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Simulated detection of syndromic classical swine fever on a Finnish pig-breeding farm

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SUMMARY

Although Finland has not experienced a classical swine fever (CSF) epidemic since 1917, the concern about early detection is relevant. The time until detection of CSF on a pig-breeding farm was predicted by simulation, and earlier detection of CSF-infected farms was assessed. Eight to 12 weeks will pass before CSF is detected on a Finnish pig-breeding farm, which resembles detection of the index farm for actual CSF epidemics in Europe. Although notification of suspected CSF on the infected farm accelerates detection the most, interventions aimed at promoting investigations of the general health problem noticed on the farm, or a more comprehensive testing of samples currently arriving from pig farms to the investigating laboratory could shorten detection time by 3 weeks. Results are applicable for further simulation of an event of a CSF epidemic in Finland, and for studying contingency options to promote more rapid detection of infectious diseases of swine not found at present in the country.

INTRODUCTION

During the last decade, a few countries in the European Union (EU) have experienced an outbreak of classical swine fever (CSF) preceded by an official disease-free period. In these cases, detection of the index outbreak took place several weeks after introduction of the virus to the first pig-production farm in the country [1–4]. Early detection of disease outbreak accelerates the commencement of the emergency response, the official preventive and disposal measures of disease, and thus, minimizes the spread of disease and related economic consequences [5, 6].

Several different courses of events can be identified which lead to detection of CSF. Some of these routes, such as surveillance or monitoring schemes, have been designed by the officials specifically for the detection of CSF. In addition, other detection routes identified in several epidemics can lead to first detection [1, 2]. As observed in these real cases, to detect the index case of an outbreak, many repeated actions on the farm and at the investigating laboratory were taken before a definite diagnosis of infection was made. It is of note that none of the detections occurred as a direct notification of suspected CSF based on observed clinical signs at the farm.

Clinical signs of CSF may become evident only 2–4 weeks after the introduction of virus to the farm. It is only in adult breeding pigs or pigs with mild strains of virus that clinical signs may become evident at a later date [7]. Apart from virus characteristics, immunity status and age of the infected host animal, other diseases and prevailing housing conditions affect manifestation of clinical signs on infected farms [8, 9]. The typical acute signs of CSF are anorexia, lethargy, fever, skin haemorrhages, constipation followed by diarrhoea, respiratory and neurological signs, or sudden death of pigs [7, 8], however, the signs

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can be vague. Affected pigs shed virus from the onset of clinical signs until death and antibodies against CSF are detectable 2 weeks after infection [10, 11]. Although virulence of the strains causing clinical signs is difficult to define, CSF is said to have appeared with moderate to low clinical signs during the epidemics in Belgium in 1993–1994, The Netherlands in 1997–1998, and the United Kingdom in 2000 [7]. Characteristic of these epidemics was the abundance of symptoms considered atypical for CSF [1, 2, 12]. Older pigs, particularly sows, showed only mild signs of disease, e.g. slight fever and temporary loss of appetite. There are several applicable laboratory methods available for CSF diagnosis: virus isolation (VI) in cell cultures, PCR techniques to detect segments of virus genome from blood or tissue, the immunofluorescence test to detect viral antigen from cryosections of organs, the virus neutralization test to determine virus neutralization activity of sampled serum, and the ELISA test to detect viral antigen from serum and suspensions of organs [13].

Finland is officially free of CSF, with no cases reported since 1917 [14]. Epizootics in central Europe have increased awareness of the disease and concern about its early detection in Finland. One investigating laboratory, the National Veterinary and Food Research Institute (EELA), analyses practically all samples of swine origin in Finland. EELA serves as the national reference laboratory for CSF diagnosis. Current surveillance of CSF in Finland consists mainly of the obligation to inform officials of suspected CSF infection. Recognition of pathological gross lesions or clinical signs of CSF infection on a farm or at slaughter can lead to direct suspicion of CSF [15, 16], or induce general investigations that indirectly lead to a CSF diagnosis. Furthermore, two surveillance systems are being implemented on a regular basis in the country. Within the voluntary health classification scheme most farms (74%) are routinely visited by a veterinarian every 13 weeks; the visit includes a general clinical inspection [17]. In addition, an active serological monitoring scheme, confined to a restricted population of breeding animals is currently operating in Finland [18]. In this paper, we wish to evaluate the likely effectiveness of the surveillance systems by determining the time of detection with a simulation model.

