Factors associated with the introduction of classical swine fever virus into pig herds in the central area of the 1997/98 epidemic in the Netherlands

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A matched case-control study of 135 infected and 99 uninfected pig herds from the central area of the 1997 to 1998 epidemic of classical swine fever (CSF) in The Netherlands was undertaken to identify factors associated with the introduction of the virus. The herds were matched on the basis of herd type and the shortest geographical distance between pairs of herds. Data on management, hygienic measures, experiences during the depopulation of an infected nearest neighbour, and the frequency of contact with professionals and other agencies were collected by means of a questionnaire taken by personal interview. There were no significant differences between the infected and uninfected herds in the median total number of contacts per year with professionals and other agencies either with or without contact with the pigs. On the basis of a multivariable analysis, five variables were found to be significantly associated with an increased risk of infection: (1) the presence of commercial poultry on the premises; (2) visitors entering the pig units without wearing an overcoat or overalls and boots supplied by the farm; (3) the driver of the lorry transporting pigs for the Pig Welfare Disposal Scheme (PWDS) using his own boots instead of boots supplied by the farm; (4) herds of moderate size (500 to 1000 animals) and very large herds (>7000 animals) were at greater risk than small herds (<500 animals); and (5) an aerosol, produced during high-pressure cleaning of the electrocution equipment used to kill the pigs on a neighbouring infected herd less than 250 m away was carried by the wind on to the premises. Two variables were significantly associated with a decreased risk of CSFV-infection: (1) more than 30 years of experience in pig farming; and (2) additional cleaning of the lorries used to transport pigs for the PWDS before they were allowed on to the premises. In the opinion of the cooperating farmers, airborne transmission of the virus and its transmission during the depopulation of an infected neighbour were among the most important routes of infection.

AFTER classical swine fever (CSF) had been absent from the Netherlands for five years and from the region concerned for 10 years, a pig farm in the municipality of Venhorst in the southern part of the Netherlands was diagnosed to be infected on February 4, 1997. The herd was located in an area with one of the highest densities of pigs and pig herds in Europe. It is most likely that the CSF virus (CSFV) was introduced into the area by a returning pig transport lorry (Elbers and others 1999). A total of 429 outbreaks were observed during the epidemic, mainly in the southern part of the Netherlands, and all the pigs (approximately 625,000) from the infected herds were slaughtered (Fig 1).

During the eradication campaign attempts were made to establish how the virus had been introduced into the infected herds. The tracing focused on pigs, visitors, transport vehicles, artificial insemination, manure and the pick-up service of the rendering plant as potential routes of transmission (Elbers and others 1999). However, in approximately 50 per cent of the outbreaks none of these possible routes of transmission was incriminated, an observation similar to that in other epidemics of CSF in Europe (Wachendörfer and others 1978, Vannier and others 1986, Terpstra 1987, Miry and others 1991, Pittler and others 1996, Vanthemsche 1996). Herds with an unknown source of infection are usually subdivided into herds within 1 km of a previously infected herd and herds at a greater distance. The former are designated as neighbourhood infections and the latter as infections with an unknown origin (Terpstra 1987). In the 1997 to 1998 epidemic in the Netherlands, 39 per cent of the outbreaks were classified as neighbourhood infections and 11 per cent as unknown. The fact that herds close to an infected herd have a higher risk of becoming infected than herds at a greater distance was observed during the 1930s in the Netherlands (Robijns 1971), and it has continued to be of importance ever since (Wachendörfer and others 1978, Kramer and others 1995, Koenen and others 1996, Staubach and others 1997, Stegeman and others 2000). These neighbourhood infections may be caused by contacts which are known to be able to transmit the virus but have not been reported to the veterinary authorities. However, they may also be caused by types of contact that are not known to be able to transmit the virus. However, apart from a suggestion that airborne spread may play a role (Laevens 1998, Mintiens and others 2000), no routes for these neighbourhood infections have been identified.

The epidemic spread extensively in the central area around the primary outbreak (Fig 2), but there were many herds in the area that did not become infected. Unknown routes of infection or unreported contacts may have been responsible for these differences, and variations in the use of hygienic measures that affect the ability of the virus to establish the infection may also have been important. The purpose of this study was to find out whether interherd contacts and herd hygienic factors which were not investigated by the veterinary authorities might have been associated with the introduction of CSFV. The findings may lead to new hypotheses concerning the transmission and prevention of CSF.

