Biosecurity Practical Applications

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Introduction

Biosecurity measures are farm management protocols designed to keep diseases from spreading from infected to healthy animals.

Developing a biosecurity protocol for your farm is just like developing a vaccination protocol for your farm. All swine farms do not follow the same vaccination program because all swine farms are different. Because of these differences, each farm will have a unique biosecurity program as well.

Developing an effective biosecurity program for your farm can be challenging. A big part of the challenge is that there is not much scientific evidence to tell us which biosecurity procedures work and which ones do not work.

Objectives

The goals of this fact sheet are to
- Present the steps needed to develop a practical biosecurity program for your farm.
- Discuss various biosecurity protocols and the science or lack of science behind them.

Steps to Develop a Practical Biosecurity Program for Your Farm

Step 1. Describe your farm. Farm differences will determine whether or not certain biosecurity measures are practical. Information regarding the type, location, facilities, pigs, and diseases present on your farm will help better design your biosecurity program. Questions to ask for each category include:

A. Classify your farm. What type and size of farm you operate?
- Genetic nucleus
- Multiplier
- Boar Stud
- Farrow-to-wean
- Farrow-to-finish
- Feeder pigs
- 4-H animals for your children
- A few pigs for your family consumption only

B. Location. Are you in a pig dense area?
- How close is the nearest swine unit to your farm?
- What is the distance of other livestock units to your farm?
- How many swine units are within 2 miles of your farm?

C. Facilities.

- Do you have an outdoor, partial confinement, or total confinement operation?
- How many sites?
- Can you control access to your facilities?
- How old are your facilities?
- Are your facilities cleanable?

D. Pigs. The ability of a pathogen to infect a pig depends a lot on the characteristics of the pig.

- How old are your pigs? Generally, younger animals are more susceptible to infection.
- Are your pigs immunocompromised? Some diseases can prevent the immune system of your pigs from working properly. Early weaned pigs do not develop natural immunity to some diseases so they are more susceptible and generally get very sick if exposed to some common swine diseases.
- What is your vaccination program? Many vaccines are very good at protecting pigs from signs of disease, while others are less effective.
- Are your pigs genetically resistant to certain diseases?
- Is your environment, nutritional program, management program, optimal for pig health. Stressors can make a pig more susceptible to disease.

E. Diseases.

- What diseases are currently infecting your pigs?
- What diseases are currently causing the most problems on your farm?
- What diseases are you concerned about that are not on your farm?

F. Movement of pigs, people or other vectors (trucks/equipment) within your farm

- How do pigs flow through your system?
- To what extent is your system closed?
- What is your source of pigs?
- What is your source of semen, feeds, etc?
- How do employees move about within your system?
- What is your current program for rodent control and exclusion of other animals (dogs, cats, raccoons, etc) from swine contact?

Step 2: Describe yourself.

- How much risk are you willing to take?
- Are you the first person to implement new technologies?
- Would you rather wait a year or two and see if the new technology works before your purchase?
- Do you estimate profit and loss for each possible investment?
- Do you spend money and then wait to see if the money was well-spent?

Step 3: Set your goals.

- Do you want to keep specific diseases off of your farm?
- Do you want to keep diseases that are already on your farm from spreading to different groups of animals or to neighboring farms?
- Do you want to do both?

Step 4: Select your target pathogens. To have a chance at an effective biosecurity program you must pick the diseases that you want to target. This process works just like selecting a vaccination protocol. You generally do not vaccinate against one pathogen to prevent a different pathogen. Next, pick the biosecurity procedures that are most likely to prevent the pathogens that you have selected. In many cases, the same biosecurity procedures can prevent other pathogens as well as your target pathogen. But selecting specific pathogens increases your chance of success and makes monitoring the success of your program easier.

Step 5: Get to know your enemy. Pathogens vary in ability to cause disease. Some questions to ask about your target pathogen include:

- How severe is the disease? How many pigs get infected? What is the death loss in infected pigs?
- What is the impact on productivity measures (ADG, FCR, pigs born live, weaning %)
- How is the pathogen transmitted? By direct contact with infected pigs? By aerosol? By rodent carriers?

- What is the infectious dose? How many bugs are needed to make the pig sick?
- How contagious is the pathogen? Do pigs shed the pathogen in large numbers?
- How long does the pathogen live outside of the pig? Can the pathogen survive for extended times in the environment?
- How often are your pigs exposed to the pathogen?
- What are the sources of the pathogen? Pigs? Rodents? Air? Water?