Several models have been used to simulate the course of a CSF epidemic [6, 19, 20]; however, none of these have simulated the course or time of identifying the infected farms in a country that has not experienced true cases. A mathematical modelling approach has previously been applied to evaluate the cost-effectiveness of several different detection routes [21], or to evaluate sensitivity and specificity of clinical diagnosis on an infected farm [22]. The objective here was, by using a modelling approach, to simulate CSF detection, at the farm level, under the prevailing conditions in Finland. Our specific aims were to assess the expected time elapsing until CSF would be detected on a Finnish pig-breeding farm, and from a preparedness point of view to point out ways to promote earlier detection of CSF on infected farms in Finland.

MATERIALS AND METHODS

Modelling objectives

A stochastic Monte Carlo simulation model (MatLab, version 6.5, MathWorks Inc., Natick, MA, USA) was constructed for simulation of two main farm-initiated routes for detecting CSF, i.e. immediate notification of suspected disease based on clinical signs at the farm and occasional pathological or laboratory findings linked to unresolved clinical health problems on a pig farm. Since both routes were known to be affected by a series of individual decision-makers on the farm and at the investigating laboratory the course of a simulated iteration includes a chain of events with multi-decision-making and structures of recursive events (Fig. 1). The chain of events starts from the manifestation of CSF-related clinical signs at the infected farm. Next, after observing the signs the pig caretaker consults a veterinarian; the veterinarian can also visit the farm according to the health monitoring scheme. Notification of suspected infection by the veterinarian is followed immediately by sampling and testing for CSF. Samples can otherwise be sent for investigation of the observed general health problem on the farm. Within the investigation procedures testing for CSF can be included. By taking into account sampling and the methods used for testing, a positive diagnosis of CSF is achieved. Based an earlier risk assessment study [18], it was assumed that the virus and clinical manifestation of disease were probably similar to CSF occurrences in Belgium in 1993–1994 and The Netherlands in 1997–1998 with mildly virulent virus strains. Detection through other swine diseases with similar clinical signs, known to be present in Finland, was accounted for in the simulations. Of the CSF laboratory diagnostic methods

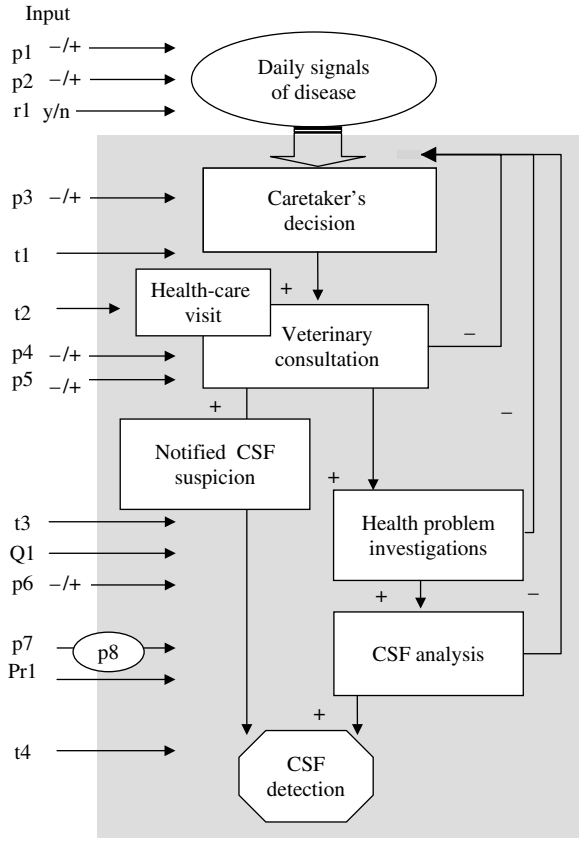

Fig. 1. Schematic diagram of a simulation model, mimicking detection of classical swine fever on a pig farm. The model is based on multi-decision-making events (□) after trigger signals of disease. The eventuality for CSF signs is time related and in addition, the Poisson process defines presence for other disease signs (y/n). In case of failure (−), repetition of events are allowed until detection of infection. Realization of events are based on probability values sampled for the input parameters (p1–p6), and defined by Bernoulli trials (−/+). Appearance of events are time related by the sampled values for the input parameters (t1–t5), dictating time lags between consecutive events. Success of laboratory diagnosis is related to the number of tested animals (Q1), presence of other swine diseases (r1, Pr1), and to the laboratory tests used (p7–p8).

available in Finland, in 2002, VI and antibody ELISA were included. In cases of notification of clinical suspicion, sampling for VI and antibody ELISA was assumed to be carried out according to the Commission's guidelines [13] and test characteristics were obtained from the literature. Since laboratory judgement is associated with the known disease status of the country [16], we assumed that greater disease awareness in the country would increase the probability of notification of suspected CSF cases based on recognized signs and influence decisions made at the investigating laboratory. If not initiated by clinical signs at the farm, other surveillance systems to detect CSF were not included in the model.

