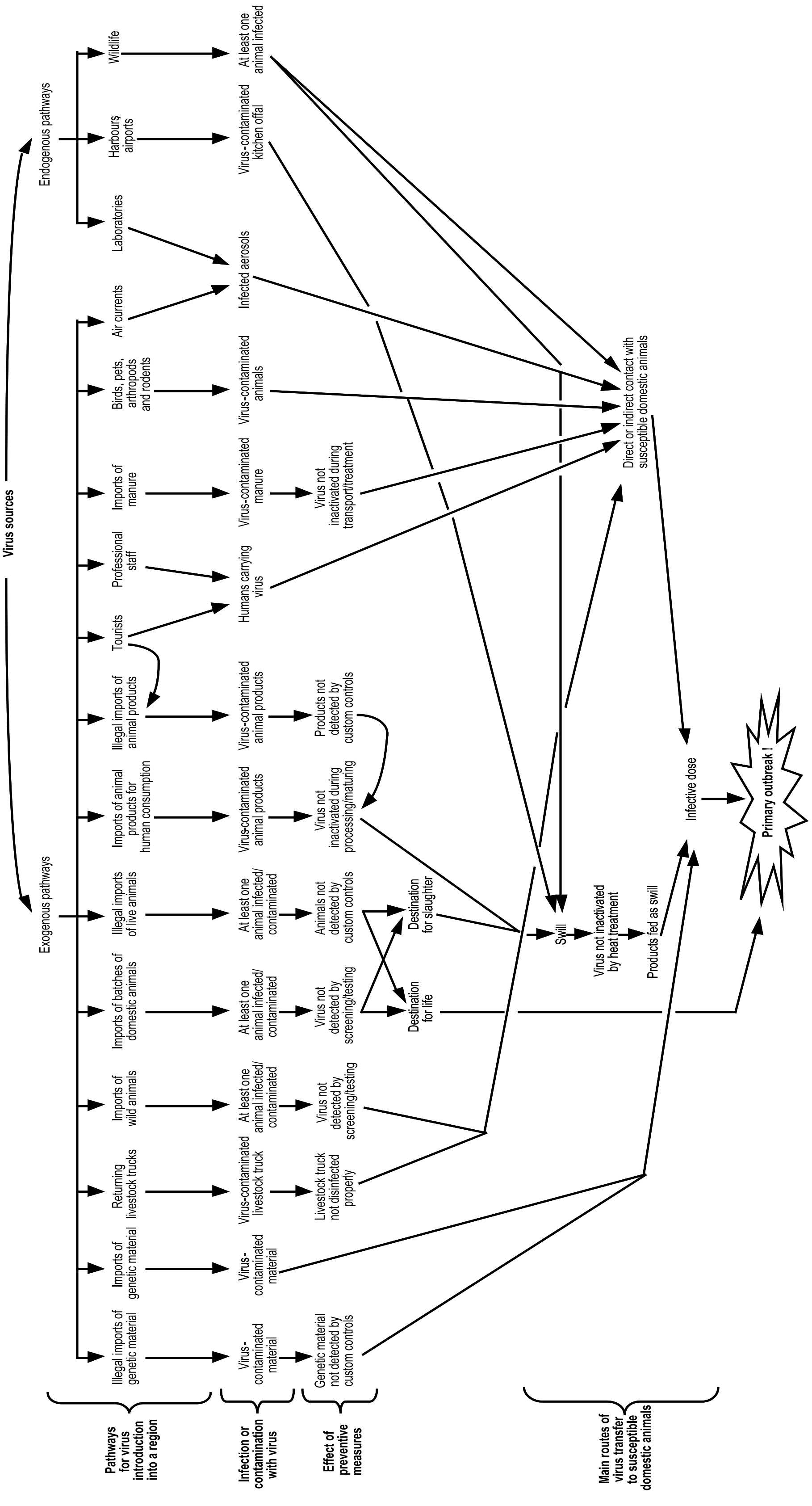


Fig. 3
Pathway diagram containing all the pathways that contribute to the likelihood of regional classical swine fever virus introduction in the European Union