Veterinary Record (2001) **149,** 377-382

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MATERIALS AND METHODS

Study population

The study population consisted of herds in an area of 339 km^2 around the primary outbreak. At the start of the epidemic there were 972 pig herds in the area; 49·7 per cent of them were finishing or replacement stock herds, and the rest were breeding herds and farrow-to-finish herds. A total of 233

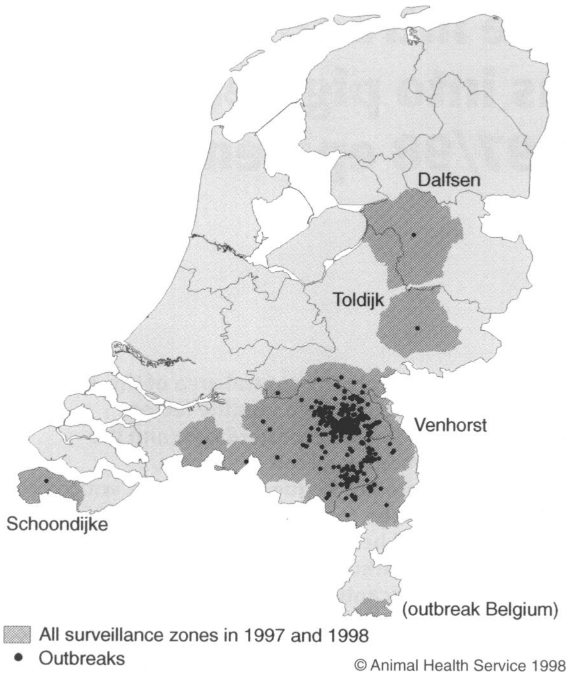

FIG 1: Surveillance zones and outbreaks of the 1997/98 classical swine fever epidemic in the Netherlands

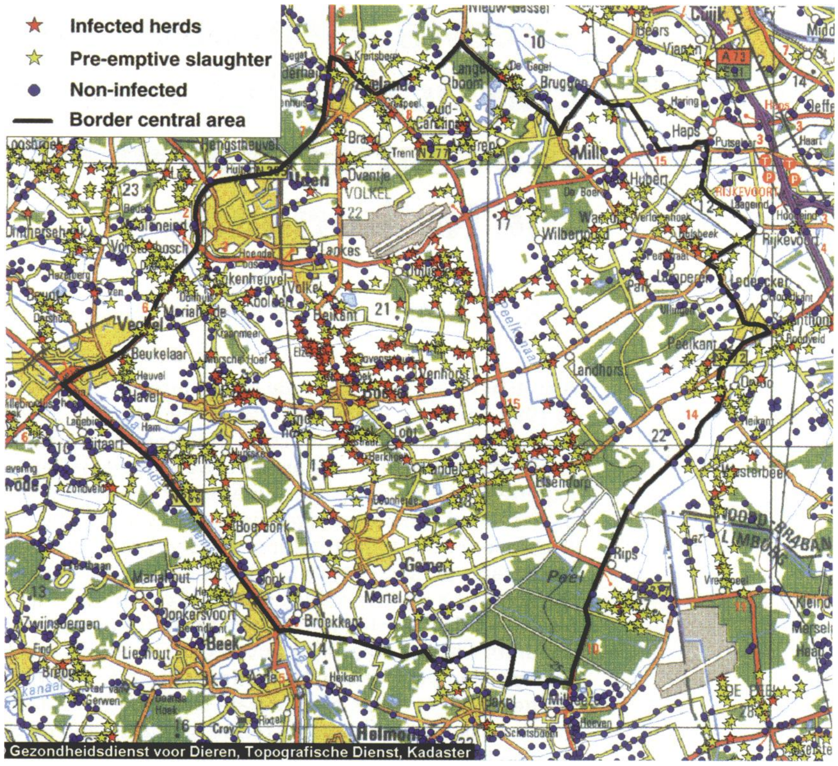

FIG 2: Central area of the 1997/98 classical swine fever epidemic in the Netherlands with infected and non-infected pig herds and pre-emptively slaughtered pig herds around infected herds

