

Swine Biological Risk Management

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Introduction

The purpose of this document is to serve as a reference for individuals involved in the swine industry to understand steps which can be taken to mitigate the risk of disease transmission. Biological risk management (BRM) is essential to all swine operations regardless of their size or mode of operation. Disease risk can never be completely eliminated. A full awareness of all risks is critical in mitigating threats of endemic, emerging, and foreign animal diseases. This document illustrates the best available “standard operating procedures” for a wide range of management practices. This is a working document that needs to be adjusted as new information is available.

The United States (U.S.) swine industry has undergone dramatic changes in the last two decades. Some of these changes have included a declining number of operations, increasing herd sizes, increasing sow productivity and farm specialization. Regionalization of the industry is also occurring with pigs fed to market in the corn belt, due to location of packers/processors and abundant grain, and peripheral areas (including North Carolina and Oklahoma) focusing in sow production.

The following graphs from United States Department of Agriculture’s (USDA) National Agricultural Statistic Service (NASS) data demonstrate the direction the industry has taken over the past several decades. The first graph includes years 1900- 2010 (Figure 1) and demonstrates the changes in the December hog inventories in the U.S. which do vary somewhat from year to year. The second graph includes years 1965- 2010 (Figure 2) and highlights the decrease in the number of farms with hogs, followed by an increase in the number of hogs per farm. These trends within the U.S. swine industry have a direct impact on and highlight the importance of mitigating disease spread within a farm, as well as between farms, as failures to control disease spread could have more costly consequences.

Since 1900, the total number of all hogs (breeding and market) in the U.S. based on December 1 inventory has generally fluctuated between 50 and 70 million with 2010 inventories being at just over 64.3 million. The lowest inventories occurred in 1934 with just over 39 million hogs and the highest occurred nine years later in 1943 with 83.7 million.

The total number of farms with hogs in the U.S. has been steadily decreasing. The number of farms dropped from 1.06 million farms in 1965 to 60,460 by 2010 (Figure 2). That is just over a 94% decrease in farm numbers in 45 years. During this same time frame, the average number of hogs per farm has increased from 48 to 1,064 head, an approximate 95% increase.

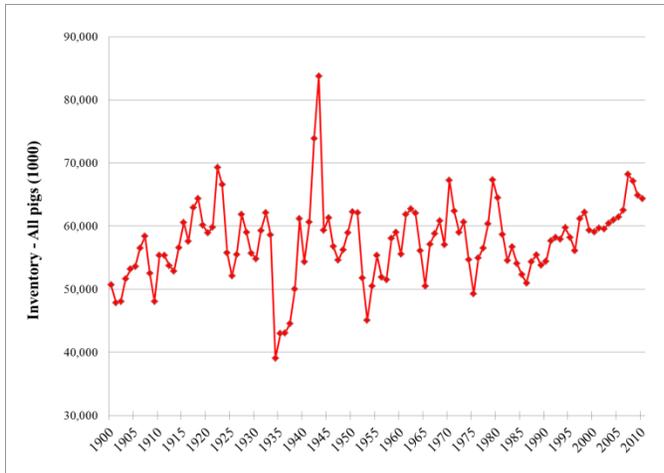


Figure 1
United States Department of Agriculture
December hog inventories for all pigs by
year from 1900 to 2010.

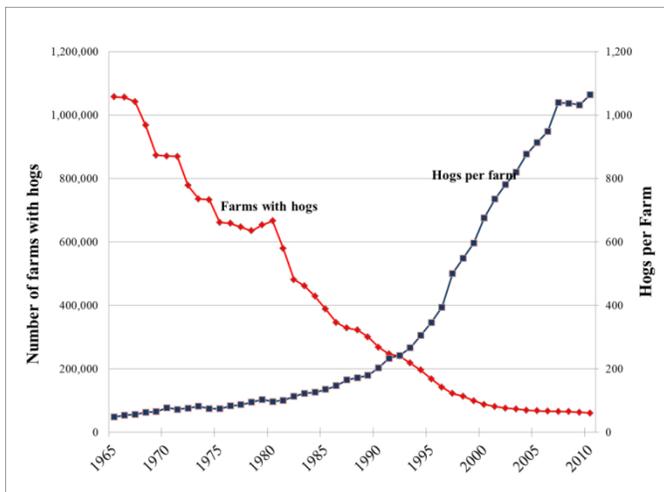


Figure 2
Number of farms with hogs and average
number of hogs per farm from 1965 to
2010 as reported by the United States
Department of Agriculture.

The swine industry is recognized as being proactive and innovative in regards to biosecurity measures. A 2008 study by Moore et al¹ identified the poultry industry as having the most extensive and consistent set of biosecurity recommendations available online followed by swine. The awareness of disease transmission is recognized by the industry, but unfortunately these practices are not always effectively implemented. With that in mind, it is best to address disease transmission from the perspective of biological risk management (BRM).

Importance of Swine BRM

The objective of the swine industry is to profitably produce a consistent, high quality, wholesome, and safe product for consumers around the world. The U.S. is the second largest pork producing country in the world, after China. In 2009, approximately 10,446,000 metric tons of pork, 10% of the world’s production, was produced in the U.S. According to data from the USDA Foreign

Agricultural Service in 2008, pork is the world's most widely eaten meat comprising 40% of the meat consumed worldwide.

Export markets have contributed to the profitability of the U.S. pork producer for several years.

According to the annual study conducted by University of Missouri economists Ron Plain and Glenn Grimes, exports contributed \$40.56 for every pig sold in the U.S. during 2008. One only has to look at the following table containing data from the U.S. Meat Export Federation to see how exports have increased over the past ten years.

Total U.S. Pork Exports 1999-2010		
Year	Volume (Metric Tons)	Value (\$Billions)
2010	1,917,649	4.781
2009	1,865,745	4.329
2008	2,052,447	4.884
2007	1,305,622	3.154
2006	1,262,499	2.864
2005	1,157,689	2.634
2004	1,023,413	2.227
2003	757,406	1.582
2002	726,357	1.504
2001	702,377	1.556
2000	581,497	1.347
1999	564,046	1.233

Total U.S. Pork Exports from 1999 to 2010, including variety meat, according to the U.S. Meat Export Federation.

The emergence of the pandemic H1N1 influenza strain caused exports in 2009 to fall below the record levels of 2008. However, 2009 exports were still above 2007 levels and continued to make a positive contribution to hog prices.

Zoonotic diseases are not the only diseases which can have a huge impact on the swine industry. In 1991, postweaning multisystemic wasting syndrome (PMWS) was identified for the first time in western Canada. The disease was characterized by wasting pigs, anemia, fever, enlarged lymph nodes, high morbidity (4 – 60%), and variable mortality (4-20%).² By 1997, PMWS was being reported as a sporadic condition in several locations throughout Canada and the U.S. At the same time, France and Spain were observing a similar syndrome which spread to other European countries. Soon it was reported that a different porcine circovirus strain (now called porcine circovirus type II or PCV2) was associated with this new disease.

This new syndrome appeared to be sporadic in North America, yet common in Europe. Clinical signs in Europe were observed in the nursery phase of production, while in the U.S. clinical signs associated with PMWS were more frequently documented in the early to mid-finishing phase of production. In the U.S., the swine industry initially ignored the problem, thinking it was just a “European” issue. Most hogs tested positive for PCV2 during the initial testing in the U.S., yet no clinical signs were being observed. Therefore, the conclusion was that PMWS was not important in the U.S.

While the European swine industry organized a significant research effort, the U.S. practically ignored the issue. The attitude of many practitioners was that the problem was not related to “our” industry. PCV2 submissions to the Iowa State Veterinary Diagnostic Laboratory increased from the late 1990 and peaked in 2002. This led many to believe the problem was over; especially considering it was never identified as a “major” issue of concern. Then, in early 2005, Canada started to experience a severe PMWS outbreak with high mortality. Initially, many in the U.S. were thinking this outbreak was just a late peak in cases for the Canadians; just like cases had peaked in the U.S. in 2002. By mid-summer, however, as health conditions in Canada deteriorated and large numbers of Canadian hogs continued entering the U.S. to be fed-out to market, the U.S. swine industry was in high alert.

This disease which had a significant impact elsewhere finally seemed like it was making its way to the U.S. Now, it was not a matter of “if” it will arrive in the U.S., but rather “when.” In November of 2005, many large operations in the U.S. noted a dramatic increase in early finishing mortality, starting in North Carolina where mortality was reaching 50 - 60% in some units. Within a few weeks, the PMWS epidemic was upon the U.S. industry. Many operations began averaging over a five-fold increase in their average mortality early in the finishing phase. At that time, no vaccines or treatment protocols could stop or mitigate the consequences of the syndrome renamed porcine circovirus associated disease (PCVAD). Although PCVAD is a multifactorial disease, it is believed that a small mutation in the PCV2 virus had a dramatic impact in the virulence of the pathogen. Why did we ignore this virus for so long? How did this virus spread so quickly across the U.S.? Many experts believe that biosecurity lapses in a highly interconnected industry are to blame.

The example of evolution of PCV2, the emergence of a more highly pathogenic strain in fall of 2005, is the best recent example of a non-zoonotic disease emerging from within the pork industry. As it emerged, the industry wide biosecurity measures were not designed or implemented in a way that

could prevent widespread distribution of the pathogen via trucking, infected semen or other routes of transmission. This example underscores the severity of health issues which can emerge and emerge suddenly.

Risk Perception

The category of risk perception examines what those involved with the industry think about the real and potential risks of infectious and zoonotic diseases. These perceptions may be influenced by on farm experiences, or by what owners, managers, and employees have read in magazines, on the internet, or in the paper. This is where one may encounter many of the obstacles and challenges to educating about risk management. Many individuals have negative perceptions associated with risk management, most of which are based around ideas of disbelief or economic concerns. Common negative beliefs include the following:

- I already know this information.
- We have always done it this way.
- I've already had most every disease on this farm.
- I don't have enough time to mess with this.
- It's too complicated.
- It won't make a difference.
- It's too expensive.
- I don't have the space.
- Our animals were tested once and we found nothing. It was just a waste of money.
- Our farm is pretty safe.
- I have a closed farm.

Risk of disease transmission cannot be totally eliminated, but attention paid to biological risk management can reduce risks and their consequences. While it is difficult to prove and measure the benefit of things that don't happen, counter-arguments tend to fall into three categories: there is a risk, it is economically worthwhile to prepare, and the overall impact must be considered.

- Infectious/zoonotic disease outbreaks can and do happen.
- Prevention is almost always less costly than treatment.
- Protecting your financial investment and your future assets from liability is worthwhile insurance.

- Protecting employees saves time and money.
- A biological risk management plan established and followed can reduce the risk of disease transmission to an acceptable level for minimizing disruptions in continuity of operation during and after a foreign animal disease event.
- A focus on preventative medicine helps to maximize public and environmental health of your community.
- Prevention of disease through awareness and management of infectious disease risk is an important part of improving animal welfare.
- Development and implementation of pro-active measures to address potential biological risks, such as infectious disease risks and other areas alike, are less expensive than reactive measures.

Risk Assessment

To increase its effectiveness and completeness, a comprehensive risk assessment should be performed from a variety of perspectives. First and foremost, the general herd characteristics and farm policies should be examined through pre-assessment questions in order to gather enough information to better understand the specific characteristics of that particular farm.

In reviewing this material, it is imperative to understand that attention is focused on routes of transmission, not specific disease entities. Assessing risk based on routes of transmission provides a more complete and holistic approach while avoiding emphasizing specific diseases. Any references made to specific diseases, syndromes or infectious agents in this material is for illustrative purposes only, and no specific recommendations are suggested as to vaccination, treatment or testing procedures. This focus will make the information applicable to a variety of audiences and remain relevant even as scientific advances improve our understanding of diseases.

Risk Management

This document illustrates the best available “standard operating procedures” for a wide range of management practices. For each production system, veterinarians and producers should engage to perform a thorough assessment of each operation to identify opportunities for improvement as well as their risk tolerance (risk they are willing to assume). Management practices and recommendations for systematic changes should focus on which ones are most important, most practical, applicable, and economically feasible. Most recommendations can be implemented independent of others. This

will result in tailoring the Biological Risk Management (BRM) program for each producer based upon current status of the operation, resources, quantified risk relationships and impact on the operation including risk tolerance. Some suggestions may not be feasible for a given facility; but recognizing what is optimum helps establish long term goals.