Most preventive actions are taken at the third level and comprise testing procedures, cleansing and disinfection and the issuing of health certificates to guarantee freedom of disease. The presence of the virus can, however, never be ruled out for certain by these types of preventive actions, due to human errors, sampling procedures, sensitivity and specificity of tests, etc. Preventive measures can also be taken at the fourth level, e.g. by a ban on swill-feeding or by assuring adequate heat-treatment of swill. However, preventing all possible contacts of pathways with susceptible domestic animals is difficult, especially when considering people and air currents. This is particularly true for pigs kept in extensive production systems with outdoor facilities. If all domestic pigs were immune to CSF and thus no susceptible animals were present, contacts with infected pathway-units would have no consequences. A policy of mass vaccination aims at reducing the population of susceptible animals to a minimum, but cannot completely prevent the presence of susceptible animals, especially young piglets, and therefore leads to the risk of undetected infections.

Eliminating the presence of pathways, i.e. intervening at the first level of the pathway diagram, is the most effective way of preventing CSFV introduction under the current non-vaccination policy of the EU. This is usually done when pathways originate from areas where the disease is known to be prevalent. This, however, does not reduce the LVI_CSF to zero, since often the virus is present in a region for several weeks or even more than a month before the first outbreak is detected (23, 29, 48, 55). Furthermore, although some pathways may be eliminated or their numbers reduced by taking preventive actions, other pathways simply cannot be excluded (38). Air currents will always exist, tourism is impossible to forbid, laboratories are required for virological and serological tests and production of vaccines, and illegal activities cannot be excluded. Moreover, the implementation of a zero-risk policy for imports of live animals and animal products would impede international trade to a large extent and is no longer attainable under the current agreements of the World Trade Organization (WTO) (32, 45, 62). In addition, a zero-risk policy is often not recommendable when considering economic aspects. There is usually a trade-off between the risk of virus introduction, the costs of preventive actions and the benefits from, for example, importing live animals and genetic material.

Application of the pathway diagram

Application of the pathway diagram will be illustrated in this section with two realistic but very different examples, as follows:

– estimation of the LVI_CSF for certain regions in the EU and

– evaluation of the direction and magnitude of change in the LVI_CSF for a region following structural changes of the pig production sector.

Qualitative assessment of the likelihood of classical swine fever virus introduction

The pathway diagram of Figure 3 was used to qualitatively assess the LVI_CSF for five DPLAs and five sparsely populated livestock areas (SPLAs) in the EU. Information about the presence of pathways (level 1 of the pathway diagram) and the possibility that they could transmit virus to susceptible domestic pigs (level 4) was used to classify the regions according to their LVI_CSF.

Table IIa presents basic information available for each region. This information was used to calculate pig and farm densities and to derive an estimate of the number of pigs exported or imported by the region (Table IIb). Net piglet imports or exports were estimated on the basis of the fattening pig/sow ratio of the region, assuming that with a ratio of about 7.4, theoretically no net imports or exports of piglets are required (figures used: weaned piglets per sow per year: 22; replacement rate: 0.4; percentage mortality from weaning to slaughter: 4%; fattening period [20 kg to slaughter weight]: 130 days). Slaughter capacity in the region was used to estimate the net imports or exports of live fattening pigs. The estimates derived are the minimum numbers of pigs imported or exported. In most cases, these are an underestimate of the gross imports and exports.

Information on the number of pathway-units present was only available for net imports and exports of live animals, the latter indicating the number of returning livestock trucks into a region, and the endogenous pathways. Furthermore, information was available on pig and farm densities and swill-feeding, which are indicators of the probability that CSFV will affect susceptible domestic pigs once the virus has been introduced.