Step 6: Implement a biosecurity program. Investigate possible biosecurity procedures to minimize the chance of infection with your target pathogens. Select those protocols that appear to be best for your farm. Some options are discussed in this paper.

Step 7: Monitor the effectiveness of your biosecurity program. This step involves periodic testing to determine how well the biosecurity protocol is working. Periodic monitoring of your biosecurity program is recommended. Your veterinarian can collect blood samples for serology to see if your animals have been exposed to a pathogen, perform necropsies and collect samples to isolate pathogens, or do slaughter checks to monitor the success of your protocols.

Finally, remember that biosecurity protocols will not work 100% of the time, just like vaccines do not prevent disease 100% of the time. The goal of your program should be to minimize the chance that your pigs will get infected by the target pathogen.

A Critical Look at Biosecurity Protocols

"Even if hundreds of authorities unknowingly make incorrect statements, they are still incorrect statements. Repetition does not transform errors into facts."-Carl A. Osborne

Biosecurity has become very popular in the past few years. Many articles on the topic have been published and many recommendations have been made. In some areas, there is no research and the only information that you will have is stories about how protocols worked on other farms. In other cases, you will be able to read scientific publications. However, there is no such thing as a perfect research project so critical reading of the science behind the recommendations is always advised. Biosecurity is a business decision and being informed will benefit your decision-making. When a protocol is recommended:

- Ask if the recommendation is based on science or opinion
- Ask if the research was done in the laboratory or in the field
- Ask for a copy of the original research
    - Were controls used?
    - Did the researchers account for other factors that could impact the results?
    - Were the study conditions natural or staged?
    - Do the results of the project support the conclusions?
    - Has the study been repeated with the same results? How many times?
    - How transferable do you believe the results will be to your farm?

Next, some biosecurity procedures and the science behind them will be discussed. The goal of this section is to present information to help you design biosecurity protocols for your farm. Not all of the procedures will be applicable for every farm for reasons stated above.

Minimizing the risk of aerosol transmission of pathogens. Many swine pathogens can be detected in the air of swine buildings. However, pathogens must be able to survive for a certain amount of time in aerosols in order to be spread by air. Survival of swine pathogens in air is dependent on pathogen numbers, temperature and humidity. Each pathogen will have a set of environmental conditions that allows for their best survival. Some pathogens survive longer in warm temperatures and some prefer cold temperatures. The same holds true with humidity. Some pathogens prefer high humidity while others survive better in a drier environment. Most swine pathogens will survive for at least a few minutes in air. In laboratory experiments, duration of survival in air was 15 hours for swine influenza virus [1], at least 5 minutes for *Streptococcus suis* [2], and at least 2 hours for *Salmonella* [3].

Another unproven factor that could affect aerosol transmission is the presence of dusty conditions. *Streptococcus suis* [4], rotavirus [5], *Salmonella* [6] and other organisms have been isolated from dust. *Streptococcus suis* survived up to 25 days in dust at 48°F [4].

Contamination of air is extended in buildings in which infected pigs are continuously shedding organisms. One study found that the concentration of organisms isolated from the air of one mechanically ventilated and one naturally ventilated swine finishing barn did not differ. Barns were stocked at a density of about 7 square feet per pig [7]. Pathogen transmission by air probably has the greatest chance of occurring when there are a large number of infected pigs, shedding high numbers of pathogens to the air, during environmental conditions ideal for that pathogen's survival. The distance that pathogens can be transmitted by aerosol is widely based on anecdotal evidence and computer modeling. Experimentally, pathogens rarely travel more than 2 miles in the air.

A couple of studies have assessed the risk of aerosol transmission. One study reported that farms located within 1.24 miles of more than four other farms were almost three times more likely to experience two or more respiratory disease outbreaks per year than farms located within 1.24 miles of less than or equal to four other farms [8]. Another study reported that herds within 2 miles of an infected herd had the highest risk for aerosol transmission of Mycoplasma hyopneumoniae [9].

Biosecurity practices that could be used to minimize the risk of aerosol transmission/infection between farms include locating in a low pig density area at least 2 miles from other swine or manure spreading locations. Other practices mainly influencing within farm aerosol transmission include dust reduction protocols (adding fat to feed), maintaining relative humidity < 60%, and optimizing ventilation systems [10].