Model design

As illustrated in Figure 1, the model is based on two interlinked structural parts; first, trigger signals are entered to the second part of the model for days that CSF can be clinically observed. Events are simulated on daily basis with day 1 representing the day of infection at the farm. The probability of daily eventuality of signs increases as time elapses from introduction of the virus (p1). The parameter is based on herd sensitivity of clinical diagnosis of CSF estimated by Engel *et al.* [22]. Trigger signals, in addition, may be due to other diseases on the farm. The potential for other diseases with clinical signs similar to CSF is tested for (p2) and, if present, the manifestation of intermixing of signs is sampled each day (r1). The second part of the model, thereafter, simulates in chronological order the events following a positive trigger signal. The iteration continues until a laboratory-confirmed CSF diagnosis is made.

Events on the farm

For each manifested trigger signal, whether or not a veterinarian is consulted by the caretaker, a sample is taken (p3). Once successful the time until consultation is selected (t1). Regardless of trigger signals, according to the voluntary health classification scheme, the veterinarian can routinely visit the farm every 90 days (t2). A health-care visit only becomes necessary if the caretaker has not consulted a veterinarian within 8 days. During each consultation, the veterinarian has two options. He/she can identify and notify of a direct clinical suspicion of CSF (p4), or launch laboratory investigations to diagnose the general health problem observed on the farm (p5) without suspecting CSF. If both options fail, a new course of events starting from daily trigger signals begins.

Sample arrival and testing at the investigating laboratory

When the veterinarian gives notice of a suspected clinical case on the farm, the probability of confirming a CSF diagnosis is modelled as a function of time since infection of the farm, for both antibody ELISA testing and VI (p8). For antibody ELISA test sensitivity, a reported seroprevalence [23] was corrected

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with a described sensitivity [24]. Data from Dewulf *et al*. [25] supplemented with additional information provided by the author, was used to estimate time-dependent alterations in sensitivity of VI from a single tested sample (Appendix). For use of both antibody ELISA and VI, the predicted positive test result for a single sample was calculated from the combined distribution for a positive test result of both testing methods, in parallel. If VI happens to give the only positive diagnosis, an extra delay time is taken into account (t4). For general-health-problem investigations, the time required (t3) and the number of tested animals (Q1) representing the number of the samples undergoing any viral analyses are tested during the investigations for each batch separately. Only pigs showing clinical symptoms are assumed to be sampled. Whether or not CSF tests are included in the viral analyses is tested (p6). If CSF tests are not included, a new course of events starting from daily trigger signals begins.

During general health investigations, CSF can be tested for by using: VI, antibody ELISA testing or both (p7). Taking into account the presence of intermixing of disease signs on the day of sampling, the proportion of CSF-infected animals tested in a batch is selected (Pr1). Thereafter, to calculate the sensitivity of the test used for analysis (p8), for each individual sample, a hypothetical time from infection of the tested animal is sampled from a uniform distribution (0 to maximum; where maximum represents the time since introduction of the virus to the farm). Finally, the laboratory-confirmed CSF diagnosis is obtained (t4). A negative test result creates a new course of events starting from daily trigger signals.

At the beginning of iteration, disease awareness status of the country is selected. In addition, the option for health-care visits can be switched off. Probabilities for events and predicted time lags are sampled from the appropriate input parameter distributions. Individual sampling rules for the different input parameters are as indicated in Table 1. The final incident of an event is defined by a Bernoulli trial applying the sampled probability for the event.

Input and output data

Data concerning events on Finnish farms with sows were obtained by a set of postal questionnaires. Respondents represented 5·6% of sow farms, and matched up to average farm size and location in Finland. According to EELA statistics, in 2002, respondent farms had sent samples for investigation the same as other pig farms. Details such as disease incidence, symptoms encountered during 2002, and the number of contacts with a veterinarian were covered. Only diseases and symptoms consistent with being intermixed with CSF were considered. Furthermore, the time until consulting a veterinarian from first observation of a suspected infection was enquired. According to answers, the caretakers claimed to re-consult a veterinarian within the same time in case disease signs would not disappear.

For laboratory records, the statistics assembled by EELA were used. The data contained pig samples sent for analyses from December 1999 to December 2002 and included information on farm history and anamnesis, all diagnostic investigations conducted, diagnostic methods used and the number of tested animals and samples in a batch. Samples included pigs or organs submitted for post-mortem examination and blood specimens. Based on EELA statistics, approximately 17% of all swine-origin samples dispatched (excluding serological monitoring or other routine samples) arrived at the institute, ended up at the Department of Virology and matched anamnesis applicable to CSF. The probability that a veterinarian would report a suspected case of CSF on the farm was estimated from official statistics (five notified CSF suspicions, 1999–2002), related to yearly veterinary consultations that was estimated from the questionnaire by scaling recorded consultations to predict the number of consultations for all registered pig-breeding farms (Pig-farm register 2002, Information Centre at the Ministry of Agriculture and Forestry, Finland).

