

Incidence of Reinfections with *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* in Pig Farms Located in Respiratory-Disease-Free Regions of Switzerland

– Identification and Quantification of Risk Factors

By R. Hege¹, W. Zimmermann², R. Scheidegger³, and K.D.C. Stärk¹

¹Swiss Federal Veterinary Office, ²Department of Clinical Veterinary Sciences, Veterinary Faculty, University of Berne, and ³Swiss Pig Health Service, Bern, Switzerland.

Hege R, Zimmermann W, Scheidegger R, Stärk KDC: Incidence of reinfections with *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* in pig farms located in respiratory-disease-free regions of Switzerland. Acta vet. scand. 2002, 43, 145-156. – The objective of the study was to identify risk factors for reintroduction of *Actinobacillus pleuropneumoniae* and *Mycoplasma hyopneumoniae* (enzootic pneumonia) onto pig farms in areas in Switzerland that were involved in an eradication programme from 1996 to 1999 and to assess the role of dealers in relation to these reinfections. The study was based on the comparison of pig farms that were reinfected in the year 2000 (cases) and pig farms that remained uninfected in the same area (controls). Additionally, data were collected from Swiss pig dealers and transport companies. Out of a total of 3983 farms, 107 farms were reinfected in the year 2000. The incidences were 0.1% for *Actinobacillus pleuropneumoniae* and 2.6% for *Mycoplasma hyopneumoniae* (enzootic pneumonia). Compared to reinfection rates prior to the eradication programme, this is a considerable reduction. Statistically significant risk factors for the reinfection were 'finishing farm', 'large mixed breeding-finishing farm', 'reinfected neighbour' and 'parking site for pig transport vehicles close to the farm'. Pig farmers that purchased pigs from only one supplier per batch had a lower risk of reintroducing infection (protective factor). As long as infected and uninfected regions co-exist in Switzerland, direct and indirect contact between farms, pig herds and slaughter sites via transport vehicles are a major pathway of disease spread. Risk management measures linked to these contacts are therefore of key importance. The survey of dealers indicated various areas for improvement such as strategic planning of pick-up routes or cleaning and disinfecting of trucks.

respiratory diseases; reinfection; swine; area; eradication; programme.

Introduction

In the early 1990s, it was shown that the majority of specific pathogen-free (SPF) pig farms in Switzerland were likely to be reinfected with Enzootic Pneumonia (EP) and *Actinobacillus pleuropneumoniae* (APP) as a result of aerosol

transmission from infected neighbouring farms (Stärk *et al.* 1992). This supported results reported earlier in Denmark (Thomson *et al.* 1992) and in the UK (Goodwin 1985). Thus, an important transmission route of respiratory

agents acting in parallel to direct transmission (Ross 1992) was documented. Protection against airborne transmission cannot be achieved by individual farmers. As a result, the Swiss Veterinary Services initiated a programme of area-wide eradication of EP and APP in all pig farms (Zimmermann et al. 2001). A similar programme was also implemented in Finland (Rautiainen et al. 2001). The control of these diseases is now compulsory for all commercial and hobby pig farms in Switzerland. The eradication campaign for EP involved partial depopulation of breeding farms and complete depopulation of finishing-only farms. Partial depopulation is essentially based on an interval of 14 days, where no pigs under 10 months of age are kept on the farm (Zimmermann et al. 1989, Zimmermann 1990, Lium et al. 1992, Baekbo et al. 1995). The eradication of APP involved complete depopulation of all types of farms. For both respiratory diseases, vaccination is forbidden in Switzerland.

After an exploratory investigation using a spatial simulation model (Laube et al. 1997) and a pilot project in 2 well-defined regions in Switzerland (Masserey-Wulschleger & Maurer 1996), a nation-wide eradication programme commenced in August 1996. The district veterinary offices annually expand the sanitations into new defined regions. The goal is to achieve eradication by the end of 2004.

Following the eradication programme in the first region in 1996, farms were reinfected regularly. Although the reintroduction of *Mycoplasma (M.) hyopneumoniae* seemed to be mainly associated with direct contact with infected swine through trade, for many cases, obvious reasons for its reinfection were not identified. The need for effective biosecurity measures on farms and during the transport of animals led to regulations being developed to control animal trade. Despite these measures, the risk of reinfection remained a threat for

SPF pig farms. Even after an extensive investigation of all potential sources of infection on these farms, some cases remained unexplained.