General Practices

Internal vs. External

Traditionally BRM is divided into external and internal risks. The objectives are different. When looking to mitigate external risks, the objective is to prevent the introduction of a new disease or strain into an operation. On the other hand, internal BRM is designed to minimize the spread of diseases which are already present within an operation. For the purpose of this paper, we will not make the distinction between internal and external BRM. Instead, our focus is the route of transmission. Veterinarians and producers may refer to internal vs. external risks when prioritizing the management recommendations identified pertinent to a particular operation based on their specific needs and goals.

Location

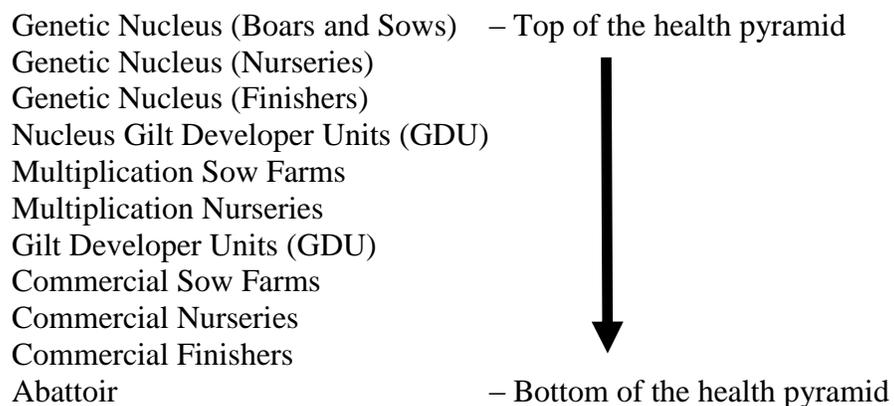
The farm/unit location is likely the single most important risk factor for new disease introduction. Although there is evidence that some bacteria and viruses may move by airborne routes, the actual range of spread by infectious particles or perhaps aerial vectors is unknown. The range of transmission is likely highly variable and dependent upon meteorological phenomena as well as local topography and will be discussed further under the aerosol section. We do know that in high pig density areas, disease agents often find their way to near-by locations even when stringent safety measures are in place (area spread). Epidemiological field studies often fail to confirm the source of new disease agents. We also know that indirect contact between the pigs and the outside world is greatly increased in these high density areas. In a recently published study, the number of direct livestock contacts (number of times animals were moved from one farm to another) per month for some pig farms in California was an average of 0.2/month, but the indirect contact rate (number of times people or vehicles that had visited more than one facility and therefore could act as fomites) was 807/ month.³ In areas of high pig density many, if not most, of the indirect livestock contact rate would be associated with pigs from other farms. Although in an ideal world one would select a location as far away from other pigs as possible (especially for higher health segments of the industry – see next section on health pyramids), many times this is not practical, feasible, or even an option.

High traffic areas (especially those used by others to transport pigs) can be a risk for aerosol transmission of different diseases. With the concept of BRM, one must realize the current limitations of all operations and concentrate on other ways one can try and mitigate disease transmission.

Iowa has been the number one state in pig numbers for many years. Because of this, most genetic companies have elected to locate their genetic nucleus herds outside this state. Locating these high health herds as far away from other pigs as possible minimizes the opportunity for exposure to swine pathogens through the air or area spread.

Health Pyramid

The swine industry has been proactive in establishing production pyramids to be able to produce high quality, high health status breeding stock. These pyramids are referred to as genetic or health pyramids. Technically, genetic pyramids focus only on the structure of genetic breeding (parents, grandparents, F1s, etc.), while health pyramids focus primarily on the health status of different operations. In essence, the concept is the same, and therefore we will address them simply as health pyramids. The number of operations in each category of a pyramid increases as you move down the pyramid. For example, one genetic nucleus can supply nine nurseries which may feed into 18 different finishers, etc. (1→9→18→etc.). The exact numbers are not important, but rather the concept that more operations are being impacted as you move farther down the base of the pyramid. The following diagram helps visualize a typical health pyramid.



The goal of a pyramid is to designate specific farms for specific production needs. Not only does this allow maximizing genetic pools, but also an opportunity to focus on health issues at these sites. As operations look at maximizing their investment returns, health pyramids help prioritize resources.

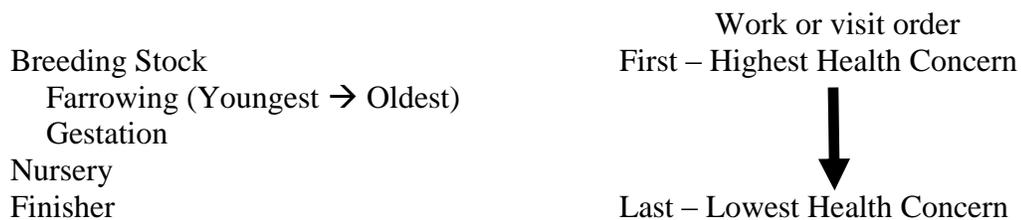
The hierarchal nature of the pyramid highlights a key biological risk management factor. The basis

for the continued success of a “disease free” herd relies primarily on its ability to continue to have a “disease free” source of replacement animals. The advent of a better understanding of the porcine reproductive and respiratory syndrome (PRRS) disease emphasized the importance of this key point. Because of this, all of the major genetic suppliers in the U.S. recognize that they needed to provide PRRSV naïve animals. There is a distinction between a naïve animal and a negative animal. The definition of a naïve animal is an animal that has never been exposed to a particular disease agent. A negative animal just implies that the animal tests serologically negative. However, this particular animal could have, at one time, been exposed to a particular agent and has become serologically negative over time. We have also realized within the past 15 years that not all positive animals are equal. This is especially true when looking at diseases such as PRRS in which there are multiple strains circulating. Just because an animal has been exposed to a particular strain does not imply in any way that it would be resistant or less susceptible to a different strain. Herds that are negative do not provide the same sense of safety as a naïve herd. With non-naïve herds, there is always the question of whether they are truly negative or just have a low incidence of disease which is not being detected through routine monitoring programs. Because of this, heavy emphasis is placed on obtaining naïve replacement animals.

Through the development of health pyramids, the industry has created a method to become more efficient at producing healthy replacement animals, but has also opened themselves up to a risk of disseminating new diseases to a larger number of operations. The use of a centralized location for producing replacement animals requires the dissemination of these animals to several other respective farms. So, in other words, a single genetic nucleus farm can provide replacement animals to several dozen commercial sow farms. A leak of an undetected infectious agent from the genetic nucleus to several dozen different sow farms can then spread the disease to many more nurseries, which can then spread the disease to a larger number of finishers. To minimize this cascading effect, operations must implement monitoring programs in order to quickly detect the emergence or re-emergence of any disease of concern. The earlier a disease is detected, the quicker a new plan can be implemented to redirect pig flow, so as to minimize the consequences of a disease break downstream.

This health pyramid concept is also applicable for all swine operations when establishing work orders (or visit sequence). Although small operations might not be relying on a different location for providing their replacement animals, they can utilize the same concepts in establishing animal and people movement within their operation. Work order could be related to the health status of a

particular stage of production within a farm. At the top of this “health pyramid”, we would have the breeding herd. Within the breeding herd, we prioritize the healthiest animals as those in the farrowing house, followed by the gestation animals, nursery animals, and finally the finishing animals. Within each of these groups of animals, we prioritize health from youngest to oldest. The older animals are more likely to have been exposed to more disease agents; and therefore, we would consider them to be a lower health risk. The concept again is the same. We are trying to minimize the downstream effects of disease by controlling disease toward the top of the pyramid. So, our work order in this case would be as follows:



This work order would change if the health status of any one of the groups changes so as to visit any potentially infected animals last, thereby minimizing the opportunity for spreading disease to other groups. In some gilt supply systems, they prefer to visit animals closest to shipping (oldest animals) first to minimize the opportunity for any new disease introduction (especially if not yet detected) to affect animals that are ready to be shipped. Frequent changes to the order of flow/ work patterns also can pre-dispose to spreading of agents.

Routes of Transmission

Pathogenic agents can be spread from animal to animal, animal to human, or human to animal through a variety of transmission routes. Animals or humans can acquire disease causing agents through aerosol, oral, direct contact, fomites, or vectors. Pathogen exposure to swine can occur in any of the aforementioned methods, and many times it occurs in more than one way. Many disease agents can survive for extended periods of time in dust or organic matter. This survival time is specific for each pathogen and dependent on many factors including temperature, light exposure, humidity, and environmental pH. While environmental contamination is not a route of transmission in itself, it must always be considered when developing a BRM plan. Each route of transmission will be discussed separately, and some general management/control strategies will be included. Training and mindsets are important aspects of the system approach to BRM, as important as infrastructure and facility design.

Aerosol

Survival of swine pathogens in air is dependent on the pathogen load, temperature, and humidity. Most swine pathogens will survive for at least a few minutes after a point exposure to air. Influenza A virus (IAV) has been reported to survive for 15 hours in air.⁴ The duration of air contamination is extended in buildings in which pigs are continuously shedding organisms. Foot-and-mouth disease virus was detected in air for 5 days,⁵ and porcine respiratory coronavirus was detected in air for 6 days in rooms housing infected pigs.⁶ The distance that pathogens can be transmitted by aerosol is widely based on anecdotal evidence and computer modeling.⁷

Airborne transmission of pathogens is facilitated by prevailing wind velocity and direction, cloud cover, and humidity.⁸ Increasing the distance between infected and susceptible animals will decrease the chances that transmission will occur because pathogen concentration in air decreases exponentially with increasing distance. Increasing distance between hogs within an operation, between other operations, wildlife, and newly introduced animals will help minimize exposure by the aerosol route. The distance that pathogens can travel and be transmitted by aerosol is not completely understood, but experimentally, pathogens rarely travel more than 2 miles in air.⁷ Herds within 3.2 km of an infected herd had the highest risk for aerosol transmission of *Mycoplasma hyopneumoniae*.⁹ Farms located within 1.25 miles of > 4 farms were almost 3 times more likely to experience two or more respiratory disease outbreaks/year when compared to farms located within 1.25 miles of ≤4 farms.¹⁰ Environmental and management practices are the most consistent means of control against respiratory disease, the main type of disease transmitted by aerosol.⁸

Proper indoor air quality and ventilation practices, which dilute and remove harmful contaminants from buildings, are important for swine health and well-being.¹¹ Proper ventilation reduces dust and feed particles in the air. These particles can carry bacteria and viruses and can increase aerosol transmission of disease.^{11,12} Dust reduction protocols can be implemented, such as adding 1% fat to feed or sprinkling oil on building surfaces, to decrease bacteria levels.^{13,14} It is important to ensure adequate air flow from a fresh source, thus displacing air that has high concentrations of organisms.⁸ Utilizing proper ventilation to keep humidity low (40-70%) can reduce the water droplets available for pathogens to travel in.^{8,12} Aerosol droplets carrying infectious agents in a low humidity environment will not allow the organisms to live; however, in an environment with moderate humidity, the pathogens can remain infective.¹⁵ At high humidity levels, the droplets will pick up water, increase in size, and precipitate out of the air, thus making it easy for transmission of the

organisms.¹⁵ Overall, air quality depends on a number of factors including density, the cubic capacity of the building, the lower and upper critical temperatures, concentrations of gasses and levels of dust in the building.¹⁵ Air quality can be monitored based on the content of certain gasses, particulate matter, and airborne microbes in the air around or in swine facilities.¹¹

Air filtration systems are currently being used in higher health status herds (especially boar studs and high risk areas) to help minimize aerosol transmission of PRRSV. The use of HEPA (99.97% DOP at ≥ 0.3 microns) filters in Europe and MERV 16 filters (95% DOP at ≥ 0.3 microns) in the U.S. have been quite successful in several operations. High Efficiency Particulate Air (HEPA) and Minimum Efficiency Reporting Value (MERV) are standardized ways to rate the effectiveness of air filters with HEPA filtration having higher standards based on dispersion oil particulate (DOP) testing rate. The PRRSV is approximately 0.065 microns in diameter which is much smaller than the HEPA or MERV filters can handle. But more important than particle size is how the virus is transported in aerosols. Bioaerosols, generally 0.4 – 0.7 microns in size, will be filtered out by these systems. The cost of implementing an air filtration system including initial construction costs is between \$180 - \$200 per sow or boar.¹⁶ The use of filtration systems in grow-finish buildings is rare today due to the high costs. As new and cheaper filter alternatives are developed, the use of this technology may dramatically increase. The implementation of these filtration systems also requires a thorough understanding and appropriate modification to an operation's entire BRM program as aerosol transmission of disease is not the main or only way for disease transmission to occur.