Minimizing the risk of pathogen transmission when introducing new pigs or new genetics. The easiest way to bring a pathogen to a herd is by introducing infected stock to that herd. Limiting the number of semen and pig sources can minimize the risk of pathogen introduction to a herd because you probably have a smaller number of different diseases among a small number of source herds, as compared to a larger variation of diseases from a large number of source herds. Herds purchasing stock from more than one source per year were almost three times more likely to become infected with Mycoplasma hyopneumoniae than herds purchasing from a single source [11]. Introduction of semen instead of live boars can reduce the risk of pathogen introduction [12] but semen still can offer a biosecurity risk.

Veterinarians of the source herds and semen suppliers should work together with those of recipient herds to determine the health status and testing procedures needed to minimize risk of disease introduction. Aggressive selection, observation, and testing of new pigs with implementation of isolation and acclimation protocols can minimize the risk of disease introduction. Isolation protocols allow time for you to observe pigs to see if they will show signs of disease. Diseases have incubation periods. The incubation period is the time between when an animal becomes infected and when that animal shows signs of disease or in the case of unvaccinated animals, indicates exposure by seroconversion. In some cases, many days may pass before an infected animal shows signs of disease. One model estimated that six to 30 days would pass before clinical signs of Transmissible Gastroenteritis were detected in a herd after the introduction of a single carrier pig [13]. Isolation also provides an opportunity to test/retest the animals for exposure to diseases of concern. The acclimation period gives you time to vaccinate the new stock for diseases that are currently on your farm. Remember, pigs in your herd can get infected from the new stock, but at the same time the new stock can get infected from the pigs in your herd.

If we use the data from the aerosol transmission work, the isolation facility for new pig arrivals should ideally be located at least 2 miles away from other pigs including your herd. This is rarely practical. Therefore, try to locate the isolation facility as far from other pigs as possible. The duration of isolation will vary and should be based on the maximum incubation period for the pathogen(s) of concern. The last dose of vaccine should be given at least 2 weeks before the new stock is introduced to your herd. This allows a reasonable amount of time for the pig's immune system to produce antibodies and develop some immunity against the pathogen for which you are vaccinating.

Minimizing the risk of pathogen transmission using pig flow. Pigs can become infected through direct contact with their dam or other pigs. Usually, older pigs are colonized by more organisms so older pigs can be the source of infection for younger pigs. An excellent example of this occurs in continuous flow units. Younger pigs are constantly exposed to older infected pigs and diseases cycle within these rooms.

Pig flow can be used to prevent contact among different ages of pigs. For example, sow-to-pig transmission of certain pathogens can be minimized using early weaning, age segregation, and strategic medication or vaccination as needed [14]. The theory behind early weaning is that the piglet consumes colostrums which protects the piglet from some of the pathogens that the sow carries for the short amount of time the piglet is directly exposed to the sow. If the pig is moved to a clean pathogen-free environment while it still has colostral protection, transmission of some pathogens from sow-to pig can be prevented or minimized. In some cases, for example, Streptococcus suis, early weaning does not prevent transmission because the pig is already infected at birth. In other cases, early weaning just lowers the dose of pathogens transferred to the pig so the pig becomes a carrier, but does not show signs of disease. If you already have a high health status herd using weaning ages greater than 17 days, a switch to early weaning probably will not benefit your herd, and can hurt your herd in terms of reproductive performance.

Age segregation can be used to minimize pig-to-pig transmission. Pigs, as close to the same age as possible, can be grouped together and moved as cohorts through the system. All-in, All-out production allows for cleaning and disinfecting in between groups of pigs so if a disease does break you can contain the infection and prevent transmission to the next group of pigs.

Parity segregation uses the same theory. Most information on parity segregation is anecdotal at this time even though some farms have been using the protocol for over 10 years. In parity segregation, gilts are separated from sows that are P2 and older. This provides time to better develop immunity in gilts before they become infected with pathogens shed by older sows. Also, the pigs from gilt litters are separated from pigs from litters of older sows. The immune system of the gilt might not be as protective as the immune system of the sow because the gilt has been exposed to fewer pathogens. Thus, gilts might infect their pigs or more likely fail to protect her piglets from some of the pathogens shed by older sows. Also, the pigs from gilt litters might be infecting the other pigs in the nursery. Again, the system is mostly based on anecdotal and individual farm data at this time.

Minimizing the risk of pathogen transmission by people. People have the potential to transmit swine pathogens. Mechanical transmission occurs when a person contacts infected pigs or contaminated facilities, becomes contaminated with the pathogen, and then tracks the pathogen around the farm. Biological transmission can occur with pathogens that infect people and pigs. A person that is sick with the pathogen can potentially shed that pathogen to the pigs that they contact.