For all simulations, the number of repetitions and the day of events since infection of the farm for: consultations with a veterinarian, sampling, samples arriving for viral diagnosis at the investigating laboratory, testing for CSF, and laboratory-confirmed CSF diagnosis were recorded and analysed as model output.

Simulations

Iteration numbers were sufficient to ensure that standard error of mean detection time did not exceed 1 day. All simulations were run with 20 000 iterations. Influence of CSF awareness in the country, was simulated after modification of relevant parameters (Table 1). To study potential effect of beta-distributed model input parameters on final detection time, the

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Table 1. *Input parameters and data implemented in a model simulating the detection of classical swine fever on a pig-breeding farm*

Parameter representing	Source of data	Parametrization and values	Sampling during an iteration
Disease signs on farm			
p1, probability, trigger signs for CSF	Engel *et al.* [22]	Reference values for: day $\leqslant$ 12 (0·033), day 41 (0·498), and day $\geqslant$ 80 (0·986)	Estimated for every simulated day
p2, probability, other diseases with CSF-related signs	Questionnaire	β-distribution for 92 farms with signs (n_1), out of 161 respondent farms (n_2)	Sampled once at the beginning of an iteration
r1, rate, intermixing signs for a day	Questionnaire	Poisson distribution for 29·5 average observations per respondent during 365 days	Value predefined
Veterinarian consulted			
p3, probability, consulting a veterinarian	Questionnaire	β-distribution for 2445 vet consultations (n_1), during 4799 reported days with disease signs (n_2)	Sampled once at the beginning of an iteration
t1, time, days until veterinarian consulted	Questionnaire	Empirical distribution of reference data (min 0, med 2, max 30)	Sampled for every vet consultation
t2, time, days between health care visits	ETU [17]	Reference value (90)	Occurs independently on regular bases
Notified suspicion on farm			
p4, probability, notification of CSF suspicion based on signs	EELA statistics, and questionnaire	β-distribution* for 1·7 average suspicions a year (n_1), out of 15 228 estimated yearly vet consultations (n_2)	Sampled for every vet consultation
Resolution of health problem			
p5, probability, non-suspicious samples sent	EELA statistics, and questionnaire	β-distribution† for 90·3 average dispatches a year (n_1), out of 15 228 estimated yearly vet consultations (n_2)	Sampled for every vet consultation
t3, time, days until samples arrive at virology	EELA statistics	Empirical distribution of reference data (min 1, med 2, max 30)	Sampled for every submission
p6, probability, CSF analysis	EELA statistics	β-distribution*† for 5·7 average samples analysed for CSF a year (n_1), out of 90·3 average dispatches (n_2)	Sampled for every submission
Positive analysis results			
Q1, quantity, tested animals in a sample batch	EELA statistics	Empirical distribution of reference data (min 0, med 2, max 47)	Sampled for every submitted batch
Pr1, proportion, CSF positive samples in a batch		Uniform distribution of an assumption: if other disease present (min 0·00, max 1·00), otherwise (min 1·00, max 1·00)	Sampled for every submitted batch
p7, probability, selected analysis method	EELA statistics	Multinominal distribution of reference data: ELISA (0·48), VI (0·08), both (0·44)	Sampled for every submitted batch
p8, probability, positive test result (test sensitivity for a specific day since infection)	Stegeman *et al.* [23], Clavijo *et al.* [24] Simulation (Appendix)	Day: 6 10 14 18 25 40 ELISA: 0·002 0·016 0·101 0·429 0·924 0·963 VI: 0·904 0·701 0·475 0·295 0·111 0·006	Calculated for every submitted sample in relation to days since infection
t4, time, days until analysis result	EC 2002 [19]	Reference values for ELISA (1), and for VI (min 4, max 10)	Sampled for every submitted batch

* For simulations after disease awareness the value is sampled from the uniform distribution: min = sample from original β-distribution, max = 1.
† Original distribution applies only on first sampling, later the value is sampled from the uniform distribution: min = first sampled value, max = 1.
For β-distributions $\alpha 1 = n_1 + 1$, and $\alpha 2 = n_2 + 2 - \alpha 1$. β-distributed prediction values stand for confidence region of true average occurrences.