Oral

Oral transmission can occur through the consumption of contaminated feed, water, feces, or any item in the environment that pigs may contact via their mouth. Feed and water troughs/feeders, pen gating and other objects that pigs can gain access to and lick can serve as means for disease transmission via the oral route. As a general rule, viruses do not replicate outside animals as they require living host cells, but some bacteria can replicate quickly. The average time for many bacteria to double in numbers is approximately 20 minutes, and an organism like *Salmonella* can increase in numbers from one organism per mL in liquid feed to up to 200,000 organisms per mL in just 48 hours at 82°F.¹⁷ The goal of mitigating oral transmission of disease involves minimizing or eliminating the opportunity for oral exposure to occur, as well as minimizing the pathogen load (fewer exposures with fewer organisms each time).

Colostrum

Piglet survival is highly dependent on receiving an adequate amount of colostrum from the dam. Consuming colostrum which contains large amounts of the dam's antibodies provides protection to the piglet during its first few weeks of life. Colostrum would not be as important if we were able to place young pigs into a pathogen free environment. But that is not possible in the production system. Therefore, ensuring adequate colostrum intake helps to protect the piglet by providing immunity against some of the pathogens in the environment. In an ideal world, every dam would produce enough colostrum for all her piglets, and every piglet would consume enough colostrum to provide adequate protection. However, in some cases, the dams do not milk well or piglets do not nurse. Care needs to be taken when cross fostering piglets. While this management technique has advantages of evening out litters, it also has a major health disadvantage of spreading disease. Many experts would advise against cross fostering after the piglet is 24 hours old. After 24 hours, the piglet may no longer absorb colostrum from the dam to protect it against the pathogens that the nurse sow could be shedding.

Feedstuff

Feed can serve as a possible source of pathogens (viruses and bacteria) as well as mycotoxins (toxins produced by fungi). All operations should be very careful about acquiring products from clean sources, transported in clean trucks as well as making sure that all diets are properly formulated to meet all macro and micro nutrient needs; no deficiencies or excesses which can cause detrimental health effects. Operations need to ask their feed providers which procedures/tests are implemented on their end to ensure source ingredients are not contaminated. Their testing protocols and frequency of testing are also important to know and verify (ask for reports). Operations also need to have their own protocols for collecting feed samples from every feed delivery as well as a mechanism for periodic testing for pathogen contamination including mycotoxins. Feed suppliers should have HACCP (Hazard Analysis and Critical Control Points) programs implemented to ensure product quality. Feed companies obtaining International Standard Organization certification (e.g. ISO 9000) are indications of verified high standards in production practices.

Distillers Dried Grains (DDGs)

From a disease standpoint, DDGs do not pose a risk of a disease introduction into a herd. However, when utilizing DDGs in a swine ration, producers do need to be concerned about nutrient balancing and the quantity of mycotoxins that may be present in the feedstuff. Mycotoxins, especially

aflatoxins, are known to suppress the immune system of animals, making them more susceptible to diseases. Mycotoxins are concentrated some 3 times in DDGs.^{86,87} Other mycotoxins such as zearalenone mimic estrogen, and therefore can present in a sow herd as a reproductive failure issue that is non-infectious.

Food Waste (Garbage) Feeding

Feeding human food waste or garbage to livestock has occurred over years evolving from a means to utilize household waste to utilizing food waste from restaurants, schools, and other institutions.¹⁸

According to the USDA, there were 2,783 licensed garbage feeders in the U.S. and nearly 1,964 in Puerto Rico (USDA-APHIS, VS, 2008). One concern related to feeding livestock food waste is the potential to transmit disease to the pigs, especially foreign animal diseases. Therefore, food waste to be fed to pigs must be heat treated as mandated by the 1980 Swine Health Protection Act. Heat treated garbage can only be fed from a facility in which the operator has a valid license for the treatment of garbage.¹⁹ However, regulations relating to food waste or garbage feeding can vary by state. In a state which prohibits the feeding of garbage to swine, a license under the Act will not be issued to any applicant.¹⁹ Therefore, in some states, feeding treated or untreated waste is against the law.²⁰

Diseases may be spread to other livestock or humans if swine consume contaminated meat in improperly treated food waste. Foreign animal diseases which may be transmitted to swine through food waste include classical swine fever, foot and mouth disease, African swine fever, and swine vesicular disease. Other pathogens of concern that could spread to humans are *Salmonella*, *Campylobacter*, *Trichinella*, and *Toxoplasma*. Food waste must be cooked as described below¹⁸:

- Food waste shall be heated throughout at boiling (212°F or 100°C at sea level) for 30 (thirty) minutes.
- It shall be agitated during cooking, except in the steam cooking equipment, to ensure that the prescribed cooking temperature is maintained throughout the cooking container for the prescribed length of time.

It is the presence of meat in food waste that necessitates cooking; all table or plate scraps resulting from the handling, preparation, cooking, or consumption of food require cooking before feeding to swine (except for those produced and fed upon household premises). The act does not require the cooking of non-meat food waste or byproduct items (such as bakery or vegetable waste).

In 2009, an Interim Rule was adopted concerning the Swine Health Protection Act. This rule added another type of material to the list of exempted materials. “Processed products” may be exempt from the cooking requirements. According to the rule, if industrially processed products contain meat, they meet the definition of garbage and must be heated throughout at boiling or an equivalent temperature for 30 minutes to be eligible for feeding to swine. In some cases, the procedures used to process such materials are controlled and monitored in such a way that it is possible to demonstrate that the materials have been heated throughout to at least 167°F for at least 30 minutes, making the additional “margin of safety” of heating the material boiling unnecessary.²¹

For production units utilizing food waste as a feedstuff for their animals, care needs to be taken to ensure the correct nutrient balance is maintained. In many instances, the type of the food waste on a day by day basis may vary and, hence, so does the nutrients included with that particular food waste. If pigs aren’t maintained on a correctly balanced diet, production can be poor and diseases may be more of a concern.

Spray-Dried Animal Plasma (SDAP)

The use of spray-dried animal plasma has become a nutrient source that more producers are trying. Concern has been expressed over the possibility of this nutrient source spreading disease to pigs. In a study published in the Journal of Animals Science in 2005, inclusion of SDAP in the diet improved growth of pigs without seroconversion. Spray-drying conditions used in this study were effective in eliminating viable pseudorabies and PRRSV from bovine plasma.²² Additionally, other studies have demonstrated that the higher drying temperatures for extended times eliminate viable pathogens for swine vesicular disease and classical swine fever viruses in addition to *Salmonella* and *E. coli* bacteria. Producers should make sure they acquire SDAP from a reputable source that has quality control measures in place to make sure drying temperatures and times are high enough to ensure viable pathogens have been eliminated.

Water

When considering the risk of water contamination, it is important to identify the source of water for each operation. Rural water sources are safe for drinking as water must meet specifications for human consumption. Deep well water is usually safe as natural filtering occurs. However, some deep well water can contain high levels of bacteria, which generally cause a digestive upset to animals (and humans) when first exposed to the new water source. The use of surface water (ponds, lakes, etc.) is a major concern for disease transmission from birds and other wildlife. Pathogens such

as influenza, leptospirosis, and avian tuberculosis are just a few that have been suspected to be transmitted to pigs through contaminated surface water.

Water chlorination is used as a way to help kill pathogens in the water. This is especially important when surface water is being used for drinking purposes on an operation. The process of water chlorination is simple, but it does require individual farm testing as the pH of water has a great effect on the ionization of the chlorine molecule. It is the free chlorine which is active against the bacteria and viruses. Routine testing of water chlorination on farm can be achieved through the use of swimming pool kits.

The use of individual nipple waters is more likely to minimize disease spread via water. Cup waters and especially troughs can serve as a source to spread pathogens between different animals. For example, PRRSV survived for 11 days in a water system after pigs left the facility.²³ The importance of disinfection between groups cannot be emphasized enough in order to prevent the spread of disease.

Bedding

In some production units such as hoop style structures, bedding is required. Bedding can serve as a source of pathogen introduction. The bedding, whether corn stalks, straw, wood chips or other material, needs to be from a pig-free source where it has been protected from birds and rodents. The bedding could serve as a vector for pathogens to enter a herd, as well as transmit a disease between groups. Care needs to be taken to remove all the bedding between groups, so as to prevent disease spread.

Although unusual, corn stalk bedding baled when containing high moisture may harbor high levels of mycotoxins. As discussed in the DDG section, high levels of mycotoxins can affect the immune status as well as reproductive performance of the animals housed with this bedding source.

Manure Handling

Decontamination of manure pits is not practical on a routine basis, but may be necessary to reduce the risk of pathogen transmission when manure pits are contaminated. Long-term storage of manure for at least six months at 4°C without addition of new manure should reduce virus titers by 1 to 2 log₁₀ units per month. The Federal Ministry of Agriculture in Germany provides two options. Forty to 60 liters of a 40% solution of lime hydrate per cubic meter of liquid manure can be used at

temperatures between 0 and -10°C. Sixteen to 30 liters of a 50% solution of sodium hydroxide per cubic meter of liquid manure can be used at temperatures between 0 and 10°C. Manure should be stirred prior to, during, and for 6 hours after chemical disinfection. The duration of exposure of manure to chemicals should be at least 4 days and preferably 1 week.²⁴ The PRRS virus can survive in lagoons for up to 14 days in 4°C,^{25,26} while IAV can survive up to nine weeks at similar temperatures. Some of the other pathogens that can survive in manure or lagoons include *Ascaris suum*, *Brachyspira hyodysenteriae*, Pseudorabies virus *Salmonella*, and Transmissible Gastroenteritis virus (TGE).

Direct Contact

Direct pig-to-pig contact is one of the most effective methods of disease spread. Litters may be combined in the nursery, pens are mixed in the grower and finisher, and sows and gilts may be penned together during part of the gestation period. Any time animals come into contact with other animals, disease may be transmitted. Disease transmission during pig-to-pig contact can be limited or minimized through a variety of management approaches. Limiting pig-to-pig contact helps limit the exposure to any pathogens which are being shed at that time. Management approaches may include vaccination, changes to pig flow such as all-in-all-out, herd closure, parity segregation, and isolation and acclimation procedures.

Vaccination

Vaccines are commonly used in swine production to mitigate the effects of disease and disease transmission. There are many different products available in many different formulations and all have different strengths and weaknesses. Vaccines can play a critical role in all BRM programs but it is important to remember that vaccines cannot prevent infection and therefore cannot be used as the sole prevention program. All pork producers need to work very closely with their herd veterinarian in determining which vaccines they should use as well as when they need to be using them as part of their BRM planning. It is also important to remember that pigs don't all respond equally to vaccination. This may be due to many reasons including, improper administration of the vaccine, nutritional differences, differences in stress levels, and simply biological variation in immune response.

Pig Flow

All-In-All-Out

All-in-all-out (AIAO) production is one of the greatest technologies that has been implemented in the swine industry, having had a tremendous positive influence on the health status of animals. The objective of AIAO is to group animals either on the basis of a room, barn, or site by which all animals in the group are completely moved out before the next group of animals is allowed to move in. Being able to practice AIAO by site is better than by barn which is still better than by room. In essence, this coordinated movement creates a break in pig flow. This break in pig flow is critical for several reasons, the most important being that the new pigs will not be in contact with the previous group. Pig-to-pig transmission is probably the greatest way to spread disease. By removing the previous group of pigs before the next group arrives, a break in pig-to-pig disease transmission is created. Having a break also allows the area that these animals occupied (room, barn, or site) to be fully emptied so that cleaning and disinfection can be performed and the room allowed to dry. Cleaning and disinfection will also be discussed in more detail later in the paper, but it is evident that by cleaning the environment and allowing it to dry, the amount of organisms the new group of animals could be exposed to is reduced.