Mechanical transmission of *E. coli*, foot-and-mouth disease virus (FMDV), and TGEV by people has been demonstrated. Under experimental conditions, decontamination methods were sufficient to prevent such transmission without the need for downtime. Showering and donning clean outerwear was effective in preventing transmission of *E. coli* by people, but hand washing and donning clean outerwear was not effective [15]. Showering and donning clean outerwear prevented the mechanical transmission of FMDV by people. Hand washing and donning clean outerwear reduced the dose of FMDV transmitted by people to below the infectious dose for pigs but a sheep-infectious dose was still transmitted [16]. Hand washing or showering and donning clean outerwear both prevented mechanical transmission of TGEV [17].

Presumably, showering and handwashing both remove contamination, but showering appears to do a better job. Handwashing lowers the dose of pathogen but might not lower the dose sufficiently to prevent pathogen transmission. No set time is recommended for hand washing or showering because the time needed will depend on the extent of contamination. A good rule of thumb, is to wash until you do not see any visible contamination. The efficacy of medicated soap varies depending on bacterial type [18]. Alcohols are not effective on visibly contaminated hands [19] Wearing gloves can decrease the gross contamination of hands but does not prevent the need for hand washing.

There is little evidence to defend contact restrictions between personnel working at different swine farms as a biosecurity practice. Transfer of FMDV between people was documented after persons in contact with infected animals spoke to unexposed colleagues in a box for 4 minutes [20]. Circumstantial evidence of transmission of swine influenza virus (SIV) among people has been documented but not definitively proven [21, 22]. In contrast, a young boy infected with SIV that lived on a swine farm did not transmit the virus to his parents or to his five siblings, despite close contact [23].

Swine herds with > 2000 pigs in California reported that they were contacted by people and vehicles that had contacted other livestock facilities between 374.9 to 1239.5 times per month with an average indirect contact rate of 807 times per month [24]. Preventing unnecessary contacts with people should minimize the risk of pathogen transmission by people. Limiting farm access to essential personnel is one method of controlling human contact. Security measures such as perimeter fencing and monitored entrances can also be used to prevent unauthorized access of people to your farm.

Minimizing the risk of pathogen transmission by wildlife and pests. Rodents, birds, stray dogs and cats, wildlife and insects can become infected with swine pathogens. Mechanical transmission by these animals can be of greater concern. Control of pests is especially difficult in outdoor systems. Professional exterminators can assist you with difficult situations. Facility upkeep such as controlling vegetation around the unit and good sanitation such as cleaning up feed spills, promptly removing garbage, and prompt carcass disposal can make your unit less attractive to pests.

Minimizing the risk of pathogen transmission by fomites. Fomites are objects such as trucks, snares, feeders, etc that can become contaminated with pathogens. Survival of an infectious dose of a pathogen on fomites and subsequent transmission to a susceptible host is dependent on many factors. Some pathogens do not survive for very long outside of the pig. Others can survive for weeks or longer in manure. Most fomite research uses experimental conditions in which researchers place a pathogen on a surface and then measure how long the pathogen survives on that surface. For example, researchers studying human influenza virus took pure cultures of influenza virus and spread them on countertops. Then, researchers asked people to rub their hands for 3 seconds on the spot where they had just placed the virus. Researchers cultured the countertop and found virus (of course they did, they put it there). They also found virus on people's fingers (of course they did, they asked people to place their fingers in the virus). Finally researchers concluded that people could become infected with influenza by touching countertops [25].

As you can see from the above example, such experiments may not reflect actual conditions because the pathogen may not be found on these surfaces in real life or the pathogen may have such a low probability of being found on the surface in the amount needed to cause infection that the risk is negligible. Thus, the first step to developing a protocol on your farm for decontamination of fomites should be to test fomites of concern for specific pathogens. Then, if you find a pathogen, you can test various decontamination protocols to determine which protocols work best on your farm. When, testing for pathogens, it is important to use virus isolation or bacterial culture so that you can be assured that the pathogen was alive. PCR testing does not tell you if the pathogen was alive or not. For example, if you place a bunch of dead Salmonella on a fomite, the *Salmonella* cannot infect pigs. If you test this fomite for Salmonella, the test will be PCR positive but culture negative. If you look at the PCR results, you might think that Salmonella is a risk, when in fact, there is not risk of infection.