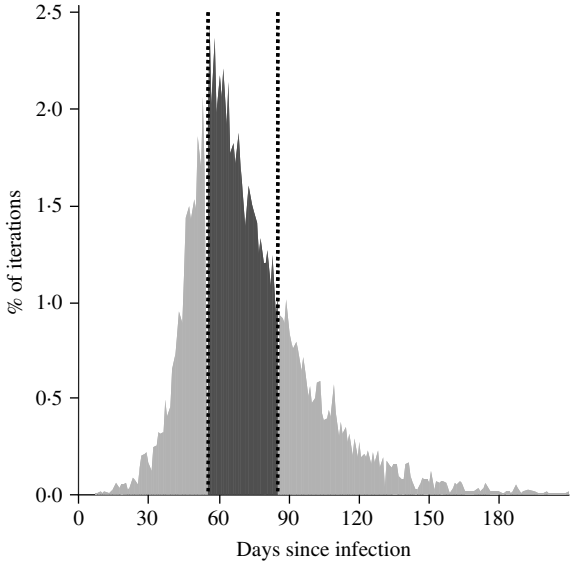

Fig. 2. Predicted detection time (in days) of classical swine fever, before knowledge of the existence of the disease in the country, on a pig-breeding farm. Monte Carlo simulation results with the interquartile range of 20 000 iterations.

model was modified with regard to the parameter of interest by replacing the parameter values, with a value of 1. Corresponding output with original input parameter values were regarded as the reference values. To study the impact of health-care visits on the farm, for half of the iterations the health-care visit alternative was not selected. The effect of health-care visits and intermixing of diseases was interpreted as significant if 95% confidence intervals of median detection time, with and without the factor, did not overlap. For data analysis SPSS version 13.01 (SPSS Inc., Chicago, IL, USA) was used.

RESULTS

Before knowing that CSF existed in the country, the median expected detection time for a Finnish pig-breeding farm, was 67 days (IQR 55–85 days) (Fig. 2). Approximately only 0·1% of iterations led to direct notification of suspected CSF on the farm. For general-health-problem investigations none of the iterations ceased with the event combination 'samples sent from the farm and tested for CSF at the laboratory on first occasions', 7% of iterations ceased with the combination 'at least one occasion to send samples from the farm has been ignored, but CSF was tested for at the laboratory on first occasion', and 93% with the combination 'at least one occasion to send samples from the farm and at least one occasion to test for CSF at the laboratory have been ignored'.

Table 2. *Simulated results of health-problem investigations confirming classical swine fever (CSF) infection on a pig-breeding farm. Results expressed as medians and 90% percentile range (in parentheses) of 20 000 iterations*

Event	First incidence day after infection	Repeated (*n*) during an iteration
Veterinarian consulted	19 (2–40)	8 (3–18)
Non-suspicious samples sent for investigations	43 (18–70)	3 (1–7)
Non-suspicious samples arrive at laboratory	46 (21–73)	2 (1–6)
Beginning of CSF analysis	67 (39–123)	1 (1–2)
Detection of CSF	67 (40–124)	1

First incidence of events and the number of repetitions of events during a single iteration are shown in Table 2. The probability of detecting CSF in a sample batch arriving at the laboratory for general-health-problem investigations (derived from: simulated number of positive diagnosis/simulated number of sample dispatches) was 90%. Ten per cent of positive sample batches were sampled on a day when intermixing of swine diseases took place. CSF was detected from a single sample batch in 40% of all iterations. Modification of parameters to equal CSF awareness in the country, shortened expected median detection time to 37 days (IQR 24–48 days).

Effect of variables

Other swine diseases on the farm accelerated median detection time by 4 days. If intermixing of diseases existed on the farm, 18% of the symptoms observed were actually signs of diseases other than CSF. Participation in the voluntary health classification scheme did not promote median detection time (1 day), compared with farms not participating in the programme. Potential effects of single input parameters on the course of events leading to CSF detection on a pig farm are summarized in Table 3. The single input parameter that had the greatest effect in the model was that governing the probability for direct notification of suspected CSF on the farm. The next greatest effect was obtained by the probability of conducting general-health-problem investigations including the sending of samples for investigation during a veterinary farm consultation, without suspicion of CSF, and by the probability of testing the samples

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Table 3. *Potential effects of input parameters of a simulation model, modelling classical swine fever detection on a pig-breeding farm. Result of 20 000 iterations expressed as the difference between the reference value of 67 days (95% CI, 1) representing detection time with original parameter values, and results when an input parameter was set to a value of 1*

Input parameter	Description of effect	Foreshorten detection time (days)
Veterinarian consulted		
p4	Without fail the caretaker always consults a veterinarian	11
Notified suspicion on farm		
p5	Without fail suspicion based on CSF signs follows a veterinary consultation	41
Resolution of health problem		
p6	Without fail samples sent for virological investigations	20
p7	Without fail CSF analysis included	19

that had arrived for viral investigations for CSF. Least effective was the probability of consulting a veterinarian.