herds became infected, 63 (27 per cent) of which had no sows. Since this investigation was focused on the introduction of CSFV by alternative routes of infection and the effect of hygienic measures, the following types of infected herds were excluded: (1) herds infected by animal contact; (2) herds possibly infected by contaminated semen from an infected boar station; (3) herds infected before the detection of the primary outbreak; and (4) the two infected boar stations in the area. A total of 196 of the infected pig herds met the inclusion criteria, and 52 (26·5 per cent) of them had no sows. However, 61 (31 per cent) of these herds refused to participate in the investigation. Of the remaining 135 herds, 29 (21·5 per cent) had no sows, a distribution not significantly different from the herds that met the inclusion criteria. Of the 131 uninfected herds that were asked to participate in the investigation, 32 refused to cooperate.

Study design

Infected herds (cases) were matched with uninfected herds (controls) in clusters on the basis of the herd type (with or without sows) and their being within a radius of 2 km. Since there were 36 fewer control herds than case herds, 1:1 matching was not possible. Sixty clusters of cases and controls were established with an average of four herds per cluster (minimum two herds, maximum 10 herds).

Questionnaire

Information on farm management and the attitudes of the farmers to hygiene was collected by means of a questionnaire. In addition, the farmers' opinions with respect to the possible reasons for the infection or lack of infection of their herd and of their neighbours' herds was recorded by personal interview. The questionnaire was based on expert opinions and its layout and the way in which the questions were asked was supported by a professional marketing research agency (MarketResponse). The questionnaire was initially tested on four pig farmers and their families, and then evaluated and revised. The farmers were interviewed by qualified staff, who received special training in interviewing and taking questionnaires.

The questionnaire took about one to one-and-a-half hours to fill in, and the farmers were compensated for their time by an allowance of 75 Dutch guilders. It consisted of questions on general demography (age, family, experience in pig farming, etc), the herd (herd size, other species, entrance to the premises, use of hygienic precautions, etc). The numbers of times per week/month/year (recalculated to numbers of times per year) that persons or agencies contacted the herd for professional reasons were recorded, and subdivided into when they contacted the premises (but not the pig units), and when they had contact with the pig units (either with or without contact with the pigs), in the period before and after the detection of the primary outbreak on February 4, 1997. Separate records were kept for the following persons or agencies: colleagues with pigs; neighbours, family and friends; playmates of children; pig, sheep, cattle, or poultry trader; forage trader; milkman; people buying fruit and vegetables at the farm; greengrocer; baker's man; oil and/or liquid gas supplier; lorry bringing frozen snacks; representative of farmers' association; dairy herd improvement agency service; breeding company consultant; agricultural extension service; representative of slaughterhouse organisation; veterinary practitioner; veterinary consultant national animal health service; environmental control technician; feed-mill consultant; vermin control consultant; gas and electricity fitter; contractor; manure/slurry transporter; pig and cattle artificial insemination technician; sow scanner; broiler catchers; poultry, cattle, sheep, dairy tanker; rendering pick-up service; journalists; excursions; agricultural trainee; (temporary) farm help; Agricultural Inspection Service; National Inspection Service for Livestock and Meat; screening and tracing teams of the CSF-eradication campaign.

Questions were asked about attitudes to hygiene and measures taken after the detection of the primary outbreak in the area, and about the attitudes towards the collection of carcases by the rendering service. Questions were also asked about

TABLE 1: Reasons given by the owners of 61 infected herds and 32 uninfected herds for refusing to contribute to the study

Reasons for refusal	Infected herds (% of owners)	Uninfected herds (% of owners)
Too busy with other duties	38	53
The subject of the study recalls too many emotions	16	16
Reasons for infection should be known by now	14	3
Ownership of herd has changed	9	6
More than one location was infected, but only one interview allowed	7	3
Allowance to cooperate in the study is inadequate	7	0
Great discontent with the organisation of the eradication campaign	5	19
Pig farmer does not want to allow visitors to the herd	3	0
Owner refuses to allow anyone to speak with the person who works with the pigs	2	0

contacts with the veterinary practitioner, the artificial insemination service, the pest control service, the slurry transport service, the sow scanning service and mechanics. Additional questions were asked about the presence on the farm and the behaviour of dogs, cats, birds, and rodents such as rats and mice.

Statistical analysis

The frequency of contact by different professional persons and agencies per year was not normally distributed, and the differences in the median total contact frequency between the infected and uninfected herds were, therefore, tested with the non-parametric Kruskal-Wallis test.