Preventing contact with contaminated fomites is the best method to minimize risk. For example, farms with parking for livestock vehicles located within 300 meters of the livestock buildings were almost ten times more likely to become infected with *Mycoplasma hyopneumoniae* or *Actinobacillus pleuropneumoniae* than farms with no parking site near the farm [26].

Good sanitation is the best method to minimize fomite contamination and to reduce the likelihood that fomites are the source of an infection. Disinfectant efficacy varies. There is no single disinfectant that will work on every farm. There is no single disinfectant that will work on every disease. There is no best disinfectant. The most important step in sanitation is to remove all visible contamination from the fomite (equipment, vehicle, facility) to be disinfected. Disinfectants do not work on dirty surfaces. Then, select a disinfectant that has a label claim against the pathogen that you are trying to kill. The label claim states that laboratory testing was performed to show that under ideal conditions, the disinfectant was able to kill the pathogens. If there is no label claim, the only evidence that you have that the disinfectant might work is the word of the person selling you the disinfectant. Moreover, just because the label claim says that the product is effective under laboratory conditions does not mean that the product will work on your farm. The next step is to try some of these disinfectants on your farm. Disinfectants should be prepared and applied according to label directions. The contact time recommended on the label should elapse (usually 10 minutes). Dipping objects in disinfectant generally is not as effective as scrubbing or wiping an object with disinfectant. Once you have disinfected a fomite, you have two options. You can continue to use the disinfectant until a pathogen becomes a problem or you can test the fomite to see if the disinfectant actually killed the pathogen of interest. If a disinfectant fails, the first thing to check is if the fomite was cleaned properly prior to disinfecting. If cleaning was sufficient, the next step is to culture the surface to see if the pathogen survived the disinfectant process. Inactivating residual disinfectant on your swab sample immediately after sampling is crucial to getting good results. Otherwise, the disinfectant continues to try to kill the pathogen during transport to the laboratory and during culture. This can result in a false sense of disinfectant efficacy.

Vigilance. Regular monitoring of pigs for signs of infection should be part of everyone's biosecurity program. The sooner that the disease is diagnosed, the better chance you have of preventing spread of the disease to other pigs. Checking pigs twice a day for signs of sick animals, death loss, fever, discoloration, decreased feed consumption, lameness, and blisters is important to catch a disease outbreak as soon as possible. Having personnel "walk" the barns each day (allocate specific amount of time that should be spent and record observations) is more reliable than an occasional "how do the pigs look?".

Record Keeping. Record keeping will not prevent a disease outbreak. However, good records can help you trace the source of the outbreak and decide which biosecurity procedures could have helped or which could be needed to prevent future outbreaks.

Summary

Every farm will have a unique biosecurity program. Biosecurity protocols should be selected based on science and on-farm efficacy trials. Periodic review of your biosecurity program is recommended. Your veterinarian can collect blood samples for serology to see if your animals have been exposed to a pathogen, perform necropsies and collect samples to isolate pathogens, or do slaughter checks to monitor the success of your protocols. Facilities, equipment, pigs, and pathogens are constantly changing so procedures that might have worked in the past may not always be effective. Moreover, new scientific studies reveal new or more effective protocols. The effectiveness of even the soundest protocol to prevent pathogen introduction and transmission is dependent on protocol compliance by personnel. Optimization of environment, nutrition, management and strategic vaccination is still probably the best way to prevent many diseases and minimize subsequent losses in a swine herd.

Literature Cited

1. Mitchell CA, Guerin LF. Influenza A of human, swine, equine and avian origin: Comparison of survival in aerosol form. C*an. J. Comp. Med.* 1972;36:9-11.

2. Madsen LW, Aalbæk B, Nielsen OL, Jensen HE. Aerogenous infection of microbiologically defined minipigs with *Streptococcus suis* serotype 2. Acta Path. Microbiol. Immunol. Scand. 2001;109:412-418.

3. McDermid AS, Lever MS. Survival of *Salmonella enteritidis* PT4 and *Salm. typimurium* Swindon in aerosols. *Lett. Appl. Microbiol.*1996;23:107-109.

4. Clifton-Hadley FA, Enright MR. Factors affecting the survival of *Streptococcus suis* type 2. *Vet. Rec.* 1984;114:585-587.

5. Fu ZF, Hampson DJ, Blackmore DK. Detection and survival of group A rotavirus in a piggery. *Vet. Rec.* 1989;125:576-578.

6. Eld K, Gunnarsson A, Holmberg T, Hurvell B, Wierup M. *Salmonella* isolated from animals and feedstuffs in Sweden during 1983-1987. *Acta. Vet. Scand.* 1991;32:261-277.