AIAO management has proven to be economically beneficial due to the ability to limit disease spread from one group of pigs to another. AIAO production can improve the feed efficiency, weight gain, days-to-280 lbs, and respiratory health of pigs compared to continuous flow production. In a study by Scheidt et al (1995),²⁷ lung lesions at slaughter were 54% less prevalent and 80% less severe in pigs raised AIAO than the same source pigs raised under continuous flow conditions. Average daily gain and feed efficiency were also significantly better in the AIAO group. Other studies have shown that a \$1-\$5 savings per pig produced may be realized when using AIAO growing-finishing in remodeled facilities.²⁷

Continuous Flow

The opposite of AIAO is continuous flow in which animals are constantly being added to a group. With continuous flow production, buildings or rooms are not completely emptied before new animals are brought in. Producers vary with how they manage continuous flow production. When pens are emptied, the pens may or may not be cleaned, disinfected and allowed to dry before filled with new animals. Surrounding pens may remain filled with animals. So, while the pen may be AIAO, the entire room or building is not. Therefore, animals which remain in the room or building may shed

pathogens and infect the newly introduced animals. The reverse may also be true. The newly introduced animals may shed pathogens and infect the remaining animals. Typically, older animals have been exposed to more pathogens than younger animals. Therefore, when new younger animals are introduced into a continuous flow unit, these animals are exposed to the pathogens that the older animals are shedding. Diseases tend to cycle through these rooms. Disease can be difficult to control in a production unit when utilizing continuous flow methods. For this reason, AIAO of some form should be practiced **at all times**.

Off-Site Production

With the advent of AIAO production, it is important to create some separation by age with pig groups. Because of this, many of today's operations function with multiple sites each specialized in a different stage of production. From a BRM standpoint alone, ideally, one would be able to have two or three sites of production. Site 1 is considered the breeding and gestation herd. Pigs are kept on this site until weaning time; then they will move to site 2. In a wean-to-finish building, pigs will remain there until market. If site 2 is a nursery-only site, pigs are moved to a finishing site (site 3) at a later date. Being able to completely flow pigs AIAO by site in both nurseries and finishing buildings can be very beneficial in helping break disease cycles. Many operations are not able to flow completely AIAO by site and then have to rely on going AIAO by building. Finally, if AIAO by building is not possible, there are still advantages for trying to flow AIAO by room.

Early Weaning

Early weaning may include many different approaches such as isowean, segregated early weaning, and medicated early weaning. The concept behind early weaning is that the pig consumes colostrum from the dam which helps protect it against infection or disease. While the pig is protected with the antibodies from the colostrum, it is weaned and moved into a clean facility where it is less likely to be exposed to pathogens. If the pig remains with the dam, eventually the colostral antibodies will no longer be protective, and there is a greater risk of pathogen or disease transmission vertically from the dam to the pig. With that in mind, producers try to determine when the group of pigs can be taken from the dams and thrive on their own, while reducing the risk of becoming infected with pathogens from each dam. Several bacterial diseases have been eliminated in today's production systems through the early weaning of pigs. At times, pigs will be weaned as young as 7-10 days of age instead of 18-21 days of age. At weaning, pigs are moved to a separate site that has been treated as AIAO. Under special circumstances, early weaned pigs will be treated with antibiotics to maximize the probability of eliminating certain bacterial pathogens, termed medicated early weaning.

Production units that utilize early weaning do so as a method to control disease, and strict AIAO needs to be adhered to. It is important to realize that although some pathogens can be controlled or even eliminated through early weaning, others cannot (including PRRSV, *Streptococcus suis*, *Haemophilus parasuis*). Diseases not eliminated by early weaning are usually associated with infected fetuses being born (in-utero transmission) or transmission at the time of birth, such as in the case of *S. suis*.²⁸

Herd Closure

Of course, one way to eliminate disease introduction into a herd through replacement animals would be to close the herd. The concept of herd closure is just as it sounds. The herd would be closed to the introduction of new live animal genetic stock and to animals leaving and returning to the farm for any reason. As with any management approach, herd closure has its advantages and disadvantages. While closing the herd eliminates the introduction of disease through replacement animals and returning animals, the herd is unable to introduce new genetic stock. The herd would need to devise a system in which they produce all their own replacement animals. Semen can be utilized from outside sources, but in many cases, a herd would need to maintain two genetic lines. Semen from maternal lines may be used to produce replacement animals for the herd while semen from terminal lines would be used to produce market animals. Herd closure requires managing these two sets of animals differently in most cases. However, the benefit would be to eliminate disease entry from replacement animals.

From a disease standpoint, when a herd is closed to eliminate an existing disease, a key objective for herd closure is to eliminate susceptible populations (i.e. young pigs) on the same site. In this sense, herd closure will occur for a specific time period and cannot go on indefinitely as new breeding stock (either purchased or home raised) will need to be introduced at some time point. If a herd is to be closed to eliminate an existing disease, it must ship all weaned animals off-site during this period of closure. Even if this is a farrow-to-finish site, weaned pigs must be removed from the site. This will create a break in pig age which is critical in creating a gap in new susceptible animals. This break in susceptible animals is vital in eliminating the opportunity for the disease to find new animals to infect and therefore the disease will “burn out” with time. Proper planning to discuss how replacement animals can be managed is critical to the success of the operation. Having off-site locations where replacement gilts can be developed and possibly even be bred can help minimize breeding herd down time. A key consideration will be evaluating the risk of having off-site animals exposed to different disease or strains.

The duration of the herd closure for disease purposes will be dependent on the pathogens that are targeted for control/elimination. For example for PRRSV, many have identified that 200 days from the last known exposure is needed for better success rates. That means that for 200 days, no animals will be allowed to enter the herd. Herd closures for less than 200 days can be successful, but field reports indicate they are less likely to be successful.

Parity Segregation

Parity segregation involves separating gilts from sows. The pigs from gilts' litters are also separated from sows' offspring in the nursery. Production units that practice parity segregation do so out of concern that the gilts' pigs may be infected with more pathogens than older sows' pigs. If the older sow has been exposed to more pathogens and has built up better immunity, she will pass that protection on to her piglets in the colostrum. However, a gilt, which has not been exposed to as many pathogens, may not pass the colostrum protection on to her pigs.

Providing sufficient facility space is a limiting factor for some production units when considering parity segregation. The success of parity segregation can be maximized by keeping the offspring from these gilts separate from older parity offspring throughout all of the growing phases.

Replacement Animals and Animals Returning to the Farm

When replacement animals need to be introduced into a herd, care should be taken to reduce the risk of disease introduction to the main herd. Anytime new animals are brought into a herd, a risk of disease introduction is possible. Veterinarians should always conduct a "Vet-to-Vet" consult before any new animals are purchased for additions to a herd. Although many times PRRSV and Mycoplasma are the current main agents of concern, there are many other pathogens such as Salmonella, APP, etc. that also need to be considered. This is especially true regarding breeding stock animals. Introducing animals from any exhibition is strongly discouraged. During the exhibition, animals are exposed to a large number of other pigs as well as humans which can all pose as a source of infection to pigs at the show. A study of Australian pig shows in 2006 indicated that pigs were 40 times more likely to be fed swill (human food including meat) by the public than by staff or exhibitors even considering concerns of introducing foot and mouth disease and classical swine fever in that country.²⁹ Awareness of human influenza transmission from humans to pigs was raised in 2009. Not only was there concern that pigs carry influenza and could possibly transmit it to people, but also the pigs could be exposed to influenza from the human visitors. Animals returning home or replacement animals introduced into a herd can carry new pathogens or isolates onto the

production site. Protocols need to be in place and followed to minimize the risk of a herd becoming infected with one of these pathogens. Incoming animals should never be allowed to enter into the herd directly and be co-mingled with herd animals.

Of course, the risk of exposure varies with the potential pathogen. However, one has no way of knowing which pathogens other animals may be shedding at an exhibition. When purchasing replacement animals, sellers should provide information on the health of the swine, such as routine vaccination and worming procedures, and diagnostic results, so that their suitability for the herd can be assessed; and where necessary, appropriate treatments and vaccinations administered. This information is usually obtained from a “Vet-to-Vet” consult.

When either a herd purchases replacement animals from more than one source or exhibition animals return home from multiple shows, the risk of pathogen exposure increases for the herd. For example, studies have shown that 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.³⁰ A study by Maes et al (2001)³¹ also identified frequency of gilt replacements as a risk factor for lung lesions at slaughter house in farrow-to-finish herds.

While incoming animals may not appear to be showing any signs of disease, they may be carrying the disease, otherwise known as incubation, or have subclinical disease. The incubation period is the time between when an animal becomes infected and when that animal shows signs of disease. 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 TGE were detected in a herd after the introduction of a single carrier pig.³² Isolating incoming animals prior to introduction into the herd minimizes the risk of disease entry.³³ The duration of the isolation period can vary greatly between farms but should always be a minimum of 30 days. Factors which determine the length of the isolation period include the health of the farm from which the replacement animals come and the health status of the receiving farm. Animals returning from an exhibition could be exposed to a large number of pathogens, therefore, making their isolation period longer. During isolation, animals can be observed for clinical signs of disease, tested for pathogens they may be carrying, and acclimated to organisms already present in the breeding herd.³³ Diligence needs to be taken when caring for animals in isolation. Because they may be carrying and shedding various pathogens, employees responsible for these animals need to take care of them at the end of the day and not return to the main herd until the following day. Separate coveralls and boots may be left at the facility. Hand

washing is also very beneficial. Equipment utilized in the isolation facility should remain there and not be utilized in the other buildings, so as not to risk carrying diseases on the equipment from isolation animals to those in the main herd.

Where should an isolation facility be located in relation to the main herd? This is a great question which has been debated with no scientific data to give a precise location. On some production sites, the isolation unit is located in a room of one of the buildings or may be its own separate building located off site. Keeping some physical separation is helpful in emphasizing these units need to be treated differently. Unfortunately, the layout of the site might restrict the separation distances as well as the actual location for this facility. No matter what the location is, many experts do agree that the isolation facility should be treated as being separate from the main herd. Therefore, this facility should have its own feeding system, manure disposal, and attention to the personnel caring for the animals. Farm staff should check on these animals at the end of the day, on their way home so as to not go back to the main farm again for that day.

While placing animals in isolation helps to protect your herd, those newly introduced animals can also become infected with pathogens present on your farm. Acclimatization introduces new breeding stock to viral and bacterial pathogens present on the receiving farm.³³ Acclimatization may be done in the same facility as isolation, although with only one group of animals at a time. The Swine 2000³³ study found that 84.1% of sites that isolated new breeding females vaccinated them as part of the acclimatization process. Other practices used commonly to acclimate gilts were: exposure to cull females (49.0% of sites); feedback of feces from other swine (25.1% of sites); feedback of mummies/placentas/stillborns (11.3% of sites); and exposure to sick pigs (7.7% of sites).

The vaccination schedule for replacement animals can be arranged with the herd veterinarian.³⁴ The vaccines utilized will vary by herd depending on the diseases present in the herd, diseases affecting animals in the area, and vaccines available and their efficacy.

The duration of the acclimation period is dependent on the disease of greatest concern. Because of PRRSV, many facilities today utilize at least 60 days of acclimation to allow animals to be fully exposed to the virus as well as “cool down” (stop shedding virus) before they can be introduced to the rest of the herd. When designing protocols and the facilities that allow their effective implementation, veterinarians rely on knowledge of two aspects: 1) when is the incoming (exposed) animal likely to have stopped shedding agent(s) for which acclimation was designed, and 2) when is

it safe for the population (i.e. resident herd) to become exposed to this incoming group of animals. Whether a herd closure has been done recently or not and other management factors affect this decision.

Throughout the isolation and acclimation periods serologic monitoring can be utilized as a tool to determine the immune status or possible exposure of the animals to various diseases. Blood and oral fluid can be collected and tested for a variety of diseases, but not all important diseases have assays available. In many cases, collecting samples and testing for the immune response to a disease at different points in time help determine the exposure of an animal and how their body is responding to that disease. For example, when replacement animals arrive on site, samples may be collected to detect their immune status to diseases that the veterinarian or producer is concerned about. Some animals may have a low titer, high titer or no titer evident at that time. Therefore, in many situations, the animals are retested 2-4 weeks later, and their titers compared. The immune response of those same animals may look different at that time. Now, the replacement animals need to be exposed to the diseases that are currently present in the main herd. Again, monitoring is a useful tool to determine when and if the exposed animals are mounting an adequate immune response to the diseases of concern as well as to make sure the animals are not shedding virus (viremic) so as to be able to enter the main herd.