The study presented here was conducted with the following objectives:

1. To undertake an epidemiological analysis of the status of the area-wide eradication programme.
2. To identify and quantify risk factors for reinfections in those areas which had completed the eradication programme for EP and APP.
3. To recommend measures to prevent the reintroduction of infection.

Materials and methods

The study consisted of 2 parts: an observational study of affected and control farms, and a survey of pig dealers and transport companies. The observational study was designed as a case-control study with an equal number of cases and controls.

Farm recruitment

The study was conducted in 3 defined regions in the Cantons of Berne, Lucerne and Solothurn where the eradication programme was undertaken between 1996 and 1999. The population at risk in these cantons consisted of 3,983 pig farms. Of these, 2,373 (59.6%) farms were members of the Swiss Pig Health Service (SPHS), a programme comparable with SPF programmes in other countries. Of the population at risk, 1,207 (30.3%) were breeding farms, 709 (17.8%) mixed breeding-finishing farms and 2,067 (51.9%) finishing farms.

All farms in the defined regions where either EP or APP was reintroduced between January 1 and December 31, 2000, were recruited as cases. A farm was defined as being reinfected if at least 2 of the following criteria were present:

clinical symptoms (e.g. coughing), gross and microscopical lesions observed at slaughter or isolation of *M. hyopneumoniae* by an indirect immunofluorescence test from lung tissue or *A. pleuropneumoniae* Biovar 1, Serovar 2 by bacteriological analysis. Although the isolation of either agent was sufficient to classify a farm as infected, additional criteria were required for those cases where isolation was unsuccessful. The suspected date of the reintroduction of infection, not the date of diagnosis, was used as a reference date for the assessment of risk factors. Farms that were linked to a reinfected case by the direct movement of animals were serologically screened to identify possible further cases. Detailed farm data of all case farms were extracted from the SPHS database. The database has data on farm health status provided by farmers, dealers, slaughterhouses and veterinarians, as well as data collected during farm visits by SPHS consultants. All members of the SPHS and all farms in areas with ongoing or completed eradication programmes are included in this database. All data retrieved for this study were double-checked by the principal investigator (R. Hege).

Farmers were contacted by phone to explain the objectives of the study and to obtain their consent to participate in the study. A personal appointment was made to conduct an interview concerning the reintroduction of infection on the farm. All farmers whose farms were reinfected before the study commenced in July 2000 were interviewed retrospectively (maximum time lag between infection and interview: 6 months). All other cases were visited as soon as possible after the reintroduction of infection was reported. All reinfected farms were visited by the principal investigator (R. Hege) and all pig farmers were interviewed between July 18, 2000 and March 14, 2001.

During the interview, a questionnaire was filled out in the presence of the farm owner. This

questionnaire was developed in collaboration with SPHS consultants to optimise the comprehension and quality of the questions.

Control farms were recruited from the same areas as case farms. The selection of control farms was undertaken by random sampling. For each case farm, a control farm was selected. Case and control farms were not matched regarding region or any other criteria. These farms were visited and farmers interviewed using the same questionnaire as for the case farms except for the section regarding the details of the reinfection (see below).

The questionnaire was divided into 4 sections: General farm information (ID-number; address; phone number; husbandry system; number of breeding and finishing animals; feeding; health status; dealer company; pig transport company), chronological information on the reinfection (date of suspicion; date of diagnosis; clinical symptoms during this time; purchase of pigs), environmental information (farm location; topography; distance to the 4 nearest neighbouring pig farms (measured on a map of scale 1:25,000); how pigs were transported; parking sites for transport vehicles; personal contact with slaughterhouses or butcheries; biosecurity measures), information on indirect factors (ammonia concentration; dust load; exchange of agricultural equipment; pets; rodents; wild pigs; visitors).

The majority of the questions were closed questions, giving the opportunity to answer either 'yes' or 'no'. For some questions, a choice of possible answers was offered from which one had to be chosen. Some questions were designed to assess the farmer's personal opinion or to capture the subjective impression of the interviewer (e.g. assessment of ammonia con-

centration in the air: score 1=no ammonia smell detected, score 2=ammonia smell detected, score 3=high ammonia concentration causing eye irritation).

The interview on the control farms was conducted similarly except that all questions regarding the reinfection were not asked. All interviews were conducted by the principal investigator.

For the investigation of pathways of transmission for case farms, the categories "transmission by purchase of animals" and "transmission by chronic, undetected infection" were based on the data collected by the SPHS. In those cases where there were neighbouring infected herds and other transmission pathways were not identified, the category "air-borne transmission" was used as a tentative classification. In all remaining cases without infected neighbours, the category "source unknown" was used.