Table IIb indicates that regions with high pig densities have larger net imports or exports of pigs than regions with low pig densities. Südoldenburg (Germany), Mantova (Italy) and West-Flanders (Belgium) are major net importers of piglets, whereas South (the Netherlands) and the Côtes-d'Armor (France) are major net exporters. Südoldenburg has a net import of fattening pigs, whereas South, Mantova, West-Flanders and the Côtes-d'Armor show net exports of fattening pigs due to a shortage of slaughter capacity. Regions with high pig densities also have high pig farm densities, except for Mantova, with pigs concentrated on large intensive farms. The number of airports with regular flights is highest for the Côtes-d'Armor which has four. The number of laboratories working with CSFV is highest in Hannover (Germany), which has three, including the EU Reference Laboratory for CSF. The number of wild boar is highest in the Orne (France), with an estimated population of 5,500 animals. No CSF infections in wild boar have, however, been detected in recent years in the regions listed in Table IIa (35). Swill-feeding is forbidden in all but the German regions. In Germany, the practice is still permitted, but only after

Table IIa
Basic information [a] on five densely and five sparsely populated livestock areas in the European Union used for the qualitative assessment of the likelihood of classical swine fever virus introduction

Variables	The Netherlands		Germany		Italy		Belgium		France	
	South	South-West	Süd-oldenburg	Hannover	Mantova	Rovigo	West-Flanders	Namur	Côtes-d'Armor	Orne
	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA
Surface area (km^2)	7,050	4,544	2,230	2,290	2,339	1,922	3,293	4,418	6,878	6,103
Number of sows (×10^3)	777	26	85	12	47	5	349	3	189	8
Number of fattening pigs (×10^3)	4,095	198	1,395	67	625	41	2,747	27	1,168	53
Total number of pigs (×10^3)	8,754	336	1,636	105	797	55	4,413	43	2,200	90
Total number of pig farms	7,688	957	3,400	695	1,101	1,364	5,376	261	7,381	1,170
Annual number of pigs slaughtered (×10^3)	7,225	600	4,676	178	1,352	208	4,639	5	2,598	21
Number of airports with regular flights	2	1	0	1	0	0	2	0	4	1
Number of laboratories working with classical swine fever virus	0	0	0	3	0	0	0	0	2	0
Estimated number of wild boar	136	0	120	>1,170 [b]	0	0	0	1,250	700	5,500
Estimated number of infected wild boar	0	0	0	0	0	0	0	0	0	0
Swill-feeding allowed?	No	No	Yes	Yes	No	No	No	No	No	No

DPLA : densely populated livestock area
SPLA : sparsely populated livestock area

a) Information was derived from the database described by Michel and De Vos (40) and from research groups participating in the EU Research Project FAIR5-PL97-3566 (8)
b) No estimate of the wild boar population was available. In the period between 1 April 1999 and 31 March 2000, 1,170 wild boar were killed

Table IIb
Calculated and estimated data for five densely and five sparsely populated livestock areas in the European Union used for the qualitative assessment of the likelihood of classical swine fever virus introduction

Variables	The Netherlands		Germany		Italy		Belgium		France	
	South	South-West	Süd-oldenburg	Hannover	Mantova	Rovigo	West-Flanders	Namur	Côtes-d'Armor	Orne
	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA
Pig density (pigs/km^2)	1,242	74	733	46	341	29	1,340	10	320	15
Pig farm density (farms/km^2)	1.09	0.21	1.52	0.30	0.47	0.78	1.63	0.06	1.07	0.19
Fattening pig/sow ratio	5.27	7.69	16.39	5.55	13.38	8.58	7.88	8.00	6.19	6.51
Net number of imported piglets per year [a] (×10^3)	–1,622	9	769	–22	281	6	182	2	–220	–7
Net number of imported fattening pigs per year [a] (×10^3)	–4,272	45	758	–11	–402	94	–3,075	–71	–681	–129

a) A negative net number of imported animals signifies a net number of exported animals
DPLA : densely populated livestock area
SPLA : sparsely populated livestock area

adequate heat-treatment. Therefore, if all regulations were observed, none of the regions of Table IIa would suffer from primary CSF outbreaks caused by swill-feeding.

Eight criteria listed in the left column of Table III were used to classify the regions as having a low, moderate or high LVI_CSF. If a region meets none or only one of these criteria, it is considered as having a low LVI_CSF. If a region meets two or three of these criteria, the LVI_CSF is considered moderate, and if a region meets four or more criteria, the LVI_CSF is considered as high. On the basis of these criteria, the LVI_CSF for the regions South, Südoldenburg, Hannover, West-Flanders, and Côtes-d'Armor was classified as high. The LVI_CSF for South-West (the Netherlands), Mantova and the Orne was considered as moderate, whereas the LVI_CSF for the remaining regions – the SPLAs of Italy and Belgium – was considered as low (Table III).