In many instances, to minimize the time needed for isolation/acclimation, some operations will actually start the acclimation process shortly after the animals arrive on farm at the same time that the isolation period is going on. Strictly speaking, from a BRM standpoint, focusing on external biosecurity is not the best practice. Animals are being exposed to the site's own agents shortly after arrival. It will become difficult to differentiate clinical signs due pathogens external to the operation (bad) or those already present in the operation (good). An operation needs to evaluate the benefits vs. the risks of running concurrent isolation/acclimation periods. It is also important to note that one reason for isolation is to allow the source herd, which may be a third party or an individual site within the same production system (for example an internal Nucleus or Multiplier herd) to continue its monitoring program and allow reporting of any findings that may be in process at the time animals were shipped or delivered. Isolation period provides for an effective "freeze-frame" opportunity to allow better decision making.

Age at entry is dependent on the health status of incoming animals as compared to the health status of the recipient herd. Some veterinarians are recommending entry as early weaned pigs. This

decreases the likelihood of introducing new diseases (as animals have less time to get exposed to different agents) and allows ample time for the pigs to become acclimated to the recipient herd's diseases. When the pigs are acclimated or exposed to the recipient herd's diseases, they will have plenty of time recover and stop shedding the disease agents. Farms with limited isolation facilities on-site have tended towards more traditional age at entry (60 days prior to breeding). A successful isolation/acclimatization program does not allow disease to get from the isolation unit to the main herd while fully exposing these new animals to all pathogens already present on farm.

The cleaning and disinfection of isolation facilities is a controversial topic, as these facilities are usually used for acclimation purposes as well. On one hand, the goal of acclimation is to expose animals to pathogens already present on the farm. By cleaning and disinfecting the isolation/acclimation facility, disease exposure is minimized. On the other hand, not cleaning the facility can create an environment that may be too contaminated, which in turn, could overwhelm the replacement gilt's immune system and create clinical disease. It may be appropriate to clean the isolation/acclimation facility possibly once or twice a year. This would allow continuation of disease exposure without overwhelming the immune system. The buildup of manure is also tough on equipment, so some cleaning will extend the life of the facility/equipment. If a facility is used strictly as an isolation facility, it is imperative that it be fully cleaned and disinfected between groups to prevent disease exposure from one group to the next so proper monitoring can be achieved. It is also important to note that if, at any time, the isolation/acclimation building has to be emptied because of unexpected disease exposure, the facility must be fully cleaned and disinfected before the next group of animals is allowed to enter.

Semen

Artificial insemination (AI) reduces the risk of disease transfer between the boar and breeding female by eliminating exposure to live animals. However, certain pathogens can be transmitted in semen.³³ Parvovirus, PRRSV, PCV2, *Brucella*, pseudorabies virus, and many other disease agents have been isolated from semen of infected boars.³⁵ As an industry, we must recognize that a new agent which can be transmitted through semen poses a potentially grave situation for monitoring and transmission. If a new agent evolves within a population, our system of genetic material transfer may predispose many herds to simultaneous exposure.

Currently 90% + of all breeding on farms is done via artificial insemination. This has allowed for quicker genetic advancements and more efficient use of boars. This broad practice makes semen a

significant risk for spreading diseases simultaneously to many different operations. As such, appropriate “containment planning” is a key aspect of BRM, whereby one boar stud may have a designated back-up and whereby a boar stud may only service a portion of a system, so as to reduce the disease risk of a single event.

Porcine reproductive and respiratory syndrome virus can be transmitted via fresh and diluted semen, and infected boars can become long-term carriers of the virus.³⁶ Currently, the U.S. boar industry is focused primarily on PRRSV transmission via semen. Boars can shed PRRSV in semen as early as 3 days after infection.³⁷ They do not necessarily show clinical signs and they can test positive via polymerase chain reaction testing (PCR) for up to 92 days.³⁷ Boar studs need to be monitored routinely for PRRSV.

There are many other important swine pathogens that have been found in semen from infected boars. Although PRRSV is currently the biggest concern in the U.S., awareness of other pathogens is important. Very few boar studs currently test for other pathogens other than PRRSV. For example, leptospirosis has been reported in swine from all parts of the world. The disease mainly causes reproductive problems in breeding herds (abortion, stillborn piglets and infertility). Clinical symptoms and infertility may also occur in acutely infected boars. Venereal transmission is thought to play an important role in the spread of infections.³⁸

The PCV2 virus has also been linked to a number of other disease conditions, including reproductive failure (late term abortions and stillbirths). However, PCV2-associated reproductive disease under field conditions does not seem to be common.³⁹

To prevent possible spread of infectious diseases via AI, several precautionary measures should be undertaken in AI centers. First, individual hygiene and general sanitation procedures are important. Personnel collecting semen or coming into contact with any materials need to understand that they can be a source of contamination or act as a carrier in transferring contamination. To minimize the bacterial load originating from the boar, preputial hairs should be clipped and ideally, the ventral abdomen should be clean and dry. Preputial fluids, which can contain high numbers of microbes, should be evacuated prior to exteriorization of the penis for semen collection. Detailed lists of measures that can be taken to minimize the risk of contamination are reported by Althouse et al.⁴⁰ To reduce the unavoidable presence of bacteria in the ejaculate and to prolong in vitro longevity of sperm, preservative levels of antimicrobials are an essential constituent of any semen extender. While

semen processing and the addition of antimicrobials may dilute pathogens, they do not eliminate viruses. Monitoring for bacterial contamination of the extended semen samples may constitute an important part of a control program. Harmless organisms that do not affect sperm quality do not need to be monitored, unless they exceed a specific threshold or would indicate a bigger problem.

The health status of the animals should be checked daily. However, as indicated before, clinical examination alone is insufficient, since clinically normal boars can shed pathogens (e.g. CSF virus, FMDV, PRRSV, PRV, and *Brucella suis*) in their semen. Vaccination of the boars can be considered for some pathogens; for example, vaccination against parvovirus may help to reduce shedding of the virus following infection.

Steps for “exclusion of pathogen entry” assist the herd and veterinarian in developing an effective and implementable health monitoring strategy. Currently, it is as impractical to monitor for every possible disease agent as it is to monitor for every potential “toxin” in a toxicology lab. Veterinarians need to know what they are looking for and also what they are not looking for, based on the population health status and biosecurity.

Disease surveillance in boar studs is a continuous process. Animals are constantly being monitored by testing the semen (especially for bacteria) as well as the blood (especially for PRRSV). Diligence is necessary in these facilities as they have potential to infect a large number of sows if a disease agent is shed in the semen. Monitoring is utilized on a regular basis as part of the protocol of disease surveillance in these facilities. It is critical that all operations purchasing semen from outside their production unit utilize a source that is reputable and progressive in their disease monitoring, with clearly established protocols and specifications. It is important to know the exact monitoring program the stud implements to better evaluate an operation’s risk for disease introduction through semen. Relationships with the boar stud should also be strong enough that the operation and its veterinarian are kept informed of any changes in their monitoring program. Periodic communications with the stud can help make sure monitoring programs are being implemented as planned. As with all BRM programs, there is no single perfect program that will eliminate all risks. The goal of all BRM programs is to minimize and mitigate as much risk as possible. All monitoring programs do add costs to the production of semen.

Fomites

Facilities and Equipment

Fomites include objects such as equipment for sorting and treating animals, feeders, boots, and clothing that can become contaminated with pathogens and infect another animal. 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 outside of the pig. Others can survive for weeks or longer in manure.⁴¹

Care must be taken to minimize the risk of disease introduction or the occurrence of disease spread via fomite contamination. One way to reduce this risk is through good sanitation. Therefore, diligence and attention to detail is essential. Equipment needs to be washed thoroughly to remove all manure and dirt that is present. A study by Kauffold et al (2005)⁴² showed that ultrasound equipment used in swine operations is commonly contaminated with both bacteria as well as PRRSV residues. Although this study did not demonstrate whether this PRRSV was infective or not, it did show that equipment can become contaminated even when plastic or household cling-film is used. This study highlights the importance of minimizing the sharing of equipment, even valuable equipment, between farms.

Another important area that may be overlooked is equipment which comes into direct contact with animals. This is especially true regarding equipment used to process baby pigs (e.g. tail docking and castration). Work by Alvarez et al in 2002⁴³ demonstrated that dipping equipment in Nolvasan® disinfectant did not significantly reduce aerobic bacterial counts on the cutting blades of the equipment. Wiping the blades with a clean cloth was actually quite effective. This study highlights the contact time disinfectants need to be effective. To allow for sufficient contact time, different sets of equipment need to be used in a rotational basis. It probably will not be practical to allow for equipment to be fully disinfected between each pig, but longer contact time can be achieved by switching equipment between litters of pigs. Although the use of a clean towel was quite effective under research conditions, it would be hard in a regular field setting to have a clean cloth available at all times.

Some pathogens can survive in and be spread through dirt and manure contamination. After the dirt and manure are removed, an effective disinfectant should be utilized. Which disinfectant is most effective on this farm? That is a tough question. While pathogens on each farm vary, some disinfectants are more effective against certain pathogens.⁴⁴ Review the labels on the disinfectants

currently being used. Are the farm pathogens of concern listed on the label? If not, review labels of other disinfectants to see if there is a disinfectant that will kill the pathogen of interest. After a disinfectant has been selected, follow the directions on how to best utilize the disinfectant to kill the pathogen. Using the product too diluted or not allowing for enough contact time can reduce the effectiveness of the product.

The ideal disinfectant has the following characteristics:⁴⁵

- Broad-spectrum activity and efficacy under farm environments
- Rapidly kills infectious agents of concern
- Stable in extreme heat or cold temperatures
- Stable when diluted, especially in footbaths
- Suitable for porous and non-impervious surfaces
- Effective when organic matter is present
- Can use in footbaths, vehicles and surfaces
- Safe for environment, animals and people using it
- Government approved for notifiable diseases
- Easy to store
- Cost effective

Footbaths are another effective way of preventing disease transmission if used properly. In some cases, footbaths serve their purpose of reducing the risk of spreading disease that may be present on boots into a facility. However, many times that is not the case. Employees and visitors are busy and may bypass the footbath by stepping over it or quickly stepping through it on their way into the facility. The disinfectants used in footbaths are not effective if there is contamination on the boots or if contact time of the disinfectant on the boot is inadequate. Therefore, for a footbath to be effective, contamination should be scrubbed off boots before the footbath is used. A boot brush should be available, so that before personnel step into the footbath, manure and contamination can be removed. Also, the brush will apply disinfectant on all surfaces of the boot while standing in the footbath. Scrubbing plays a major role in decontamination of boots as shown in Table 2 below.^{46,47} Selection of a proper disinfectant not inactivated by organic material as well as maintenance of the footbaths is another concern.^{48,47,49} At any given time on many farms, one could inspect footbaths and find that a majority are poorly maintained, containing contamination. Footbaths need to be cleaned and fresh disinfectant solution replaced on a daily basis to be effective.

Treatment	Mean bacterial count
No foot bath	2.78 X 10 ⁸
Step through disinfectant	1.76 X 10 ⁸
Stand in disinfectant for 2 min	2.59 X 10 ⁷
Scrub in disinfectant for 30 sec	20
Scrub in water for 30 sec	1.04 X 10 ⁵
Scrub in water for 30 sec then step through disinfectant	120

Bacterial counts from boot soles after respective treatments in study by Amass et al ⁴⁷

Aside from correctly cleaning and disinfecting all fomites, several other procedures can be utilized to reduce the risk of disease transmission. If possible, avoid sharing equipment among premises. When treating sick animals, utilize new needles and clean snares and sorting panels between animals if possible. Handle biologics aseptically. Disposable boots and coveralls are a great alternative when visiting different sites. Caution must be taken when removing coveralls or boots for disposal as the person may accidentally contamination their hands.⁵⁰ For operations with different sites, having a set of boots and coveralls that stay at each site can also be very helpful in mitigating the transmission of disease between sites.

Some operations require anyone (except for on-site employees) getting out of their vehicles to have some type of disposable foot covering such as plastic boots. These plastic boots are placed over footwear while still inside the vehicle just before taking the first step on the ground. The use of this protective covering will minimize the opportunity of any contamination from having direct contact with the site traffic area.