The questionnaire data were analysed by using a generalised linear model (PROC GENMOD; SAS 1993). To account for the 'matched design' of the investigation, clusters of matched pig herds were entered into the model as a fixed effect. The response (infected or uninfected) was modelled by using a binomial probability distribution and the fixed and random components of the model were linked with a logit-link function. The response was also modelled as an infection rate, in which case the response was scaled by the 'population of pigs at risk per unit time'.

By using this scaling process, the herds became more comparable, because the level and duration of exposure was quantified. The scaling factor was calculated by accumulating the average number of pigs present in a herd each week since January 1, 1997, the presumed date of introduction of CSFV into the Netherlands, until the estimated date of infection of the herd. For the uninfected herds this period ended at the date of pre-emptive slaughter, or complete buy-out of the herd in the case of finishing-pig herds, and for herds with sows that continued to produce piglets, in the summer of 1997, when the last infected herd in the data set was detected. The infection rate was modelled by using a Poisson probability distribution and a log-link function (PROC GENMOD; SAS 1993). Because modelling the infection rate produced virtually the same significant risk factors as modelling the response, the results of modelling the infection rate are not presented separately. The linearity of the regression estimates for the continuous variables was checked graphically. When there was a lack of linearity, continuous variables were categorised. The first step in the statistical analysis involved screening all the single explanatory variables in a bivariate regression model. Variables with a $P<0 \cdot 20$ were considered for further analysis if there was a biologically plausible association between the variable and the response. In the second step, a backward step-wise selection of variables in a cluster of biologically related variables, for example, variables concerning the hygienic measures taken by the farmer, was applied in a multivariate model. In the final step, variables that turned up during the second step were put together in a multivariate model and, by a backward selection process, variables were selected until a model remained with variables with a $P \leq 0 \cdot 05$. The strength of an association was measured in terms of odds ratios (OR). An OR significantly smaller than 1·0 indicates that the factor reduces the probability of the event, whereas an OR significantly greater than 1·0 indicates that the factor increases the probability of the event. In using the multivariate model, the OR for a specific risk factor has been adjusted for the other factors in the model. An OR was considered to be statistically significant if 1·0 did not fall within the 95 per cent confidence interval (CI) of the OR.

Complete separation – that is, a factor which was present only in the infected group and not in the uninfected group, or vice versa – occurred during the modelling (Hosmer and Lemeshow 1989). In this case, the factor does not fit into the model, although there can be a biologically meaningful association between the factor and the response. The factors responsible for complete separation during the modelling are presented separately.

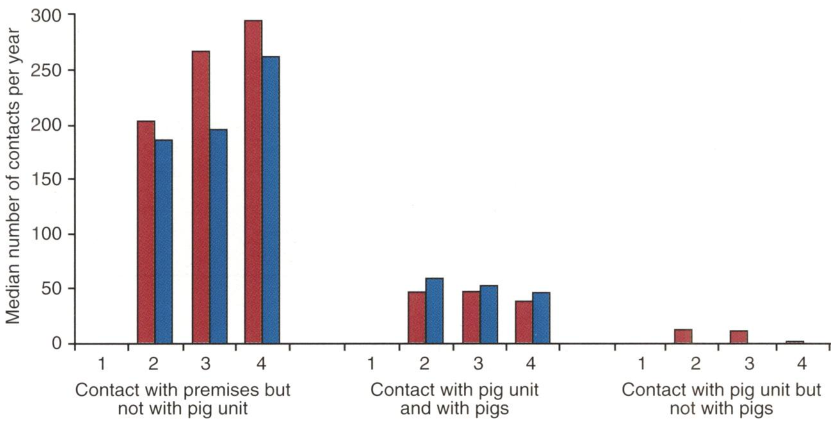

FIG 3: Median numbers of self-reported contacts of different types per year in the period before (red columns) and after (blue columns) the detection of the primary outbreak of classical swine fever recorded in 58 finishing herds of different sizes (1: <500 pigs, 2: 500-1000 pigs, 3: 1000-7000 pigs; 4: >7000 pigs)