Table III
Classification of five densely and five sparsely populated livestock areas for their likelihood of classical swine fever virus introduction, using eight criteria (left column)

Classification criteria	The Netherlands		Germany		Italy		Belgium		France	
	South	South-West	Süd-oldenburg	Hannover	Mantova	Rovigo	West-Flanders	Namur	Côtes-d'Armor	Orne
	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA	DPLA	SPLA
Net number of piglets imported > 1×10^5 per year	–	–	+	–	+	–	+	–	–	–
Net number of pigs exported > 5×10^5 per year	+	–	–	–	–	–	+	–	+	–
Airports with regular flights present	+	+	–	+	–	–	+	–	+	+
Laboratories working with classical swine fever virus present	–	–	–	+	–	–	–	–	+	–
Wild boar present	+	–	+	+	–	–	–	+	+	+
Pig density > 50 pigs/km^2	+	+	+	–	+	–	+	–	+	–
Pig farm density > 1 farm/km^2	+	–	+	–	–	–	+	–	+	–
Swill-feeding allowed	–	–	+	+	–	–	–	–	–	–
Expected likelihood of classical swine fever virus introduction	High	Moderate	High	High	Moderate	Low	High	Low	High	Moderate

DPLA : densely populated livestock area
SPLA : sparsely populated livestock area
– : no
\+ : yes

The impact of structural changes in the pig production sector on the likelihood of classical swine fever virus introduction

Parts of Dutch legislation to restructure pig production (4, 5) and ideas of explorative studies on the prospects for future pig production in the Netherlands (6) were used to elaborate three scenarios for structural changes in the pig production sector at regional level. These scenarios, their main aims and expected consequences, are described in Table IV. The pathway diagram was used to qualitatively evaluate the effects of the scenarios on the LVI_CSF, assuming that current risk management at farm level will not be changed by the different scenarios.

Table IV
Three scenarios for structural changes in the pig production sector at regional level in the Netherlands

	Scenario 1	Scenario 2	Scenario 3
Name	Reduced pig population	Clustered areas with pig-free corridors	Integrated chains of industrialised pig farming
Description	Pig population of each farmer reduced by 20%. Pig production rights for remaining 80%. Extending a farm only possible after buying production rights from other farmers	Clustered areas of pig production separated by pig-free corridors of at least 1,000 m in width. Differentiated levies for stamping-out fund used to finance control of epidemic disease outbreaks: the fewer farms with which pigs are exchanged, the lower the levy a farmer has to pay	Pig production in large industrialised farms located in 'industrial parks', together with supplying and processing industries, thus providing a well-closed production system
Main aim	Reduce environmental problems of intensive pig farming industry	Reduce risk of contagious animal diseases in densely populated livestock areas	Reduce risk of contagious animal diseases
Expected consequences (in comparison to current situation)	Reduced pig numbers and thus less manure production. Reduced pig farm density because small pig farmers and farmers for whom pig production is of secondary importance will discontinue production	Equal pig density. Reduced pig farm density because small pig farmers in corridors who are forced to move will discontinue production. Fewer pig farm contacts	Well-closed pig production systems that are concentrated in small areas with extremely high pig densities
References	4	4, 5	6

The scenarios in Table IV do not directly affect the pathways of illegal imports, imports of wild animals, imports of animal products for human consumption, tourists, laboratories, harbours and airports and wildlife. For the other pathways, the direction and magnitude of expected change in the LVI_CSF compared to the current situation are given in Table V.