When purchasing work boots, it is very helpful to look at the tread on the bottom of the boots. Each brand has a different pattern. There are also great differences in how easy these boots can be cleaned. Boots with a very narrow tread are very difficult to clean even when using a brush. This is especially true when you have been walking on these boots for some time and the manure/dirt has been compacted heavily in these crevices. Boots with wide tread are much easier to clean thoroughly. This will speed up the cleaning time, and most likely improve your BRM compliance as well. It may also be helpful to use different color boots (and coveralls) for different sites or purposes. For example, blue boots and red coveralls are to be used when taking animals to the dead pile (rendering, compost or incinerator). This helps with compliance in different ways. First of all, it serves as a reminder for all employees that changes in clothing and boots are necessary. It also allows anyone from a distance to know whether proper BRM practices are being followed. Employees are also aware that others can identify when they do not follow protocol; and therefore,

they themselves are more likely to follow the rules. The hassle with dealing with special orders and different suppliers does make it more difficult to implement these color codes, but the benefit of a better BRM program are definitely worth it.

Regarding people and fomites, the following summarizes from the safest practice to the most risky:

Shower-in and shower-out with complete change in boots and coveralls	Safest
Change in boots and coveralls and washing hands	
Change in boots and coveralls	
Change in boots	
Simply “clean & disinfect” boots worn elsewhere	Most risky



The concept of shower-in and shower-out will be discussed in greater detail under the employee section of the BRM. Hand washing is the single most important measure to reduce the risk of disease transmission to humans. It is also a great way to minimize the spread of disease from animal to animal. Hands should be washed between different animal contacts (different age, different barns, different sites) and after contact with secretions, excretions, or tools/equipment contaminated by them. Hands should also be washed before working in the office or eating. Proper installations (sink and water supply) and supplies (soap and towels) are critical in making sure workers have good access to hand washing equipment as well as ensure their use.

Besides boots and coveralls being a source of contamination, other equipment and supplies arrive almost daily. The risk of disease transmission from these is unknown. Research by Dee et al (2002) has shown that cardboard boxes can become contaminated with PRRSV especially in the winter when the virus can survive longer in snow.⁵¹ This snow can melt once inside the building which can then serve as a source of contamination to anything placed on the floor.⁵¹ Because of the risk supplies and equipment can pose to an operation, several BRM techniques can be implemented. Probably the most common one is a double bagging system. With this system, operations will ask suppliers to double bag everything they purchase. Once arriving to the farm, the outside bag will be opened and the inside bag will then be grabbed from someone in the clean side to carry in the supplies. This will prevent the box and outside bag from entering the facility as they are considered dirty. For larger pieces of equipment, this practice is not practical. A second method used by some operations is to build a small room where all products entering the facility can be fumigated with a proper disinfectant. This process does require a special room as well as means to make sure that the fumigation plume reaches all of the outside surfaces of all equipment. This is difficult to do in one step as all supplies need to be placed on some type of heavy duty screen so provide better access to

the bottom of the equipment/supplies. To alleviate this, many operations will actually run the fumigation process twice with a rotation of all supplies/equipment occurring once between each of the fumigations. For equipment/ supplies too large to fit in the fumigation room, a simple manual decontamination process needs to occur.

Loading

The loading area can prove to be an area of disease exposure for any farm. Design and location should be carefully considered to ensure that any vehicles loading or unloading pigs are kept on the dirty side of the unit. In fact, some production units designate areas as a clean area and a dirty area with an actual painted line separating the two areas. This painted line serves as a continuous reminder that a separation is necessary to maximize BRM. Personnel and equipment in the clean area must stay on the clean side while the truck driver and any loading equipment from his truck must remain on the dirty side. Once an animal crosses over from the clean side to the dirty side, it must not be allowed to turn back. The same is true for employees. If a production employee crosses over the line, they must re-enter the facility by following the set protocol which may include showering, changing coveralls and boots, or hand washing as if they were entering for the first time that day.

Materials used for the loading bay must be easy to clean and disinfect. The truck driver should wear clean clothes and boots each time, especially with each individual farm. The loading facility should be heated so it can be washed and disinfected after each use, and should not drain into the building. If cleaning of the load-out facilities is done by farm personnel, cleaning should be done at the end of the day so that personnel do not need to re-enter the building that day.³⁴

Ideally, every load-out should be constructed to prevent entry by truck drivers. Load-out areas should have a roof and fencing installed to the roof's edge. The chute gate should have a guillotine mechanism which prevents animals from re-entering the load-out holding area. "Sacred zones" should be designated to truck drivers by management. These areas are strictly off limits to the drivers.⁵² It is extremely helpful to have a great working relationship with your truck driver so they, too, are very familiar with your BRM practices without requiring a full explanation every time someone shows up to deliver or load-out hogs.

Transport Vehicles

Many trucks enter and exit a production site in one day. Feed trucks, delivery vehicles, farm employees, veterinarians, and trucks to load-out pigs can all put a production site at risk for disease exposure. The recovery of *Salmonella* from the truck swabs taken in one study suggest that feed trucks might serve as a potential source of contamination.¹⁷ A 1995 study by Bech-Nielsen et al suggested that PRV virus was transported from swine markets to farms, by either the farmer or trucker.⁵³ Proper sanitation methods between loads, including washing with a disinfectant and hot water, should be implemented to minimize the likelihood that the truck would contribute to contamination of subsequent loads.¹⁷ Vehicles can potentially transmit swine pathogens when manure containing disease agents are adhered to tires or the vehicle frame. There is evidence that *Actinobacillus pleuropneumoniae*, TGE, PRRSV, and *Streptococcus suis* can be spread by contaminated vehicles.^{35,54}

It is recommended that vehicles be specifically designated for different jobs. For example, a trailer that is used to move animals within a farm should be different than the one used to deliver pigs outside the farm. A trailer used to transport isowean pigs should be different than the one that is used to take market pigs or cull animals to slaughter. Some larger systems also separate their transport vehicles into PRRSV status as much as possible. Transport trailers are dedicated for animal movements to and from PRRSV negative systems. If a PRRSV negative trailer has to be used in a PRRSV positive system, the trailer will then have to undergo additional cleaning and disinfection steps and also be required to have down time so it can completely dry before it is allowed back into the PRRSV negative system. The more specific and dedicated tasks that trailers can be assigned, the less likely it will be that they can serve as a fomite for disease transmission, while still maintaining some operational efficiency.

Providing an enclosed, well lit, and heated building for shelter will greatly improve the quality of the washing. Federal regulations require that all the wastewater be captured in an approved holding facility. If bedding is used, it must be held until it can be disposed of properly or applied to agriculture land. Proper slope for washing out the trailer is necessary. A minimum of 2% to 3% slope to get the wash water to run out is recommended. A pressure washer with high pressure and hot water is needed. Recommendations include using a minimum of 2,000 psi with 4 gallon per minute of water. An accurate metering device is important in the application of the soap and disinfectant.

Trucks which arrive on the farm contaminated with manure should be asked to leave the property and invited to return when the trailer has been cleaned and disinfected.⁵² All employees on a farm should have the authority to reject any vehicle that is dirty.

Procedures for Cleaning and Disinfecting Transport Vehicles:^{55,56}

1. Bedding and large debris should be completely removed before entering the wash area.
2. The use of detergents is highly recommended to reduce washing time by loosening debris. Normally it is applied on low pressure and by soaking the entire trailer at once. This will provide some time to loosen debris. However, don't allow the soap to dry or it will be harder to rinse.
3. Start rinsing and cleaning the trailer from the top down. Do not forget the trailer cab.
4. Rinse and clean each deck from front to back and ceiling down starting with the top deck. All trailer areas and equipment need to be fully cleaned including unloading ramps, sorting boards, paddles, and boots after every load.
5. After the trailer has been rinsed inside and out, apply the disinfectant at the appropriate dilution rate. Start on the inside of the trailer and finish on the outside. Disinfectant should be applied at low pressure because many of the metering devices will not dilute properly on high pressure.
6. Clean the inside of the cab, including washing and disinfecting floor mats.
7. After disinfection, park the truck on a slope so all the remaining water can drain out. Allow enough time for the trailer to fully dry.

The disinfectant and cleaning protocol a system uses depends on many factors including the diseases present on the farm, the stage of production of the animals hauled, where the animals were hauled to, and what the trailer will be used for next. Dee et al (2006) tested a protocol using conditions found on commercial swine production units, for sanitation of 1:150 scale models of commercial transport vehicles contaminated with PRRSV.⁵⁷ The group concluded that high-pressure washing of transport trailers, followed by 90 to 120 minutes exposure to either modified potassium monopersulfate or quaternary ammonium chloride disinfectants applied with a hydrofoamer is likely to eliminate residual infectious PRRSV.⁵⁷

Following sanitation, the vehicle must be allowed adequate drying time after disinfection. As with facilities, this is the most important step in the sanitation protocol to completely inactivate the virus. The use of high volume warm air can decrease the amount of time needed for drying. The Thermo-

Assisted Drying and Decontamination (TADD) system developed by PIC is recommended to achieve a dry trailer in the shortest amount of time. Studies have indicated that 120 minutes of high volume warm air applied via the TADD method can effectively remove PRRSV from contaminated surfaces in transport trailers.²⁵ One system heats and holds at a minimum of 142°F for 10 minutes before flushing with fresh air.⁵⁸

The use of truck-mounted tire sanitizers have also been evaluated for effectiveness in minimizing bacterial contamination found in tires. Although this type of system theoretically should be effective, two different studies have shown that there is too much variability in bacterial contamination during different seasons and therefore their effectiveness is hard to prove. Cold weather conditions also make it challenging to implement control measures.^{59,60}

Aside from implementing biosecurity measures to keep trucks clean, controlling traffic is another way to control disease entry. Installing a perimeter fence can prevent uninvited visitors, whether human or animal, from entering your production site. Keeping the fence locked also controls entry of vehicles and allows for employees to monitor those vehicles entering the site. Entry can be limited to only select individuals. Also, all trucks can be inspected for cleanliness. Any truck which does not pass inspection can be refused entry. Keeping the gate locked and having an employee unlock the gate for those entering, does allow that employee to monitor those driving onto the site. If no gating is available, then proper signage at the entrance of the site is critical in helping limit traffic. Although signs will not prevent unauthorized entry, they will help limit access to those who unintentionally would be wandering on-site.

Parking

Restricting entrance to the site as well as establishing an area for designated parking is very helpful in controlling traffic on site. Placing the parking area in an obvious location, preferably with signage, will prevent visitors from pulling their vehicles too close to livestock buildings. This is especially true during inclement weather when people's tendencies are to minimize their discomfort without thinking about the risks posed to the livestock. Having vehicle traffic close to where animals are located can increase the risk for disease transmission including aerosol transmission.

Employees

Employees provide another conduit for pathogen entry into a production site. Research has proven that diseases such as FMD, *Mycoplasma hyopneumoniae*, and IAV have been transmitted from

people to pigs. People wearing clothing or boots contaminated with manure from sick animals can be a source of pathogens.³⁵ However, exposure doesn't only occur through contaminated clothing and boots. People can carry pathogens on their skin or in nasal passages. Sellers et al (1971) reported that FMDV could be transferred by human beings, from infected pigs, to susceptible cattle.⁶¹ Results from Seller's work appear to be the origin for the "48 hour rule" (down time or time to be away from pigs before making contact with the next group of pigs) used by many producers even though different viruses and bacteria may be harbored for longer or shorter periods by humans.⁴⁶ Goodwin and others (1985) could not recover *Mycoplasma hyopneumoniae* from the breath or hair of exposed personnel, but could recover the organism from clothing over a 24–48 hour period post-infection.¹⁰ However, recent work by Amass and Batista appear to refute these results, indicating shorter recovery times of FMDV from people and the inability of personnel to spread *Mycoplasma hyopneumoniae* from infected to naïve herds, despite multiple attempts over extended periods of time.^{62,63} Recent reports by Otake and Alvarez demonstrated the inability of personnel to harbor or transmit PRRSV and TGEV, respectively, following completion of basic sanitation protocols.^{64,65} The former study demonstrated that if PRRSV was to be detected on personnel, it was only present on the palms of the hands. In 2009 the pandemic novel H1N1 virus was documented in Canada to have been transmitted from human to pigs.⁶⁶ This incident should help remind everyone that down times are important for zoonotic purposes; and therefore, company policies need to be flexible to allow employees to stay home when they are sick without concerns of losing their job.