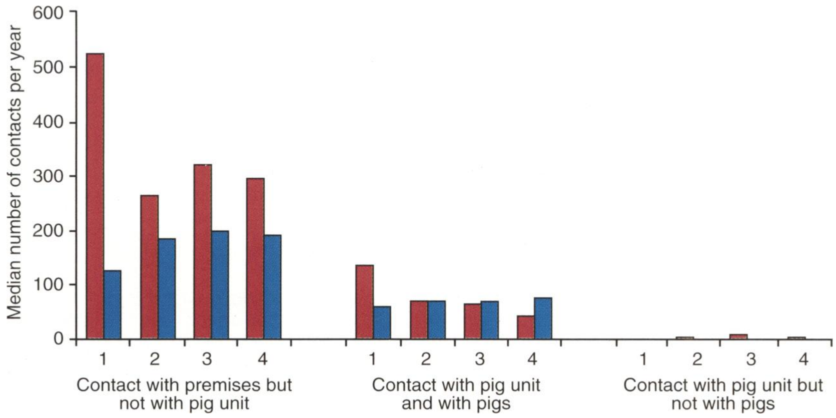

FIG 4: Median numbers of self-reported contacts of different types per year in the period before (red columns) and after (blue columns) the detection of the primary outbreak of classical swine fever in 176 sow herds of different sizes (1: <500 pigs, 2: 500-1000 pigs, 3: 1000-7000 pigs; 4: >7000 pigs)

RESULTS

General

The reasons for farmers' refusal to cooperate with the study indicate that there were no big differences between the cases and the controls (Table 1), except for 'having no time' and 'having trouble with the organisation of the eradication campaign'.

Self-reported contact frequency

There were no significant differences between the infected and uninfected herds in the median total numbers of contacts by professional persons and agencies per year either with the premises (but not in the pig units), or with the pig units (either with or without contact with the pigs), in the period before and after the detection of the primary outbreak on February 4, 1997. The median total number of contacts with the premises and with the pig units without having contact with the pigs inside was significantly higher ($P<0·001$) in the period before than after the detection of the primary outbreak (Figs 3, 4). In contrast, there was a slight tendency for the median total number of contacts with the pig units and with the pigs inside to be larger in the period after than before the detection of the primary outbreak. In general, there was no positive relationship between the herd size and the median total number of contacts, and only in the case of pig-finishing farms was an increase in mean herd size related to an increase in the median total number of contact with the premises.

Factors associated with risk of infection

A frequency distribution of the factors associated univariately with the response ($P<0·10$) is given in Table 2. The relationships needed to be biologically plausible with respect to the interpretation of risk awareness or risk-seeking. It gives a first impression of the potential associations between the factors and the response. There were no associations between the presence (or increased presence after depopulation of an infected neighbouring herd) of birds (sparrows, crows and birds of prey), cats, rats or mice around the premises and an increased risk of infection. In the final model seven factors remained ($P\leq0·05$), five of which were associated with an increased risk of infection (Table 3):

(1) The presence of commercial poultry in addition to pigs;
(2) Visitors could enter the pig units without wearing an overcoat or overalls and boots supplied by the farm;
(3) The driver of the lorry transporting pigs for the Pig Welfare Disposal Scheme (PWDS) used his own boots instead of boots supplied by the farm;
(4) The herd was of moderate (500 to 1000 animals) or very large size (>7000 animals) rather than small (<500 animals) or large (1000 to 7000 animals) size;
(5) An aerosol produced during the high-pressure cleaning of the electrocution equipment used to depopulate a neighbouring infected herd within 250 m was carried by the wind on to the premises.

Two factors were significantly associated with a decreased risk of infection:

(1) The farmer had more than 30 years of experience in pig farming;
(2) The lorry used to transport pigs for the PWDS was cleaned by the farmer outside the farmyard before it was allowed to enter.

As an example of the strength of the association between a factor and the response, pig herds whose farmers had less than 30 years of experience in pig farming were 33 times more likely to become infected than herds whose farmers had more than 30 years of experience.