Table V
Expected impact [(a)] of three scenarios [(b)] for structural changes in the pig production sector on the likelihood of classical swine fever virus introduction

Pathway	Scenario 1	Scenario 2	Scenario 3
Imports of genetic material	0/+	0	++
Returning livestock trucks	++	+	+
Imports of batches of domestic animals	++	+	+++
Professional staff	0	0	++
Imports of manure	0	0	0
Birds, pets, arthropods and rodents	+	+++	+++
Air currents	+	+++	+++

0 : no change
+ : slight reduction
++ : considerable reduction
+++ : major reduction, almost reducing the likelihood to zero

a) Changes in the likelihood of classical swine fever virus introduction in comparison to the current situation

b) Scenarios:
1 : reduced pig population
2 : clustered areas with pig-free corridors
3 : integrated chains of industrialised pig farming

In scenario 1, the pig population is reduced and hence the number of pig transports. Moreover, the LVI_CSF by pathways that disseminate virus over short distances might be somewhat decreased because of reduced pig farm density. In scenario 2, the LVI_CSF over short distances is reduced due to pig-free corridors. Furthermore, farmers will try to minimise the number of contact pig farms because of the differentiated levies for the stamping-out fund. This will result in a reduced number of pig transports. Movement of pigs over long distances is, however, not reduced by this scenario. In scenario 3, the transport of pigs and genetic material is no longer necessary. Between-chain contacts with professional people can be largely avoided since the extensive industrial pig farms contain all the stages of the livestock production chain and thus have most expertise at their disposal. Virus transmission over short distances will also be decreased since these industrial farms are located at a minimum distance of 3,000 m from one another (6).

All the scenarios are expected to reduce the LVI_CSF. Although reducing the LVI_CSF was not the primary aim of scenario 1, this scenario seems comparable with scenario 2 in terms of reducing the LVI_CSF. The latter scenario would reach this goal more effectively if discounts on the levy for the stamping-out fund were only granted if contact pig farms were located in the same cluster. This would eventually lead to more closed clusters and therefore higher reductions in the LVI_CSF by pig transports. Scenario 3 reduces the LVI_CSF most, but is difficult to implement. Changing pig production from family-based farming to an industrial activity implies high costs and requires significant turnover in the general perception of pig farming, as well as high adaptability of the primary and secondary industries involved.

Structural changes in the pig production sector will not only affect the LVI_CSF, but also the possible spread of virus once introduced and hence, the economic consequences of virus introduction (Fig. 2). The latter aspects should also be taken into account when evaluating the three scenarios for their impact on the risk of CSFV introduction. Although scenario 3 reduces the LVI_CSF most, it might result in major economic losses once the virus has been introduced. Only a comprehensive quantitative risk analysis will provide insight into which set of structural changes most reduces the risk of CSFV introduction.

Discussion and conclusions

Regional approach

The establishment of the free internal market in 1993 led to the abolishing of veterinary border checks between Member States. Controls on animal movements now mainly occur at the place of dispatch, but can also be carried out at the place of destination if deemed necessary. The conceptual framework described in this paper therefore aimed at exploring the risk of regional CSFV introduction in the EU.

The regions used for controlling CSF epidemics are usually based on the installed control and surveillance zones around infected premises. Using such regions is, however, impossible for the prevention of CSFV introduction. The authors therefore decided to employ the administrative regions used by the EU systems to prevent disease introduction and spread, such as the ADNS. A major advantage of these regions is that they are under the control of local veterinary authorities. A disadvantage is that styles of pig production are not definitely homogenous when referring to administratively defined regions. However, the smaller the regions considered, the more homogenous pig production will be.

The regional approach for disease prevention seems to function relatively well as long as no threats of nearby epidemic diseases exist. However, as soon as, for example, CSF or foot and mouth disease (FMD) outbreaks occur in the EU, Member States take preventive measures at national level and revert to national border controls. Nevertheless, exploring the risk of CSFV introduction at regional level is a valuable exercise as this approach provides more insight into which regions are most at risk. Up until the present, the most densely populated regions such as the south-eastern part of the Netherlands, Flanders in Belgium, Lower-Saxony in Germany, and Brittany in France have been considered to be 'problem areas' (19), not least because some of the most recent CSF epidemics occurred in these regions. However, pig density is not the only determinant for the risk of CSFV introduction. This risk is also assumed to be markedly higher in areas where CSFV circulates in the wild boar population. As an example, the majority (80%) of all primary outbreaks in the period between 1993 and 1997 in Germany were in areas at risk from wild boar fever (7).