Survey of pig dealers and transport companies

Data on all registered dealers and transport companies in Switzerland were extracted from the database of the SPHS. A questionnaire was sent together with a covering letter explaining the objectives of the study to all 212 companies. After identification and deletion of companies that had ceased business during 2000 or 2001, the database was updated. Finally 158 dealers and transport companies remained. All companies who did not respond to the first mailing were sent a reminder.

The questionnaire was divided into 6 sections: General information (address; phone number; responsible person), logistics (number of transport vehicles and company drivers; contractors), information on dealing activities (regions; areas not included in the eradication programme; non-SPF animals; number; time and

frequency of transport of piglets, sows, slaughter animals; criteria for planning transport routes; transport of other animals such as cattle, horses, sheep, goats), biosecurity (clothing; changing room; shower facilities; possibilities of changing the route), cleansing and disinfection (control of hygiene status of the vehicles; contact with slaughterhouses; butcheries and emergency slaughter sites), transport vehicles (equipment such as loading areas; loading ramps; the surface material of ramps).

Data management and analysis

The data from both questionnaires were entered into a database management system (Microsoft Access) and then imported into a statistical software package (NCSS 2000, Number Cruncher Statistical Systems, Kaysville, Utah). A descriptive statistical analysis was conducted. For the case-control data, each potential risk factor was screened for significant association with reinfected farms. Associations between the outcome (reinfection) and continuous data were tested using the Wilcoxon Signed-Rank test, whereas binomial data were tested using the Chi-Square test. Associations were expressed as odds ratios (OR) with their 95% confidence intervals (CI). Each variable with a statistical significance of $p \leq 0.05$ at the univariate level was considered for multivariate analysis. This cut-off level was chosen because of the high number of variables with a value of $p \leq 0.05$ and the limited number of farms in the study. A backward stepwise selection procedure with a cutoff level of $p = 0.05$ was used. One-way interactions that were biologically plausible or for which scientific evidence was available were tested for significance in the final model.

Results

Case-control study

Out of a total of 3,983 farms at risk, 107 farms were reinfected in the selected areas of the 3 Cantons during the year 2000. Fig. 1 provides an overview of the location of the 3 Cantons and the ratio of case and control farms per district. A total of 103 farms were infected with EP and 4 farms with APP. This resulted in an annual incidence of the reinfection of 2.6% for EP and 0.1% for APP. In breeding farms the incidence was 1.7% (20 farms), in mixed breeding-finishing farms 2.4% (n=17) and in finishing farms 3.4% (n=70). A total of 71% (n=76) of the case farms were members of the SPHS, 29% (n=31) were not members.

Out of all reinfected finishing farms (n=75), 26.7% (n=20) operated an all-in/all-out system,

and 73.3% (n=55) restocked continuously. Due to missing data in the SPHS database, some of the denominators vary. Among 92 reinfected herds with complete data, pigs were coughing in 77.2% (n=71) and gross lesions in lungs were found at slaughter-inspections in 83 out of 105 (79.0%) farms. The causative agents (*M. hyopneumoniae* or *A. pleuropneumoniae*) were isolated in 86.7% (91 out of 105) of the case farms. Obvious pathways leading to the reintroduction of infection were identified in 74 (69.2%) cases. The main reasons were: purchase of animals in 46 cases (43.0%), air-borne infection on 24 farms (22.4%), and chronic, undetected infection in 4 cases (3.7%). In 30.8% of cases, a pathway leading to the reintroduction of infection was not identified.