DISCUSSION

Uncovering the factors affecting detection of diseases like CSF provides crucial information for contingency planning and state of readiness in countries that have not recently experienced an epidemic. Since CSF has not been detected in Finland for almost 90 years, the distinct pattern related to CSF detection in the country is unknown. Learned from real cases of CSF [1, 2], it become obvious, that detection courses in reality would probably involve recurrent events such as several laboratory diagnostic attempts. Instead of a real-time exercise, we chose a modelling approach by which we mimicked current conditions and present events, as such, leading to any disease diagnosis on a pig farm, not specifically aimed to detect CSF. In addition, we supplemented trigger signals representing daily appearances of visible signs of disease on a farm infected with CSF. The appearance of disease signs were thought to be similar to those observed for real cases of CSF in the EU [12, 26].

With a stochastic simulation model we reproduced variable chains of events, each representing a distinct course of detection of CSF on an infected farm. To control for excess of variability, the number of iterations was increased sufficiently. In addition, acquired results are conditional on the input data that was checked for representativeness as far as possible. Regarding that the objective here was to study factors not related to the infective agent or host, the accurate relation between manifestation of CSF signs and their observation by the caretaker were not included in our model, except for the information on whether or not detection is conceivable for each simulated day, e.g. the intensity and prevalence of signs remains unknown. In that respect, lack of epidemiological data in the model, however, could not be regarded as greatly affecting the results achieved; precision of the first part of the model could be improved by taking into account inter-herd transmission of virus, age of infected pigs, and perhaps housing conditions. In addition, such an approach would accommodate sensitivity of CSF analysis in the model.

Detection of CSF

Under the current conditions for a pig-breeding farm, CSF was estimated to be detected within 8–12 weeks of infection. As presupposed and verified by simulation, CSF would most probably first be detected via several consultations with a veterinarian, several sample submissions for investigation and incorporation of CSF tests into the analysis panel at the laboratory to solve the diagnostic problem that appeared on the CSF-infected farm.

By having a positive impact on detection time, other diseases at the infected farm appeared to promote CSF detection. This could be explained by the high probability that a veterinarian would be consulted upon the occurrence of any visible signs, and any of these consultations could lead to investigations that might eventually establish confirmation of CSF. Based on the questionnaire, more than half of the pig-breeding farms in Finland have had some diseases

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with signs similar to CSF, although the frequency of signs was low. In reality, other diseases manifested as unresolved sporadic health problems might well accelerate CSF detection by a few days on infected farms with moderate to low clinical signs of CSF. Recurrent signs of other diseases on the farm, on the other hand, might not promote such an accelerating effect.

Although coverage is not 100%, the voluntary health classification scheme can potentially counteract any non-responsiveness on the part of the caretaker. Nevertheless, the current 13-week interval between veterinary visits on farms did not seem to affect CSF detection time. This result is consistent with an earlier study [21] where an even shorter interval between health-care visits did not accelerate detection time significantly. According to the simulations, even if no signs of CSF are present on the farm, observing other disease signs and consulting a veterinarian are likely to occur before the health-care visit, promoting detection more efficiently. Instead we showed that a shorter detection time could be gained with only minor modifications of the current detection pathways. A supportive system that encourages the earlier sending of samples from the farm could at most advance detection by some 3 weeks. In addition, a more comprehensive analysis of samples currently arriving at the investigating laboratory from pig farms could theoretically shorten detection time by 3 weeks alone. In practice this would mean that about 100 samples ought to be tested for CSF each year. Failure to diagnose a true positive farm is likely to result from a too small sample number sent for investigation, as indicated by Bouma *et al*. [27]. Therefore, a greater number of samples should be encouraged. The course of decisions at the investigating laboratory was not constructed in detail here; only the time for samples to arrive for viral analysis and the final decision to conduct CSF testing were estimated. Final CSF diagnosis at the laboratory is based on the clinical judgement of anamnesis and gross pathological findings by pathologists [16], with the endorsement of virologists and other experts. Influencing recognition of disease at a time of low disease awareness in the country could be thus regarded as a challenge.

Theoretically, in a case of CSF established by simulation, if the veterinarian were to give notification of suspected CSF on his first visit to an infected farm, it could at most advance detection by 6 weeks. One can only assume that greater disease awareness in the country would increase the probability of notifying suspected CSF cases based on recognized signs and of testing for CSF [16], and as simulated could shorten detection time to approximately 5 weeks, corresponding with true epidemiological findings [23]. The ability to recognize true CSF signs and to differentiate them from other swine diseases and the real influence of disease awareness on decisions made at the infected farm and at investigating laboratory in Finland, however, have not been evaluated.