Three factors associated with an increased risk of infection could not be included in the model because the infected and uninfected groups were separated completely by the covariate:

(1) The lorry carrying portable electrocution equipment which had been used to depopulate an infected neighbour turned into the farmyard in order to be able to drive in another direction, owing to its lack of manoeuvarbility on small country roads;
(2) The container in which carcases of small to medium size pigs were disposed, was carried into the farmyard after it

TABLE 2: Unvariable associations with P 0·1 between factors on 135 infected herds and 99 uninfected herds present after the official detection of the primary outbreak on February 4, 1997 and infection with classical swine fever virus

Factors	Infected herds (%)	Uninfected herds (%)
Commercial poultry present in addition to pigs	5·9	2·0
More than 30 years of experience in pig farming	4·4	18·2
Visitors have to give notice of their presence (ring) at the residence of the pig farmer in order to reach the pig units	72·7	60·7
Overcoat or overalls and boots are always supplied to visitors before entrance is allowed to the pig units	88·9	93·9
Disinfection mats were in place at the entrance for cars and lorries to drive over	23·7	38·4
The farmer's dog can walk freely on and outside the premises	60·7	47·5
Someone from outside helps with household cleaning	17·0	9·1
The above person has pigs at their own home	0·7	0
Neighbouring pig farmer helps to carry carcases of heavy finishers or sows to the pick-up location at the entrance of the farmyard to be picked up by the lorry from the rendering plant	5·9	1·0
The lorry from the rendering plant has contact with the farmyard	19·3	13·1
The container in which carcases of small to medium size pigs were disposed of was transported by the farmer into the farmyard after the rendering service had emptied it	1·5	0
The lorry used to transport pigs for the Pig Welfare Disposal Scheme (PWDS) is cleaned by the farmer before it is allowed to enter the farmyard	54·1	63·6
The driver of the lorry used for the PWDS used his own boots instead of boots supplied by the farm	14·8	4·0
Veterinary practitioner used overcoat or overalls supplied by the farm when entering the pig units	94·1	98·0
Veterinary practitioner used boots supplied by the farm when entering the pig units	95·6	98·0
Vermin control service enters the pig units	21·5	11·1
The vermin control service went directly from the pig units to their car to pick up additional equipment without using the hygiene lock	2·2	0
An aerosol produced during high pressure cleaning of the electrocution equipment used to depopulate an infected herd within 250 m was carried by the wind on to the farmyard	11·1	3·0
The lorry carrying portable electrocution equipment used to depopulate an infected neighbour turned into the farmyard in order to drive in another direction	0·7	0
Herd size – <500 animals	36·3	49·5
– 500-1000 animals	42·2	21·2
– 1000-7000 animals	19·3	28·3
– >7000 animals	2·2	1·0
Lorries from the rendering plant, used to transport pigs killed by electrocution during the depopulation of an infected neighbouring herd, turned into the farmyard in order to drive in another direction	3·0	1·0

TABLE 3: Multivariable associations with P 0·05 between potential risk factors present after the official detection of the primary outbreak on February 4, 1997 and infection with classical swine fever virus

Risk factors		OR	95% CI
Commercial poultry present in addition to pigs	Yes	24·8	2·5-80·7
	No	1*	
Experience in pig farming	≤30 years	33·4	6·2-178·3
	>30 years	1*	
Overcoats or overalls and boots always supplied to visitors before they are allowed to enter the pig units	Yes	1*	
	No	34·9	1·4-861·1
Lorry used to transport pigs for the Pig Welfare Disposal Scheme (PWDS) is cleaned by the farmer before it is allowed to enter the farmyard	Yes	1*	
	No	5·9	2·3-15·1
Driver of the lorry used to transport pigs for the PWDS used his own boots instead of boots supplied by the farm	Yes	8·1	1·8-37·1
	No	1*	
Herd size (sows + finishers + replacement stock)	<500	1*	
	500-1000	6·6	2·5-17·7
	1000-7000	0·7	0·3-1·2
	>7000	397·5	1·1-15x10^4
An aerosol produced during high-pressure cleaning of the electrocution equipment used to depopulate an infected herd within 250 m was carried by the wind on to the premises	Yes	39·1	5·2-294·2
	No	1*	

* Reference category
OR Odds ratio, CI Confidence interval

TABLE 4: Farmers' opinions of the most important routes of infection with classical swine fever (CSF) virus, derived from 135 infected herds and 99 uninfected herds