Each variable was compared individually with

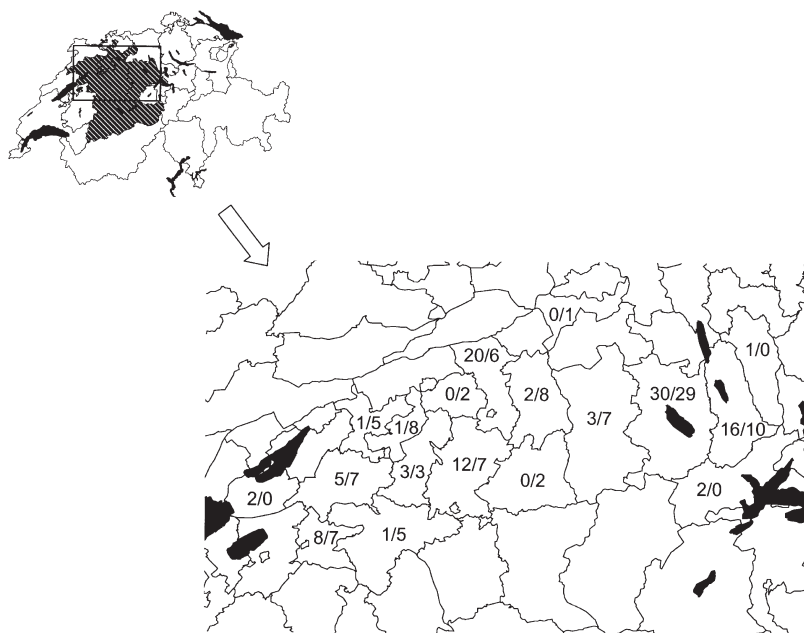


Figure 1. Map of districts included in a case-control study of pig farms regarding re-infections in respiratory-disease-free areas in Switzerland.

The hatched areas in the total view of Switzerland represent the 3 Cantons of Berne, Lucerne and Solothurn. The number in each district in the enlarged view shows the ratio of case farms to control farms.

Table 1. Frequencies of farm characteristics in farms re-infected with respiratory diseases and control farms as assessed during a case-control study conducted in Switzerland (only variables with $p < 0.2$).

Variable description	Cases (%), n=107	Controls (%), n=107	P	OR
<i>Production system</i>				
Membership of Swiss Pig Health Service	71.0	82.2	0.052 ^{a)}	0.5
Breeding farms	19.6	45.8	<0.001 ^{a)}	0.3
Finishing-only farms	67.3	37.4	<0.001 ^{a)}	3.4
Mixed breeding-finishing farm with at maximum 99 fattening pigs	4.7	15.0	0.011 ^{a)}	0.3
Mixed breeding-finishing farm with at least 100 fattening pigs	8.4	1.9	0.030 ^{a)}	4.8
<i>Environment</i>				
Farms with exercise area or pasture	2.8	9.3	0.045 ^{a)}	0.3
One additional re-infected neighbour	n.a. ^{b)}	n.a. ^{b)}	<0.001 ^{a)}	3.7
Transport route close to farm	66.4	47.7	0.006 ^{a)}	2.2
Parking site for transport vehicles close to farm	21.5	4.7	<0.001 ^{a)}	5.6
Distance to parking site ≤ 300 m	9.3	1.9	0.017 ^{a)}	5.4
Veterinarian may enter the pig stable	63	81	0.009 ^{a)}	0.5
Moderate smell of ammonia in the stable	30.6 ^{c)}	9.9 ^{c)}	0.053	1.9
Dust film on window sills in the stable	12.2 ^{c)}	5.0 ^{c)}	0.066	2.7
An increased altitude of the farm location by 50 meters	n.a. ^{d)}	n.a. ^{d)}	<0.001 ^{a)}	0.7
<i>Animal purchase practices</i>				
Pigs typically loaded before 0700 a.m.	73.8	44.9	<0.001 ^{a)}	3.5
Pigs typically loaded between 0700 a.m. and noon.	22.4	54.2	<0.001 ^{a)}	0.2
Pigs typically loaded between noon and 0800 p.m.	2.8	0.0	0.081	Not calculable
Drivers of transport vehicles may enter the stable	32.7	24.3	0.173	1.5
Pig owner has complained about cleanliness of transport vehicles	11.2	0.9	0.002 ^{a)}	13.4
Farmers delivers pigs to the butcher himself	66.4	77.6	0.068	0.6
Farmer cleans his transport vehicle after being at the butchery	43.9	55.1	0.101	0.6
Farmer disinfects his transport vehicle after being at the slaughterhouse	5.6	1.9	0.149	3.1
Always the same animal suppliers	22.4	42.1	0.002 ^{a)}	0.4
No supplier (closed farm)	21.2	18.2	0.529	1.2
Only 1 animal supplier	21.5	56.1	<0.001 ^{a)}	0.2
2 or 3 animal suppliers	18.7	12.1	0.185	1.7
more than 3 animal suppliers	32.7	8.4	<0.001 ^{a)}	5.3

^{a)} Variables included in the logistic model.

^{b)} n.a. = not applicable; mean value of cases = 0.5, mean value of controls = 0.1

^{c)} Some farmers did not allow access to the pig stables. Here, the number of case farms was 98, the number of control farms 101.

^{d)} mean (cases) = 541, mean (controls) = 554.

Table 2. Final logistic model of risk factors for re-infection with respiratory diseases into farms (n=214) in sanitised areas in Switzerland ($R^2=0.35$).