Regardless of the production type of the infected farm, underlining decisions related to detection of infection are likely to be similar in Finland. Nevertheless, since pathognomic clinical signs of CSF are known to be expressed earlier in fatteners than in sows [10–12], CSF could be expected to be detected a few days earlier in a farm with finisher pigs than in a pure piglet-producing sow farm. Moreover, according to the present legislation, in an artificial insemination (AI) or a performing testing station [28, 29], for every observed disease sign, a veterinarian should be consulted and the general health problem investigated. According to the simulation results it might be concluded that CSF would be detected in these stations within a month, agreeing with the detection time for an AI station during an actual CSF epidemic [1].

Although detection time was studied for only a single farm, detection of the index farm in Finland could be expected to occur within the same timeframe, with the detection time corresponding to that published for real epidemics in EU countries [1, 2]. Although not evaluated, the ongoing active serological monitoring is not expected to markedly influence detection currently in Finland. Crauwels *et al*. [30] reported that employing serological surveillance does not efficiently promote earlier detection of CSF in a country. The time between introduction of the virus to the first farm and the first detection of an infected farm have a major influence on the final size and duration of an epidemic [5]. As an example, out of the 429 infected farms in The Netherlands in 1997–1998, 38 farms are thought to have become infected during the 6-week detection period [1]. In the United Kingdom in 2000, respectively, out of the 16 infected farms, 3–4 farms are thought to have become infected during the 9½-week detection period [2]. Based on the estimated time for CSF detection, an epidemic outbreak can be expected in Finland.

CONCLUSIONS

By elucidating the expected time of detection and the main factors leading to detection events on a farm and

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at the investigating laboratory, information was provided to help contingency training and executing of simulated exercises in regard to preparedness for potential CSF epidemics and other contagious swine diseases in Finland. The data acquired can be utilized to study the efficacy of such interventions as active monitoring schemes or modifications of the present monitoring of CSF, before and after being aware of the existence of CSF. Moreover, the results could be applied to further simulations of CSF epidemics under the current conditions in Finland.

APPENDIX. Sensitivity of VI for a single positive sample

A distinct Monte Carlo simulation was performed (MatLab version 6.5, MathWorks Inc.) to parameterize sensitivity of VI (Table 1, p8) with 10000 iterations. For the data provided, the days since infection of a pig that reproduced a positive VI were found to be Weibull-distributed (scale 11·7101, shape 1·4576). The first day for a positive VI was assumed to be Discrete-uniformly (DU) distributed $\sim$DU (min = 1, max = 5), and the last day to be $\sim$DU (1, 5) + Weibull (11·71, 1·46). The expected probability for a positive VI on day i since infection, was then interpreted as the number of positive iterations for that day divided by the total number of iterations. Finally, the gained probability was corrected with the reported maximal sensitivity for the test [25].

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DECLARATION OF INTEREST

None.