Conceptual framework

Insight into all the factors contributing to the risk of CSFV introduction is required to decide which preventive actions are cost-effective, i.e. achieve considerable risk reduction at reasonable costs. Preventive actions should therefore not only be evaluated for their potential to reduce the LVI_CSF, but also for their impact on spread and economic losses once the virus has been introduced. The pathway diagram presented in Figure 3 was found to be helpful in qualitatively assessing the LVI_CSF for regions in the EU. Additional tools, such as simulation models as described by Saatkamp *et al.* (47) and Jalvingh *et al.* (31) and the economic model described by Meuwissen *et al.* (39), are required to evaluate subsequent spread and economic consequences.

The elaboration of a pathway diagram provides further insight into all possible pathways and events contributing to the occurrence of an adverse event. This process should therefore be recommended as part of hazard identification, which is the first step in risk analysis (61). The more pathways involved, the more complex the diagram becomes. For this reason, only the main events leading to the occurrence of a primary CSF outbreak were involved in the pathway diagram shown in Figure 3. Scenario trees can be used to describe each pathway in more detail (14, 41, 46, 50).

The pathway diagram in Figure 3 was especially designed for CSFV introduction into regions of the EU under a non-vaccination policy. The diagram might also be applicable to other highly contagious viral pig diseases such as FMD, African swine fever and swine vesicular disease. If used for other parts of the world or other diseases, the diagram should be carefully examined for redundant or missing pathways or events.

Application of the pathway diagram

The pathway diagram was used to qualitatively assess the LVI_CSF for DPLAs and SPLAs in the EU. This qualitative assessment showed that DPLAs generally had a higher LVI_CSF than SPLAs, although this could not be attributed to pig density only. The results should be interpreted with care as for some of the pathways in the diagram, no information was available. Furthermore, the contribution of pathways to the overall LVI_CSF will differ, but to what extent is unknown. Some pathways play a more important role in introducing CSFV to a region than others (Table I). The criteria of Table III were, however, given equal weight in the qualitative assessment. The relative contribution of the pathways also differs per region as a function of the number of pathway-units present, the region of origin of the pathway-units and their use. Horst *et al.* obtained expert estimates of the relative importance of pathways for CSFV introduction (29). These were, however, specifically for CSFV introduction into the Netherlands and could therefore not be used for different European regions. Quantitative information on the presence of pathways and their main events is therefore required for a more adequate estimation of the LVI_CSF for regions in the EU.

The pathway diagram was also used to explore the impact of preventive actions on the LVI_CSF. Three scenarios of structural changes in the pig production sector were evaluated. These scenarios mainly reduced the number of pig transports and dissemination of virus over short distances. The scenario of integrated chains of industrialised pig farming reduced the LVI_CSF most effectively. However, more information is required to decide on preventive actions. The reductions in the LVI_CSF achieved by the scenarios should be quantitatively assessed and the impact of the scenarios on virus spread and economic losses once the virus has been introduced should also be taken into account. Furthermore, the financial and social costs of implementing the scenarios need to be determined, as does the possible impact of the scenarios on the risk attitude of farmers, i.e. risk management at farm level.

The scenarios for structural changes in the pig production sector were derived from legislation in the Netherlands and explorative studies on the prospects for intensive pig production in the Netherlands by the end of 1999. Scenarios considering more extensive pig production as a starting point were not taken into account in this qualitative assessment. Recent crises in the livestock production sector of the EU, caused by, among others, FMD and bovine spongiform encephalopathy, have strengthened the call for more organic farming. Although this will result in lower pig and pig farm densities and less long-distance pig transports, organic farming also implies new risks of contracting contagious diseases due to, for example, outdoor pig keeping.