Risk factors	P	OR	95% CI
<i>Type of pig production</i>			
Breeding farm	-	1	-
Finishing farm	<0.001	4.31	2.13 - 8.71
Mixed breeding-finishing farm with at least 100 finishing pigs	0.009	10.12	1.80 - 56.77
<i>Number of suppliers per unit</i>			
Number of suppliers <1 og >2	-	1	-
Only 1 animal supplier	<0.001	0.17	0.08 - 0.36
<i>Risk of air-borne transmission</i>			
No re-infected neighbour	-	1	-
One additional re-infected neighbour	0.001	3.47	1.66 - 7.24
<i>Pig transports</i>			
No parking site	-	1	-
Parking site for transport vehicles close to the farm	<0.001	9.28	2.67 - 32.23

respect to the outcome, that is, if it was more frequent in the case than in the control group. The frequencies of farm characteristics for all farms are presented in Table 1.

Since there were no missing values for the variables entered into the multivariate logistic model, all 214 farms were included in this analysis (107 cases, 107 controls). The results of the final model are presented in Table 2.

There were no statistically significant one-way interactions for risk factor combinations. The logistic regression showed an agreement between the predicted and the observed result for 77.5% for the control farms and 81.3% for the case farms. The model's ability to correctly classify a farm was 79.4%.

Survey of dealers and transport companies

After the first mailing, 42 (26.6%) responses were received. Following a reminder, an additional 36 replies were obtained. Thus, out of 158 questionnaires, 78 (49.4%) were returned completed. The denominator for all results

shown below was 78. The collected data were analysed descriptively. Regarding general information of all respondents, 94% of the companies owned the vehicles they used, while 24% were working with contractors. In 37%, at least one driver lived on a farm and in 19% owned pigs himself.

Information on dealing activities provided an indication of how extensive the activities of the companies were. Out of all companies, 71% were only active in one of the 26 Swiss cantons, and 51% were limiting their activities to regions involved in the eradication programme. Regarding age classes of animals, 63% were dealing with sows and boars and 93% with finishing pigs. Regarding combined animal transports, 48% were dealing with breeding and finishing pigs. Only 14% of all companies had different vehicles for breeding and finishing pigs.

In 45% of the companies, it was possible to change pigs from one vehicle to another during the pick-up run, and in 16%, trailers holding animals were sometimes parked temporarily. Spe-

cific criteria for planning transport routes, for example, according to health status of the farm, the distances involved and the number of pigs transported, existed in 70% of the companies. A visual hygiene check of their vehicles was conducted in 58% of the companies.

Approximately 80% of respondents reported that vehicles could be cleaned and disinfected at the slaughterhouse, but only 41% were checked by an employee of the slaughterhouse before leaving the slaughterhouse. At butcheries, emergency slaughter locations and knackeries, <25% of the vehicles were cleaned and disinfected.

The data were analysed for small-scale companies and large-scale companies separately to determine if there were statistically significant differences between the working practices of one-man-companies compared to larger companies. A small-scale company was defined as being a one-man-company owning just one transport vehicle. Out of all questionnaires filled in correctly, 39 (50%) came from small-scale companies.

Ten factors were statistically significant at a probability level of $p \leq 0.05$. One-man-companies owned an animal farm ($p=0.010$) or pigs ($p=0.002$) less often than large-scale companies. Their activities were more often limited to one Canton ($p<0.001$) and more often in regions participating in an eradication programme ($p=0.003$). They were dealing less frequently with sows and boars ($p=0.041$). Regarding biosecurity measures, small-scale companies rarely had any concept of planning transport routes ($p=0.014$). They transported other livestock in the pig transport vehicles more often ($p=0.025$). During transportation, they were less likely to reload pigs ($p<0.001$) or parking their trailers temporarily ($p=0.012$). One-man-companies rarely provided a room for changing the driver's working clothes ($p=0.013$).

Discussion

This case-control study showed that reinfections are a problem in areas where EP and APP have been eradicated. In the 3 areas in Cantons involved in this study, 107 out of 3,983 farms were reinfected. In the past, reports of the Swiss Pig Health Service demonstrated a steady annual reinfection rate of 2-3% (Keller 1988, Stärk 1991). Our data confirm a decrease of the risk of reinfection following eradication.