REFERENCES

1. **Elbers ARW, *et al.*** The classical swine fever epidemic 1997–1998 in the Netherlands: descriptive epidemiology. *Preventive Veterinary Medicine* 1999; **42**: 157–184.
2. **McKinnon JD.** Some clinical and epidemiological aspects of the outbreak of classical swine fever in East Anglia in 2000. DEFRA. *State Veterinary Journal* 2001; **11**: 2–7.
3. **Fritzemeier J, *et al.*** Epidemiology of classical swine fever in Germany in the 1990s. *Veterinary Microbiology* 2000; **77**: 29–41.
4. **Mintiens K, *et al.*** Descriptive epidemiology of a classical swine fever outbreak in Limburg Province of Belgium in 1997. *Journal of Veterinary Medicine B* 2001; **48**: 143–149.
5. **Murray G, McCutcheon S.** Model framework and principles of emergency management. *Revue Scientifique et Technique Office International des Epizooties* 1999; **18**: 15–20.
6. **Mangen JM, Nielen M, Burrell AM.** Simulated effect of pig-population density on epidemic size and choice of control strategy for classical swine fever epidemics in The Netherlands. *Preventive Veterinary Medicine* 2002; **56**: 141–163.
7. **Moennig V, Floegel-Niesmann G, Greiser-Wilke I.** Clinical signs and epidemiology of classical swine fever: a review of new knowledge. *Veterinary Journal* 2003; **165**: 11–20.
8. **Van Oirschot JT.** Hog cholera. In: Straw BE, *et al.*, eds. *Diseases of Swine*. Iowa: State University Press, 1999: pp. 159–172.
9. **Moennig V.** Introduction to classical swine fever: virus, disease and control policy. *Veterinary Microbiology* 2000; **73**: 93–102.
10. **Dewulf J, *et al.*** An experimental infection with classical swine fever virus in pregnant sows: transmission of the virus, course of the disease, antibody response and effect on gestation. *Journal of Veterinary Medicine B* 2001; **48**: 583–591.
11. **Laevens H, *et al.*** Experimental infection of slaughter pigs with classical swine fever virus: transmission of the virus, course of the disease and antibody response. *Veterinary Record* 1999; **1450**: 243–248.
12. **Koenen F, *et al.*** Epidemiological characteristics of an outbreak of classical swine fever in an area of high pig density. *Veterinary Record* 1996; **139**: 367–371.
13. **European Commission.** Approving a Diagnostical Manual establishing diagnostic procedures, sampling methods and criteria for evaluation of the laboratory tests for the confirmation of classical swine fever. Commission Decision 2002/106/EC Annex: Classical Swine Fever Diagnostic manual, Chapter VI and VII. *Official Journal of the European Commission L* 2002; **39**: 71–88.
14. **Ministry of Agriculture and Forestry.** Animal diseases and animal welfare in Finland 2004. *Publications by the Department of Food and Health* 2005; **8**: 8–10.
15. **Elbers ARW, *et al.*** Assessment of the use of gross lesions at post-mortem to detect outbreaks of classical swine fever. *Veterinary Microbiology* 2003; **96**: 345–356.
16. **Elbers ARW, *et al.*** Ability of veterinary pathologists to diagnose classical swine fever from clinical signs and

gross pathological findings. *Preventive Veterinary Medicine* 2004; **66**: 239–246.
17. **ETU-palvelut.** Health Classification Register (https://www.etu-palvelut.net). Accessed December, 2004.
18. **Rosengren H, *et al.*** Qualitative risk assessment of the spread of classical swine fever into and within Finland. *National Veterinary and Food Research Institutes Publications* 2002; **6**: 26–48.
19. **Jalvingh A.** Spatial and stochastic simulation to evaluate the impact of events and control measures on the 1997–1998 classical swine fever epidemic in Netherlands. I. Description of simulation model. *Preventive Veterinary Medicine* 1999; **42**: 271–295.
20. **Karsten S, Rave G, Krieter J.** Monte Carlo simulation of classical swine fever epidemics and control I. General concepts and description of the model. *Veterinary Microbiology* 2005; **108**: 187–198.
21. **Klinkenberg D, *et al.*** The effectiveness of classical swine fever surveillance programmes in The Netherlands. *Preventive Veterinary Medicine* 2005; **67**: 19–37.
22. **Engel B, *et al.*** When can a veterinarian be expected to detect classical swine fever virus among breeding sows in a herd during an outbreak? *Preventive Veterinary Medicine* 2005; **67**: 195–212.
23. **Stegeman A, *et al.*** Transmission of classical swine fever virus within herds during the 1997–1998 epidemic in The Netherlands. *Preventive Veterinary Medicine* 1999; **42**: 201–218.
24. **Clavijo A, *et al.*** Application of competitive enzyme-linked immunosorbent assay for the serologic diagnosis of classical swine fever virus infection. *Journal of Veterinary Diagnostic Investigation* 2001; **13**: 357–360.
25. **Dewulf J, *et al.*** Analytical performance of several classical swine fever laboratory diagnostic techniques on live animals for detection of infection. *Journal of Virological Methods* 2004; **119**: 137–143.
26. **Elbers ARW, Bouma A, Stegeman JA.** Quantitative assessment of clinical signs for the detection of classical swine fever outbreaks during an epidemic. *Veterinary Microbiology* 2002; **85**: 323–332.
27. **Bouma A, *et al.*** Evaluation of diagnostic tests for the detection of classical swine fever in the field without a gold standard. *Journal of Veterinary Diagnostic Investigation* 2001; **13**: 383–388.
28. **Ministry of Agriculture and Forestry.** Health requirements for boar semen. Circular letter 3/1993. *The Finnish Veterinary Legislation* G 8.
29. **Ministry of Agriculture and Forestry.** Voluntary National Health Monitoring Scheme of domestic swine. Decision 24/EEO/1997. *The Finnish Veterinary Legislation* D 85.
30. **Crauwels A, *et al.*** The effectiveness of routine serological surveillance: case study of the 1997 epidemic of classical swine fever in the Netherlands. *Revue Scientifique et Technique Office International des Epizooties* 1999; **18**: 627–637.