Presumption of most important route of infection with CSF virus	Farmer's own infected herd (%)	Importance of Infected herd on infection of a neighbour's herd (%)	Uninfected herd on infection of a neighbour's herd (%)
CSF-eradication organisation	22·2	6·7	9·1
Airborne transmission	21·5	20·7	13·1
Depopulation of infected herd within 1 km	17·8	13·3	12·1
Unknown	10·4	39·3	38·4
Transport lorry of market support system	10·4	3·7	4·0
Pick-up service of rendering plant	6·7	5·9	10·1
Contaminated semen of boar stations	3·7	1·5	0
Open effluent lagoon of infected neighbouring herd	1·5	0	0
Supply of infected pigs	0·7	0	2·0
Transport lorry of feed supplier	0·7	0	1·0
Pig trader	0·7	0	0
Birds	0·7	2·2	0
Sow scanner	0·7	0·7	0
Lorries transporting carcases of pigs from depopulated infected herds driving close by	0·7	0·7	1·0
Neighbourhood infection	0·7	2·2	2·0
Farmer transmitted infection from one site of his own herd to another	0·7	0	0
Rats and/or mice	0	0·7	1·0
Dogs and/or cats	0	0	2·0
Too many contacts with outside world	0	0	2·0
Slurry/manure transporter	0	0	1·0
Inseminator	0	1·5	0

had been emptied by the pick-up service of the rendering plant;

(3) An outside helper with household cleaning had pigs at their own home.

There was no indication of a lack of fit of the model (Pearson residuals were between 2·2 and –2·3).

Perception of farmers concerning routes of transmission

In the opinion of the farmers, the three most important reasons why their herds had been infected were, first, the introduction of the virus by the governmental eradication organisation, secondly, airborne transmission, and thirdly, the transmission of infectious material to the herd during the depopulation of a neighbouring infected herd (Table 4). The majority of farmers had no clear view of any specific routes of infection of their neighbour's farm but, again, airborne transmission and the depopulation of an infected neighbour were suggested as possible routes.

TABLE 5: Farmers' opinions of the most important methods for preventing the introduction of classical swine fever virus (CSFV), derived from 135 infected herds and 99 uninfected herds

Presumption of most important method for preventing the introduction of CSFV	Farmer's own uninfected herd (%)	Importance of Infected herd on a neighbour's uninfected herd (%)	Uninfected herd on a neighbour's uninfected herd (%)
Unknown	30·3	71·1	55·6
Additional hygienic measures after detection of primary outbreak	21·2	2·2	9·1
Minimisation of personal contacts from outside the herd	18·2	2·2	8·1
Closed farm management system	9·1	4·5	5·1
No infected herd in close vicinity	8·1	1·5	3·0
Rapid depopulation of herd by welfare slaughter	7·1	14·8	11·1
Observing rigorous hygienic measures	5·1	3·7	5·1
Conscious choice of less contact with lorry from rendering plant	1·0	0	0

The majority of farmers had no clear view about the best methods for preventing the introduction of the infection into either their own or their neighbour's herd (Table 5). However, additional hygienic measures, observing all hygienic measures rigorously, and minimising personal contacts from outside the farm were among the measures most commonly suggested.

DISCUSSION

The number of contacts between an infected herd and uninfected herds, the infectivity of these contacts, and the susceptibility of the target herds determine whether CSFV will spread from a primary outbreak to other herds. The current policies of the European Union (EU) discourage vaccination – apart from emergency vaccination – against CSFV (EU Directive 80/217) and as a result it is not possible to decrease the susceptibility of pigs. The total stand-still and the general sanitary measures introduced during a CSFV eradication campaign aim to minimise both the number of potentially infectious contacts and the infectivity of these contacts. The results of this study show that there was a small decrease in the number of contacts with the premises and with the pig unit (but without contacting the pigs) after the detection of the primary outbreak. However, the results also indicate that there was no difference, and even a tendency for a slight increase, in the median number of contacts with the pigs in the pig units between the period before and after the detection of the primary outbreak. This increase was due to the visits by screening and tracing teams. In general, the self-reported frequency of contacts with pigs in the pig units in the period before the detection of the first outbreak was comparable with the results of a study in areas with a high density of pigs in the southern part of the Netherlands (van der Gaag and other 1998).

The fact that there was no difference in the frequency of contacts between the infected and uninfected herds in the present study suggests that differences in the infectivity of the contacts, influenced by hygienic measures, may help to explain why certain herds did not become infected in an area where the epidemic spread extensively.