7. Predicala BZ, Urban JE, Maghirang RG, Jerez SB, Goodband RD. Assessment of bioaerosols in swine barns by filtration and impaction. *Current Microbiol.* 2002;44:136-140.

8. Rose N and Madec F. Occurrence of respiratory disease outbreaks in fattening pigs: Relation with the features of a densely and a sparsely populated pig area in France. *Vet. Res.* 2002;33:179-190.

9. Goodwin RFW. Apparent reinfection of enzootic-pneumonia-free pig herds: Search for possible causes. *Vet. Rec.*1985;116:690-694.

10. Stärk KDC. The role of infectious aerosols in disease transmission in pigs. *Vet. J.* 1999;158:164-181.

11. Jorsal SE, Thomsen BL. A cox regression analysis of risk factors related to *Mycoplasma suipneumoniae* reinfection in Danish SPF-herds. *Acta. Vet. Scand.* (suppl.).1988;84:436-438.

12. Bouma A. Transmissible virus diseases in porcine reproduction. *Reprod. Domest. Anim.* 2000;35:243-246.

13. Hone J. A mathematical model of detection and dynamics of porcine transmissible gastroenteritis. *Epidemiol. Infect.*1994;113:187-197.

14. Clark LK, Hill MA, Kniffen TS, Van Alstine W, Stevenson G, Meyer KB, Wu CC, Scheidt AB, Knox K, Albregts S. 1994. An evaluation of the components of medicated early weaning. *S.H.A.P.* 1994;2:5-11.

15. Amass SF, Halbur PG, Byrne BA, Schneider JL, Koons CW, Cornick N, Ragland D. Mechanical transmission of enterotoxigenic *Escherichia coli* to weaned pigs by people, and biosecurity procedures to prevent such transmission. *J.S.H.A.P.* 2003;11:61-68.

16. Amass SF, Pacheco JM, Mason PW, Schneider JL, Alvarez RM, Clark LK, Ragland D. Procedures for preventing the transmission of foot-and-mouth disease virus to pigs and sheep by personnel in contact with infected pigs. *Vet. Rec*. 2003;153:137-140.

17. Alvarez RM, Kelly JA, Amass SF, Schneider J, Ragland D. Evaluating the efficacy of protocols foe decontaminating tail-clipping instruments. *J.S.H.A.P.* 2002;10:209-211.

18. Puthucheary SD, Thong ML, Parasakthi N. Evaluation of some hand washing and disinfection methods in the removal of transient bacterial flora. *Malaysian J. Path*. 1981;4:49-55.

19. Centers for Disease Control and Prevention. Guideline for hand hygiene in the health-care settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. M.M.W.R. 2002; 51:1-34.

20. Sellers RF, Donaldson AI, Herniman KAJ. Inhalation, persistence and dispersal of foot-and-mouth disease virus by man. *J. Hyg*. 1970;68:565-573.

21. Top FH, Russell PK. Swine influenza A at Fort Dix, New Jersey (January-February 1976). IV. Summary and speculation. *J. Infect. Dis.*1977;136:S376-S380.

22. Wells DL, Hopfensperger DJ, Arden NH, Harmon MW, Davis JP, Tipple MA, Schonberger LB. Swine influenza virus infections. Transmission from ill pigs to humans at a Wisconsin agricultural fair and subsequent probable person-to-person transmission. *J.A.M.A.*1991;265:478-481.

23. O'Brien RJ, Noble GR, Easterday BC, Kendal AP, Shasby DM, Nelson DB, Hattwick MAW, Dowdle WR. J. Infect. Dis. 1977;136:S390-S396.
24. Bates TW, Thurmond MC, Carpenter TE. Direct and indirect contact rates among beef, diary, goat, sheep, and swine herds in three California counties, with reference to control of potential foot-and-mouth disease transmission. *Am. J. Vet. Res.* 2001;62:1121-1129.].

25. Bean B, Moore BM, Sterner B, Peterson LR, Gerding DN, Balfour HH. Survival of influenza viruses on environmental surfaces. *J. Infect. Dis.* 1982;146:47-51.

26. Hege R, Zimmermann W, Scheidegger R, Stärk KDC. Incidence of reinfections with *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumnoniae* in pig farms located in respiratory-disease-free regions of Switzerland- identification and quantification of risk factors. *Acta. Vet. Scand.* 2002;43:145-156.

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