As in any observational study, this study is not free from potential bias. Regarding misclassification of controls, farms may have been subclinically infected with EP at the time when they were visited and their data were collected. Also, as tracing of contacts is often incomplete, secondarily infected cases may have remained undetected. However, we believe that this would only involve a sporadic number of farms. As this type of misclassification would be non-differential, it would result in an underestimation of the odds ratios. Furthermore, it is known from the Swiss Pig Health Service that the information provided by the farmer is often not complete. Similarly, the data that we collected could be affected by information bias. Farmers from case farms could have looked for an external cause of the reintroduction of infection and therefore make more pessimistic statements regarding pig suppliers, dealers and transport companies or visitors than farmers from control farms. Additionally, disease detection on finishing farms may have been easier because the likelihood and the intensity of coughing is often greatest in growing-finishing swine (Gardner & Hird 1990, Sheldrake et al. 1990, Clark et al. 1991). A possible consequence could be an overestimation of trade-related risk factors. Finally, because the participation of dealers and transport companies in the study was not compulsory and the questionnaire was mailed out, the quality of the data may not be equivalent to that obtained from a

personal interview. Because there were only 4 cases where APP was reintroduced, the results of this study are limited regarding this agent. Consequently, the risk factors described here are more relevant for EP reinfections.

The risk factors in this study are not new but confirm earlier work (Stärk 2000). Five variables were identified as important for the reintroduction of infection. Results from the logistic model showed a 4 times higher risk for finishing-only farms compared to breeding-only farms. The effect of herd type was also seen in the difference between the incidence rates for finishing-only and breeding-only farms, (OR=2.08; CI 1.26-3.44). Finishing-only farms had a higher risk of becoming reinfected. One reason for this is that finishing farms are dependent on breeders for animal supply. If a breeding farm is reinfected the risk of infection for finishing farms purchasing animals from it is high. Thus, a flow of infection from breeding to finishing herds may develop. There are always 2 different transportation routes for animals on a finishing farm, one to the farm (i.e. from a breeder or mixed breeder-finisher) and one from the farm to the slaughterhouse. Every purchase necessitates the transportation of animals, and related factors become important, e.g. dealing companies, transport vehicles, drivers, other loaded animals.

The survey of dealers and transport companies indicated that in only 80% of the situations, vehicles could be cleaned and disinfected at the slaughterhouse. As a result drivers who do not thoroughly clean and disinfect their vehicles may pick up bacteria and spread them to other farms. Comparing the incidence rates for breeding-only and mixed breeding-finishing farms in general, the study did not show any significant differences. However, the results do indicate a significantly higher risk for mixed breeding-finishing farms with at least 100

growing-finishing pigs compared to breeding-only farms. Mixed breeding-finishing farms with a maximum of 99 growing-finishing pigs did not show any difference to breeding-only farms. The difference is likely to be due to the fact that large mixed breeding-finishing farms are exposed to many of the same risk factors for finishing-only farms described above.

As reported in the literature, multi-source purchases are a risk factor (Stärk 2000). This study did not distinguish between the different types of purchases (e.g. breeding animals, piglets or finishing pigs). Farms purchasing from one only source were at less risk than farms with other purchasing practices. Well established, limited trading relationships appear to be advantageous regarding the risk of reinfection. In contrast, having a closed farm was not a statistically significant protective factor in this study when compared to all other purchasing strategies. One explanation may be that the variable "number of suppliers" only accounts for "trade" contacts associated with purchasing but not selling pigs.

In contrast to APP, EP is often spread by airborne transmission (Goodwin 1985, Stärk et al. 1992, Thomson et al. 1992). Several potential sources of aerosol transmission were identified as risk factors in this study. If there were infected neighbours present, reinfection was more likely. To control air-borne transmission, it is necessary to depopulate pig stables where infection has been reintroduced as soon as possible. However, partial depopulation of a reinfected breeding farm takes time, often several months, because all animals older than 10 months have to develop an immune response in order for partial depopulation to work (Zimmermann et al. 1989, Zimmermann 1990). In a situation where an infected farm poses a significant risk to its SPF neighbours, total depopulation rather than partial depopulation may have to be employed. The importance of size and dis-

tance to infected neighbours as described by other authors (Goodwin 1985, Jorsal et al. 1988) was not observed in our study. However, parking sites for transport vehicles close to pig farms were found to be a risk factor. They may act as a source from where aerosols can spread. In this study, parking sites were at a distance from between 10 and 2000 meters from a farm. Based on the findings of this study, recommendations for the prevention of reinfections can be made at different levels. Newly introduced infections, so called index cases, within SPF areas need to be detected as early as possible. However, the long incubation periods associated with *M. hyopneumoniae* and *A. pleuropneumoniae* hinders a prompt follow-up. With the decreasing occurrence these pathogens and the absence of severe clinical signs in pig reared in hygienic environments, detection requires a high level of awareness of disease and reporting of suspicious, even vague, clinical symptoms. This needs to be supported by checks routinely conducted at slaughter and continuing clinical surveillance through farm visits. Furthermore, serological screening may be applied as described by Rautiainen et al. (2001). For example, tests based on meat juice analysis at slaughter may be particularly well suited to this situation. All data should be entered into a registration system to enable epidemiological data to be routinely updated. As the pig density in Switzerland is unlikely to decrease in the next few years, the risk of air-borne transmission can only be reduced by minimising the number of index cases and eliminating temporary aerosol sources (e.g. parked trucks).