The results suggest that aspects of hygiene associated with welfare slaughter, for example, the use of boots by the lorry driver and additional cleaning of the lorry before it entered the premises, may have been involved in the introduction of CSFV into the pig herd. The use of electrocution equipment on the premises of neighbouring herds, and the possible transmission of the virus by an aerosol produced when it was cleaned with high pressure hoses may also have been a factor. There was also evidence of a lack of hygienic awareness by the pig farmers; for example, the need to equip visitors with clothes and boots, and lack of care with the container used to dispose of the carcases. A striking factor was the 'protective value' of many years of experience in pig farming. Pig farmers with more than 30 years experience were working in the 1960s and 70s when hundreds to thousands of outbreaks of CSF were common in the Netherlands (Robijns 1971). Those experiences may have increased their awareness of how to prevent the virus being introduced by infectious contacts.

The results provide no evidence of any new important routes of infection. There were no associations between the presence (or increased presence after the depopulation of an infected neighbouring herd) of birds, like sparrows, crows and birds of prey, cats, dogs, rats or mice around the premises and an increased risk of infection with CSFV. These possible routes have been discussed (Westergaard 1996), but there is very little scientific evidence for them.

In the opinion of the farmers, airborne transmission was among the most important modes of transmission, but there are few data supporting the hypothesis. The airborne transmission of CSFV has been demonstrated experimentally over a short distance and with a forced air stream (Hughes and Gustafson 1960, Terpstra 1987) but it is considered to play only a minor role in the transmission of the virus, and only between mechanically ventilated pig barns less than 10 m apart. Laevens (1998) and Mintiens and others (2000) found evidence of airborne transmission by analysing data from the epidemic in East Flanders (Belgium) in 1994: the more frequently a neighbouring herd was downwind of an infected herd, the more likely it was to become infected. Owing to the design of this study, matching the herds on distance, it was not possible to investigate this hypothesis. Clearly, it needs further research, and data from the 1997 to 1998 epidemic has been used to investigate it (Crauwels and others 2000).

The results of this epidemiological study should be interpreted carefully. It is a retrospective study, in which farmers' memories of specific situations and circumstances have played an important role, and the recollections of the farmers with infected and uninfected herds may be substantially different. However, since both groups were deeply involved and affected by the epidemic, recall bias is unlikely to have been a serious problem. However, it is possible that personal and material contacts by the infected herds may not have been reported, either on purpose or by accident, which could have introduced a bias. Furthermore, 'socially acceptable' answers may have been given when respondents were asked about their behaviour and attitudes, and a bias could have been introduced which resulted in potential risk factors not being detected.

Preventing the introduction of pathogens into a pig herd is a continual challenge for pig producers and veterinarians. Biosecurity protocols that deal systematically with the risks of the introduction of contagious agents and with possible preventive measures will need to be introduced and complied with (Amas and Clark 1999). Greater hygienic awareness and compliance to a high level of biosecurity, not only by the eradication organisation but also by pig farmers, were recommended by the evaluation report of the Ministry of Agriculture, Nature Management and Fisheries (1998). These recommendations are included in the newly written CSF contingency plans.

ACKNOWLEDGEMENTS

The authors would like to thank the pig farmers without whom this study could not have taken place. Several agencies and people contributed to the discussion on the nature and content of the questionnaire: MarketResponse (Market Research and Information, Amersfoort, The Netherlands), and in alphabetical order Drs J. Bakker, A. Bouma, T. Duinhof, H. M. Ekker, M. Frantzen, M. Hamans, W. Heling, R. Herbes, W. A. Hunneman, N. de Jong, C. J. Kuiper, J. Lambers, C. Mensink, H. Moser, M. Nielen, S. Scheer, A. J. de Smit, C. Terpstra, B. Thien, R. Voets, P. W. v/d Wolf, L. Züchner, and the veterinary students L. van Oyen and R. Sweys. W. Buist (ID-Lelystad) prepared the data-set for modelling the infection rate, and Dr B. Engel (ID-Lelystad) provided helpful consultancy on the statistical modelling. The authors also thank the Tophographical Service of the Land Registry Office and the Animal Health Service for use of the coordinates of farm locations. The study was funded by the Netherlands' Ministry of Agriculture, Nature Management and Fisheries.

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Factors associated with the introduction of classical swine fever virus into pig herds in the central area of the 1997/98 epidemic in the Netherlands

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Veterinary Record 2001 149: 377-382
doi: 10.1136/vr.149.13.377