Having a visitor log is important in helping keep track of people traffic on site as well as making sure visitors and repair personnel sign off on how long it has been since they have had contact with pigs. Having people sign a sheet helps emphasize the importance of your operation's BRM program. It also makes investigations more effective through helping identify how a break possibly occurred as well as by helping track movements to better identify other farms possibly at risk.

Presumably, showering and hand washing both remove contamination,^{64,62} but showering appears to do a better job.⁶⁷ Hand washing 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 according bacterial type.⁶⁸ Alcohols are not effective on visibly contaminated hands.⁶⁹ Wearing

gloves can decrease the gross contamination of hands but does not remove the need for hand washing.⁴¹

Showers for employees and visitors can be laid out in a variety of ways. In most cases, the shower is placed at the only entrance into the building so the shower facility cannot be bypassed. The employee may pass through a door to an area where they will undress, leaving their clothes and jewelry in a designated area. This street side is considered the dirty side. The employee would then step into the shower. The employee must shower, washing body and hair. After showering, the employee steps into the next room which has clean undergarments, coveralls, and boots. This barn side is called the clean side. If at any time the employee needs to return to the dirty side, they must take another shower before returning to the clean side. Some of the shower layouts have curtains or doors with or without locks. Employees' privacy needs to be considered when designing what will work for each production unit. Unfortunately, due to the nature of human beings to take shortcuts, showers can be viewed as a nuisance, resulting in personnel skipping the showering process completely or partaking in a cursory rinsing.

Operations with shower facilities also need to have washers and dryers on site. Being able to do laundry on site ensures that clean apparel will be available, minimizes the tracking of contaminated clothing off-site, and prevents bringing items from off-site into the operation. Preventing the contamination of off-site premises is very important especially from a public health standpoint. It is best to leave all contaminated clothing at the site to minimize taking any pathogens home where others, including children, could be exposed to zoonotic pathogens.

However, a newly recognized weakness, particularly in cold climates, is the anteroom area, located just prior to the entry of the actual shower facility.⁵¹ The anteroom is the section of the farm encountered immediately upon entry through the main door. Here, boots and coats are removed and stored throughout the day. Work by Dee et al (2002) indicated that the anteroom floor could serve as a site of PRRSV survival and a contamination point for shipping parcels that frequently enter swine farms, including styrofoam semen coolers, toolboxes, cardboard containers for pharmaceutical shipments, and lunch pails.⁵¹ While the frequency of parcel contamination was significantly higher during cold weather versus warm weather, these studies emphasized the need for biosecurity protocols to focus upon the anteroom area throughout the year.

One other method that can be used to minimize disease introduction/spread without using a shower (or in addition to a shower as an extra BRM practice) is utilizing the so called “Danish system or boot exchange.” In this system, a solid bench is built to create a physical separation between two sides of a room. As a person enters the room from the dirty side, they will then sit on the bench, remove their footwear and street clothing and then swing their legs over the bench to the opposite side (clean side) where they can now put on clean coveralls and boots provided by the farm. The person will then exit the building through a door on the opposite side from where he/she entered. This bench serves as a physical barrier that will prevent the accidental stepping over into the clean side.

Another area of concern identified by these studies was the infamous “pass-through window”, the sliding pane of glass that separates the office area (clean area) from the anteroom (contaminated area). This so-called “barrier” is frequently abused, being left open, allowing for shaking hands of visitors with farm personnel and for the introduction of containers that have set on the potentially contaminated anteroom floor.

Employees who remain on site during their workday need to be provided with a designated kitchen area. Disease can be brought onto a site in meat products if those products are carried into the production units. This risk is minimized if employees have an area where they can eat lunch away from the buildings, so that food is not carried into one of the production units. For example, classical swine fever and FMD can be transmitted in improperly cooked meat products such as sausage. If contaminated product were carried into a production unit and the pigs consumed scraps, the pigs could become exposed to classical swine fever. Granted while this type of scenario is a little less likely than other disease introductions, it is possible and would have a devastating impact. Changes in trade policy that permit importation of animal products from designated regions of countries with FMD could increase the chance of inadvertent introduction of the virus, and the threats of agroterrorism that include the release of exotic animal diseases increase the chance of intentional introduction of FMD into the U.S.^{70,71}

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.⁴¹ It is also helpful to have all doors on site locked. This added security will prevent accidental entry by an unauthorized individual. It also serves as a deterrent for those who are looking for a quick way to get in and out of a place.

Many operations will also restrict employees from owning or working with other pigs. This practice helps ensure that accidental cross contamination from one group of pigs to the other is minimized. This is especially important because many times when animals first pick up a disease, they may be shedding the organisms for some time before they actually show clinical signs of illness. So simply agreeing to stay away from sick hogs will not be sufficient.

Some operations also restrict employees from living with other individuals that may work with pigs from a different company. The concern is that by having different people from different swine operations share a common living space, cross contamination can occur possibly putting both operations at risk. This could be a risk, but currently there is no science to support this. As long as employees do not bring home any contaminated clothing or boots, the risk is truly non-existent. The risk of zoonotic transmission from pigs to humans then to another human and then back to pigs although theoretically possible is also highly unlikely and has not been ever reported to date. There are many other BRM practices (especially shower in and shower out practices) to be implemented on farm, which are closer to the pigs, to mitigate this particular risk more effectively.

To effectively implement, management must also manage the knowledge, training and mindset of workers in these critical areas. It is not reasonable to expect high level of “buy-in” to key procedures without appropriate training, on-going reinforcement and effective leadership. Open communication and dialog should be fostered to insure questions get asked and answered at timely intervals.

One other important BRM tool related to employees has to do with human food. As discussed under the garbage feeding section, human food especially imported cured meats can pose a risk for swine disease transmission. In the case of imported products, there is concern regarding diseases such as African swine fever, CSF and FMD. Because of this, it is important to have strict rules that prohibit employees from eating in any area where pigs can accidentally get access to these foods. In some operations, all meat products are prohibited in the buildings and are allowed only in office areas that are located away from animal premises. Some human food for employees contained in cans has been fogged in the same way other products are as they are brought onto the site. Another method utilized is to double bag the lunch so the outside bag can be removed in the entry room while someone on the clean side removes the inside bag to carry into the break room.

Visitors

Employees are not the only people entering a production site during the day. Many visitors frequently enter production sites. These visitors may prove to be someone of very low risk of carrying a pathogen; however, they may also be carrying a new strain of PRRSV for example. Entry should always be limited to essential personnel only. This includes service personnel (electricians, welders, etc.) that may have access to other facilities as well as their specialized equipment.

According to the USDA's National Animal Health Monitoring System (NAHMS) report, about 80 percent of sites in 2006 did not allow anyone except employees to come in contact with areas where swine were housed, compared to about 65 percent of sites in 2000.⁷² As mentioned previously, a California study did show large swine farms as having some 807 indirect contacts with pigs per month with 95% of these occurring through people.⁷³

The Ohio State University Extension published a Factsheet titled, "On-Farm Biosecurity: Traffic Control and Sanitation"⁷⁴ in which visitors were divided into three different categories including low-risk, moderate-risk, and high risk visitors. The level of risk depends on the possibility of exposure to other animals, especially swine, the frequency in which they visit farms, and the type of contact they have with animals. Low-risk visitors are those who come from urban areas or others who don't have any livestock contact. This group of people has minimal risk of introducing disease into the farm. Moderate-risk visitors would be those that have little or no contact with animals but routinely visit farms. Salesmen, repair people, feed and fuel delivery people are examples. This group does present a moderate risk of disease introduction. Finally, high-risk visitors would include anyone who is in direct contact with animals and their bodily secretions/excretions. This group would include livestock haulers, livestock-owning neighbors, processing crews, and veterinarians. This last group does pose a higher risk for disease introduction.

In all cases, providing a shower facility along with requiring a complete change in boots and coveralls (preferably provided by your own site) will dramatically decrease the probability that an accidental introduction will occur. Visitors should be restricted from entering pens or having direct contact with animals unless necessary. Providing gloves as an added safety measure can also be beneficial. All equipment and tools brought in by visitors should be cleaned and

disinfected as discussed in the fomite section previously. This includes tools brought in for maintenance by outside contractors/servicemen.

International Visitors or U.S. Citizens Traveling Abroad

One type of visitor that has not been addressed is the visitor from a foreign country or U.S. citizen who has recently traveled abroad. The risk that this type of visitor could pose would depend on a number of factors including the following: the diseases present in their country or the country they were visiting, if they visited any livestock production sites, if they came in direct contact with any animals, and if they entered the U.S. with any clothing they wore on those sites. For example, a visitor from China who lives in a large city and never has had contact with livestock would pose a low risk even though the country they come from has classical swine fever. In this case, they have never come in contact with pigs. However, a U.S. citizen who visits a hog production site in Brazil and then returns to the U.S. would pose a much greater risk. In most cases, the U.S. citizen would bring their own clothes back home and potentially carry disease into the U.S.

Human diseases in foreign countries need to be considered also when determining the precautions necessary when allowing foreign visitors. The 2009 pandemic influenza situation reminded many production units to go to greater lengths to protect their pigs from zoonotic diseases. According to their website, the National Pork Board recommends that if entry of a foreign visitor is essential, consider requiring that these people wear face masks, or preferably properly fitted, valveless N95 respirators, and gloves, upon entering and while inside a swine housing facility. The bottom line is to understand the background of the visitors entering your production unit and react accordingly.

The National Pork Board distributed a pamphlet titled “Are you hosting international visitors to your farm?” reminding producers of precautionary measures to take when hosting an international visitor.⁷⁵ The following points were included in the pamphlet:

- Did you know that many swine viruses can survive on clothing, footwear or equipment for weeks and in some cases months?
- Supply a complete set of coveralls, hairnet and boots. If they are disposable, immediately collect them in a plastic bag and incinerate them. If they are not disposable, immediately wash them in a solution of chlorine bleach (30 ml of bleach to 1 gallon of water) or other disinfectant.

- Do not allow cameras, equipment, food items or other items that cannot be properly disinfected into areas where livestock are present.
- Visitors should have had no contact with livestock for at least 48 hours prior to visiting your pork production site. If visitors are from a Foot-and-Mouth Disease infected country they should have no contact with livestock for at least 5 days prior to visiting.
- Utilize shower in / shower out, if possible.
- Supply a dust mask for all visitors to wear. The mask should be tight fitting and have two straps to secure it over the mouth and nose.
- All visitors should completely wash their hands, including scrubbing fingernails, with a disinfectant soap prior to entering the farm and again before exiting.
- Control the traffic flow and allow visitors only in carefully selected areas. Do not allow them to unnecessarily handle the livestock.

As we continue to learn more about how disease transmission occurs, these procedures and the farm policy should continue to be updated to prevent the introduction of a disease by international visitors.

Carcass Disposal

Unfortunately, even the most productive sites need to dispose of dead pigs. However, the method to dispose of these animals and the biosecurity precautions taken may determine if the production site exposes itself to a pathogen from the outside or spreads disease internally. Farms can choose between on-farm disposal techniques and off-farm carcass disposal. Either choice has its benefits and risks; therefore, each production site needs to determine which technique can be managed better at their site. Again this is the focus of a BRM plan.

It has been estimated that a 1,000 sow farrow-to-finish operation with annual mortalities of 7% in the sow herd, 10 % pre-weaning, 5% nursery, and 2% finishing will produce approximately 85 dead pigs a week.⁷⁶ Disposing of all these animals in an appropriate, timely, biosecure and environmentally correct way requires some planning.

On-farm disposal techniques may include burial, incinerations and composting. The major advantage of an on-farm system is biosecurity. Outside mortality collection trucks are not required to visit the farm, nor do farm trucks have to risk contamination when delivering mortality carcasses to a rendering plant or central collection site.

Burial was used extensively when operations were smaller because it was an inexpensive and efficient method of mortality disposal. Due to today's larger size operations as well as environmental concerns, many states limit the number of animals that can be buried on a per acre basis, making this practice impractical. The major disadvantage of burial is the possibility of contaminating groundwater, particularly in areas with sandy soils and a high water table. In colder areas it is difficult, if not impossible, to dig trenches when the ground is frozen. Also, predators can uncover carcasses if they are not buried deep enough, which is unsightly and increases the risk for the spread of diseases.