Some cases where infection was reintroduced in this study may have been connected to chronically infected breeding-only herds. Partial depopulation may not have been successful on these farms or they may have been misclassified initially as being not infected. The latter situation was also reported from the Finnish pro-

gramme (Rautiainen et al. 2001). This can occur, if the infection is still active in animals older than 10 months of age remaining on the farm. Where the reintroduction of infection is suspected or confirmed, all infected pigs should be removed from the particular farm. These pigs should either be slaughtered or finished at well-isolated locations. This will ensure the rapid removal of infection sources and therefore the occurrence of secondary cases.

The transportation of pigs needs to be optimised. Regarding the information collected from dealers and transport companies, several factors should be analysed further to derive recommendations for the prevention of index as well as secondary cases. In the context of a nation-wide eradication programme, the area in which a dealing company is active is important. As long as SPF and non-SPF regions exist in Switzerland, it is likely that spread of EP and APP is facilitated by direct and indirect contact between farms, pig herds and slaughter sites via transport vehicles. The data collected in our survey indicate that improvements are possible. For example, the strategic planning of transport routes and hygiene are likely to be essential components of the Swiss eradication programme, contributing significantly to its success. Cleaning and disinfecting stables, loading sites, transport vehicles and washing areas at the slaughterhouses are basic measures for preventing the spread of infection. Permanently accessible areas to clean and disinfect transport vehicles need to be provided at butcheries, emergency slaughter sites and knackeries. To plan transport routes and improve hygiene dealers, producers, the Swiss Pig Health Service and the Veterinary Services will all need to cooperate closely.

Acknowledgements

The authors wish to thank all the pig farmers, dealers and transport companies who participated in the study, the Swiss Pig Health Services in Berne and Zurich-Sempach and the Monitoring Team of the Swiss Federal Veterinary Office. The study was funded by the Swiss Federal Veterinary Office.

References

- Baekbo P, Madsen KS, Larsen LP, Szyncer J: Eradication of *Mycoplasma hyopneumoniae* from infected herds without restocking. *Am Assoc Swine Prac, Proc 26th Ann Meet 1995*, 457-459.
- Clark LK, Armstrong CH, Freeman MJ, Scheidt AB, Sands-Freeman L, Knox K: Investigating the transmission of *Mycoplasma hyopneumoniae* in a swine herd with enzootic pneumonia. *Vet Med*, 1991, 5, 543-550.
- Gardner IA, Hird DW: Host determinants of pneumonia in slaughter weight swine. *Am J Vet Res*, 1990, 51, 1306-1311.
- Goodwin RFW: Apparent reinfection of enzootic-pneumonia-free pig herds: Search for possible causes. *Vet Rec*, 1985, 116, 690-694.
- Jorsal SE, Thomson BL: A Cox regression analysis of risk factors related to *Mycoplasma suis* pneumoniae reinfection in Danish SPF-herds. *Acta Vet Scand* 1988, Suppl. 84, 436-438.
- Keller H: The Swiss Pig Health Service. 10th IPVS Congress, 1988, 334.
- Laube P, Stärk KDC, Keller H: A GIS-based computer program for the region-wide eradication of Enzootic Pneumonia (EP). *Epidémiologie et Santé Animale VIII ISVEE Paris*, 1997, 31-32, 12.13.1-12.13.2
- Lium B, Skomsøy A, Jørgensen A, Loe B, Szancer J: An attempt to eradicate *Mycoplasma hyopneumoniae* from selected Norwegian farrowing to finishing herds. *Proc 12th IPVS Cong, Hague*, 1992, 300.
- Masserey-Wullschleger Y, Maurer T: The area-wide eradication in pig farms in the two Swiss regions of Burgdorf and Luzerner Michelsamt. Inaugural Dissertation, University of Zurich, 1996.
- Rautiainen E, Oravainen J, Virolainen JV, Tuovinen V: Regional eradication of *Mycoplasma hyopneumoniae* from pig herds and documentation of freedom of the disease. *Acta vet scand*, 2001, 42, 355-364.
- Ross, R.F: *Mycoplasmal diseases*. In: Leman, A.D., Straw, B., Glock, R., Mengeling, W.L., D'Allaire, S., Taylor, D.J. (Editors), *Diseases of Swine*, 7th Edition Iowa State University Press, Ames, 1992, 537-551.
- Sheldrake RF, Gardner IA, Saunders MM, Romalis LF: Serum antibody response to *Mycoplasma hyopneumoniae* measured by enzyme-linked immunosorbent assay after experimental and natural infection of pigs. *Aust Vet J*, 1990, 67, 39-42.
- Stärk KDC: Risk factors regarding reinfections of specific-pathogen-free breeding farms with EP. Inaugural Dissertation, University of Zurich, 1991.
- Stärk KDC, Keller H, Eggenberger E: Risk factors for the reinfection of specific pathogen-free pig breeding herds with enzootic pneumonia. *Vet Rec*, 1992, 131, 532-535.
- Stärk KDC: Epidemiological investigation of the influence of environmental risk factors on respiratory diseases in swine – a literature review. *Vet J*, 2000, 159, 37-56.
- Swiss Pig Health Service: Annual Reports. 1990-1999.
- Thomson BL, Jorsal SE, Andersen S, Willeberg P: The Cox regression model applied to risk factor analysis of infections in the breeding and multiplying herds in the Danish SPF system. *Prev Vet Med*, 1992, 12, 287-297.
- Zimmermann W: Experiences of the eradication program of the Swiss Pig Health Service. *Tierärzt Umsch*, 1990, 45, 556, 559-562.
- Zimmermann W, Odermatt W, Tschudi P: Enzootic Pneumonia (EP): The partial depopulation of sow farms reinfected with EP as an alternative to the complete depopulation. *Schweiz Arch Tierheilk*, 1989, BI, 179-191.
- Zimmermann W, Masserey Y, Maurer T, Keller H: Area-wide eradication of EP and APP – a health programme in the pig production. *Tierärzt Umsch*, 2001, 7, 339-344.