Quantitative estimates of the likelihood of classical swine fever virus introduction

Quantitative assessment of the LVI_CSF requires obtaining information for all the events distinguished in the pathway diagram, as the overall LVI is the sum of all the probabilities for the individual pathways. Databases can be used to obtain exact figures or estimates for the number of pathway-units entering a region. The number of animals imported or exported can, for example, be derived from national identification and recording systems and the European animal movement system. For most pathways, however, information at regional level is not readily available and will have to be derived from national statistics or expert opinion. Obtaining estimates for the probabilities expressed at levels 2, 3 and 4 of the pathway diagram is difficult, all the more so since they might differ per region. Some probabilities might be derived from past outbreaks, experiments or scientific literature. This information is, however, scarce and might already be outdated due to rapid changes in, for example, trade patterns and control strategies. Expert opinion is therefore an important source of information for most probabilities. Sensitivity analysis should indicate the possible impact of missing and uncertain data and therefore help to set priorities for further (empirical) research (20).

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■

Cadre théorique pour l'évaluation du risque d'introduction de la peste porcine classique dans une région de l'Union européenne

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Résumé

L'apparition récente de foyers de peste porcine classique dans l'Union européenne (UE) a clairement souligné le caractère prioritaire des mesures destinées à prévenir l'introduction du virus responsable de la maladie. Or, le choix d'actions préventives et rentables ne pourra intervenir qu'à l'issue d'une étude approfondie de tous les facteurs contribuant au risque d'introduction. Le cadre théorique présenté dans cet article a permis d'analyser le rapport qui existe entre l'introduction et la propagation du virus, la prévention et la prophylaxie, et les pertes économiques. Le diagramme de flux donne un aperçu de l'ensemble des paramètres qui influencent la probabilité d'introduction de la peste porcine classique (LVI_CSF) dans les régions de l'UE. Une évaluation qualitative réalisée à partir de ce diagramme de flux a montré que les zones à forte densité de population porcine se caractérisaient aussi par une LVI_CSF plus élevée, même si cette dernière ne dépendait pas uniquement de la densité porcine. Par ailleurs, le diagramme de flux a également permis d'évaluer la baisse qualitative de la LVI_CSF observée après la restructuration de la filière porcine. Les chaînes intégrées spéciales de production industrielle des porcs entraînent une réduction significative de la LVI_CSF ; toutefois, leur mise en place s'avère difficile et onéreuse. Les résultats des évaluations qualitatives décrites dans l'article devront être confirmés par une évaluation quantitative de la LVI_CSF au moyen du diagramme de flux.

Mots-clés

Analyse qualitative des risques – Diagramme de flux – Introduction du virus – Peste porcine classique – Prévention – Risque – Union européenne.

■

Matriz teórica para estudiar el riesgo de penetración a escala regional del virus de la peste porcina clásica en la Unión Europea

C.J. de Vos, H.W. Saatkamp, R.B.M. Huirne & A.A. Dijkhuizen

Resumen

Las recientes epidemias de peste porcina clásica (PPC) en la Unión Europea (UE) han dejado patente que el objetivo de prevenir la penetración del virus de esa enfermedad merece atención prioritaria. Conocer y comprender todos los factores que aumentan el riesgo de penetración de ese virus es un requisito previo para determinar las medidas preventivas que resultan rentables. Utilizando los principios teóricos expuestos en este artículo, los autores han descrito los vínculos existentes entre la penetración del virus, su propagación, prevención y control y las pérdidas económicas que ocasiona. Por medio de un árbol de hipótesis se determinaron todas las posibles situaciones que influyen en la probabilidad de penetración del virus de la PPC (LVI_CSF) en determinadas zonas de la UE. A partir de ahí se llevó a cabo una evaluación cualitativa, de la cual se desprende que dicha probabilidad es mayor en las regiones con elevada densidad de población porcina, aunque éste no sea el único factor que entra en juego. El árbol de hipótesis sirvió también para evaluar cualitativamente la reducción de la probabilidad de penetración que acompaña la reestructuración del sector de producción porcina. Aunque la existencia de cadenas de producción industrial especialmente integradas reduce sensiblemente esa probabilidad, la implantación de ese tipo de procesos industriales resulta complicada y onerosa. Para corroborar los resultados de la evaluación cualitativa aquí descritos es preciso determinar cuantitativamente la probabilidad de penetración del virus a partir del árbol de hipótesis.

Palabras clave

Árbol de hipótesis – Evaluación cualitativa del riesgo – Penetración de virus – Peste porcina clásica – Prevención – Riesgo – Unión Europea.

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