Sammendrag

Incidensen af reinfektioner med Mycoplasma hyopneumoniae og Actinobacillus pleuropneumoniae i svinebesætninger beliggende i områder af Schweiz fri for respirationsvejssygdomme - identifikation og kvantificering af risiko-faktorer.

Formålet med studiet var at identificere risikofaktorer for reinfektion med *Actinobacillus pleuropneumoniae* og *Mycoplasma hyopneumoniae* (enzootisk pneumoni) i områder af Schweiz, der var del i et sa-

nerings-program i perioden 1996 til 1999, og at estimere omsætters rolle i forbindelse med disse reinfektioner. Undersøgelsen var baseret på sammenligning af besætninger, der var reinficeret i år 2000 (cases) og svinebesætninger, der forblev ikke inficeret (kontroller) i samme område. Desuden blev der indsamlet data fra schweiziske omsættere af svin og transportører.

Af i alt 3983 besætninger blev 107 besætninger reinficeret i år 2000. Incidensen var 0,1% for *Actinobacillus pleuropneumoniae* og 2,6% for *Mycoplasma hyopneumoniae* (enzootisk pneumoni). Sammenlignet med reinfektionsraterne for saneringen er dette en betydelig reduktion. Statistisk signifikante risikofaktorer for reinfektion var "slagtesvinebesætning",

"stor so og slagtesvinebesætning", "reinficeret nabo" og "parkering af transportvogne til svin tæt ved besætningen". Svinebesætninger, der indkøbte svin fra én besætning pr. hold havde en lavere risiko for at introducere infektion (beskyttende faktor). Så længe inficerede og ikke-inficerede områder findes side om side i Schweiz vil direkte og indirekte kontakt mellem besætninger og mellem svinebesætninger og slagtesteder via transportvogne være en vigtig kilde til spredning af sygdom. Håndtering af risici, der er forbundet med disse kontaktyper, er derfor særdeles vigtigt. Undersøgelsen blandt omsættere indikerede forskellige områder, som kunne forbedres, så som strategisk planlægning af kørsels-ruter og desinfektion af transportvogne.

(Received January 18, 2002; accepted May 16, 2002).

Reprints may be obtained from: Dr.med.vet. K.D.C. Stärk, PhD, Swiss Federal Veterinary Office, Schwarzenburgstrasse 161, 3003 Bern, Switzerland. E-mail: katharina.staerk@bvet.admin.ch, tel: +41 31 323 95 44, fax: +41 31 323 95 43.