Incineration has become quite popular in recent years. In the past, incineration generated the most public complaints in the U.S.⁷⁷ Limited size of the equipment for dealing with larger animals (late finishing as well as adults) and limited space to deal with sporadic high mortality problems are of major concerns with most operations. Incineration eliminates all pathogens but high operational costs and incineration's potential to contribute to air pollution (if not properly maintained and operated) decreases its usefulness for widespread use as a mortality carcass disposal option.

Composting uses organic by-products such as dead pigs, straw, or sawdust and converts them into an odorless, generally pathogen-free product that can be used as a soil amendment or organic fertilizer. Composting pigs has gained a lot of popularity in the past few years due to its lower operational costs and better environmental sustainability. There are a lot of great resources available for properly building and maintaining a successful composting pile. Composting does work even in cold areas, although it is slower, but it does require proper management to be successful.⁷⁶ Under normal circumstances, if proper composting practices are used, rodent and scavenger activity will not be a problem. It is always good though to take additional steps to minimize any possible rodent or scavenger activity. Review the next section on vectors. In areas with large amount of wildlife, fencing off the compost pile area might be necessary to create an additional separation between the operation and wildlife.

Rendering and landfill are the two main opportunities for off-farm carcass disposal.⁷⁸ To use a rendering service, farm personnel should deliver dead pigs to an off-site point where the renderer can pick them up. If at all possible, farms should use a drive access that is different from the one rendering services use to minimize contamination of vehicles used to transport dead pigs. Be sure rodents and other animals do not have access to dead pigs.³⁴

Landfill opportunities are rapidly decreasing as municipal authorities refuse to accept carcasses. With landfill fees of \$10-50 per ton, costs are becoming prohibitive in areas that still allow this practice. Landfills are most often used when death losses exceed everyday disposal capacity or under disaster situations. For producers with access to a protein recovery plant, rendering has been, and will continue to be, the best means for converting swine carcasses into a nutritionally valuable and biologically safe protein by-product meal. Unfortunately, the number of rendering facilities operating in the U.S. is decreasing, especially small local plants that accept mortality carcasses. Many rendering plants have closed because of stringent EPA regulatory action and/or because of decreased prices for fat, protein, and hides.⁷⁸ As a consequence, the remaining plants are further apart making it cost-prohibitive to transport carcasses to these locations for disposal, leaving on-farm composting as the primary new means to dispose of carcasses.

Biosecurity guidelines need to be respected with either on-farm or off-farm carcass disposal. Because carcasses can serve as a reservoir for disease, they should be disposed of daily. Employees need to be cautious in their work duties not to dispose of the carcass on-site then track back into any groups of pigs. Care must also be taken when delivering carcasses to an off-site point (preferably some type of dead box located off site) so as not to track back into the herd. Options for the employee may be to dispose of carcasses on-site or haul the carcasses to the off-site location at the end of the day and not re-enter the production until the following day. If employees need to re-enter, they need to follow the set protocol which may include showering, changing coveralls and boots, or hand washing as if they were entering for the first time that day.

Vectors

Rodents, feral animals, pets, birds and even insects can be sources of pathogens for pigs. The disease that each of these vectors transmits varies as may the route in which transmission occurs.

Rodents

When rodent infestations are not diligently managed they quickly become severe, which, in turn, can pose significant economic problems to a swine producer. Rodents consume and contaminate feed, destroy utility components, and weaken concrete slabs and walkways via their burrowing activities. Norway rats and large populations of mice are especially destructive to building insulation. Mice and rats spread diseases to uncontaminated areas via their droppings, feet, fur, urine, saliva, or blood. For example, mice may travel through infected manure and then contaminate the food and water of

healthy animals several hundred feet away, or introduce a disease to nearby uninfected barns. Biosecurity is difficult if rodents are not controlled in or around swine facilities.⁷⁹

Rodents have been implicated in the transmission of many disease agents including pseudorabies, *Bordetella* (atrophic rhinitis), encephalomyocarditis virus, leptospirosis, *Salmonella*, swine dysentery, *Toxoplasma*, and *Trichinella*.^{79,80} Facility sanitation plays a critical role in controlling rodent populations. It is obviously impractical to eliminate all food sources for rodents in and around swine facilities. Still, feed spills, or equipment malfunctions that provide rodents with unlimited amounts of food should be removed or repaired as soon as possible. Easily accessible harborage is also one of the key reasons rodent populations continue to expand.

Any exterior debris such as old equipment, junk piles, and old boards should be eliminated. Controlling weeds is also important. Weeds provide rodents with food, water, nesting material, and cover from predators. Maintaining a weed-free graveled perimeter without debris around buildings deters rodents. Gravel should be at least 1 in. in diameter and be laid in an area at least 3 ft. wide and 1/2 ft. deep.⁷⁹ Rats and mice populations can be controlled by using poison baits (rodenticides) and /or rodent traps. In the majority of cases involving established infestations, rodenticide baits strategically placed in area inhabited by rodents will provide the most cost effective control.⁷⁹

The three keys to effectively control using rodent baits are the following:⁷⁹

1. Installing fresh baits in the rodent's high activity areas where droppings and gnaw marks are located;
2. Placing enough bait stations to ensure the rodents come in contact with the baits during their nightly search for food;
3. Matching the right bait formulation (e.g., pellets, vs. blocks, vs. packets, etc.) to the specific area needing to be baited. Putting out baits in corners of barns and buildings, or stuffing rodent bait packets down rat burrows will have little long term effect on rodent population reduction, regardless of the bait brand used.

To treat exterior rat burrows in a cost effective and safe manner, loose bait pellets can be inserted directly into the burrow, or permanent bait stations containing blocks, packets or loose pellets can be established nearby the burrows. Stuffing bait packets or blocks down burrows and caving in the burrow is often inefficient and sometimes hazardous because rats will kick out some of the baits.

These baits on top of the ground the next morning, may be found by dogs, cats, wildlife and even young children.⁷⁹

For minor infestations of rats and mice, or to stop new populations of incoming rats or mice, the use of traps, placed strategically where rodents have been noticed is very effective, and inexpensive. But traps are too labor intensive for anything beyond a minor infestation.⁷⁹

Feral Swine

Feral swine, while abundant in the southeastern U.S., Texas, and California, have become more widely distributed in the U.S. in recent years. The USDA currently estimates the current feral swine population to be around 3-5 million and are established in at least 32 states. These increases in distribution have resulted in increased risks for transmission of disease agents between feral swine and commercial and transitional swine. Furthermore, the association of feral swine with commercial and transitional swine also presents a risk for transmission of foreign animal diseases.⁶⁷ Modern swine confinement buildings have been quite successful in minimizing exposure of domestic hogs to wild hogs. Having a perimeter fence can also be helpful in preventing wildlife coming too close to your facilities. However, when feral swine do come in contact with commercial swine, producers should call their veterinarian who can contact USDA APHIS Wildlife Services. Surveillance for PRV and Brucellosis is routinely performed on feral swine.

Pets

Dogs can spread swine dysentery and brucellosis pathogens. They have been shown to harbor TGE for up to 14 days and *Brachyspira hyodysenteriae* for up to 13 days.⁵² Cats are a potential source of *Pasteurella*, leptospirosis and toxoplasmosis to pigs. Although some producers feel that cats can serve as a good rodent control program, it is impossible for a cat to eat that many mice. Dogs and cats can keep rodents out of sight, but the rodents are not necessarily gone. The risks of disease transmission from pets to pigs are probably much greater than the benefits in regards to rodent control.

Birds

Natural transmission of swine pathogens from birds to pigs has not been demonstrated. However, it has been determined that birds can carry *Bordetella* and tuberculosis. There is also evidence that birds can transmit the viruses that cause classical swine fever, PRRSV, IAV, and TGE to swine.³⁵

Birds can transmit TGE (36 hour survival and 25 mile range) and can carry erysipelas and *Salmonella*.⁵² All buildings need to be bird proof to prevent direct contact of pigs with any birds.

Insects

In some cases, insects can serve as a biosecurity risk. Houseflies may contribute to horizontal transmission of PRRSV among pigs within infected commercial farms.⁸¹ Flies (*Musca domestica*) will travel distances of up to 2 miles and can transmit *S. suis* serovar 2 (2-5 days in the crop), *Brachyspira hyodysenteriae* (4 hours) and TGEV (3 days), and may potentially transmit *Salmonella*, *Actinobacillus pleuropneumoniae*, and *Pasteurella*.⁵² However, mosquitoes and stable flies (*Stomoxys calcitrans*) are not likely to serve as biological vectors of PRRSV.^{82,83}

Integrated pest management is an effective way to manage fly populations. Monitoring should begin before fly season and continue every two weeks throughout the season. Cleaning up spilled feed, removing feces from pens and alleyways, spraying around facilities and keeping grass mowed are all environmental control methods to reduce fly populations. Fly bites on animals should be treated. The easiest way to control mosquito populations is to control populations at the egg stage by removing breeding grounds. Mosquito control can also center on larvae and adult populations as well. Insect screens can be very effective in facilities to minimize exposure to outside insects.³²

Zoonotic

Zoonotic diseases are pathogens which are naturally transmissible from animals to humans. In pigs, these zoonotic pathogens can be divided into foodborne pathogens and occupational pathogens.⁸⁴ Foodborne pathogens from pork mainly include *Salmonella*, *Yersinia*, *Toxoplasma*, and *Campylobacter*. Influenza A virus, *Streptococcus suis*, brucellosis, colibacillosis, campylobacteriosis, erysipelas, and leptospirosis are all examples of diseases which could be spread to employees while they handle or care for their pigs. Therefore, these pathogens could be categorized as occupational zoonoses. A few pathogens have the potential to cause both foodborne and occupational zoonosis. For many of these pathogens, prevention of human infection is the same as with pigs - focus on hygiene. Employers need to make sure employees have access to hand washing stations, and personnel protective equipment (gloves, coveralls, N95 masks, etc.) are properly stocked and functional. Employees should be informed about zoonotic diseases and prevention techniques which they should implement. Practicing several specific simple hygiene steps can prevent infections in employees.

Steps to prevent disease transmission from pigs to man:⁸⁵

1. Wear gloves when caring for pigs, handling their wastes (feces or urine), or handling any body product such as: blood, meat, viscera, nasal discharges, or fluids draining from wounds. After removing your gloves, wash your hands with soap and water.
2. Never eat or drink in areas where pigs, their wastes, or body products are handled. Absolutely no eating, drinking, or smoking in areas where pigs are housed.
3. Report concerns of sick pigs to your veterinarian, so the veterinarian may determine the cause of the illness and implement any additional protective steps. Follow any procedures recommended by veterinarians such as wearing protective clothing such as masks, or rubber or plastic boots.
4. A normal, healthy adult person may have only mild symptoms if they become infected with a zoonotic disease; however, that person may expose others to the disease. Cases of animal handlers "carrying home" zoonotic diseases to their infants, with serious consequences can occur.
5. For personnel on the farm, wear a designated pair of shoes and jeans, or coveralls, while working. Wash the designated clothing separate from the family wash, or leave the designated clothing at the farm and have the farm unit do the washing to reduce chance of contamination.
6. Before leaving the farm, either change to another pair of shoes, or clean the "farm" shoes before getting into your vehicle. When cleaning the farm shoes, use a brush to remove manure and mud, then apply a commercial disinfectant.

Reporting Suspect Foreign Animal Diseases

As discussed previously in this document, the U.S. swine industry is at a continuous risk of a foreign animal disease (FAD) introduction. If a producer or veterinarian observes clinical signs that could resemble a FAD, call your State Animal Health Official (SAHO) and Area Veterinarian-In-Charge (AVIC) to report your concerns. Contact information for the SAHO and the local AVIC can be obtained by calling (866) 536-7593. You can also call the USDA APHIS Veterinary Services National Center for Animal Health Emergency Management at (800) 940-6524 (24 hours) for assistance. The SAHO and AVIC will let you know if or approximately when the Foreign Animal Disease Diagnostician (FADD) will conduct a site visit. Precautions to take concerning people movement and contact with animals should be discussed while waiting

for the FADD to arrive. They will also want to start gathering information from you and the producer. Discuss the next steps to follow with the SAHO or the AVIC you have contacted. Information will be held confidential to prevent unwarranted sharing of information.

Some of the concerns to be discussed over the phone or when the FADD arrives include the following:

- When were the first lesions evident?
- When were animals last transported from the farm and what was their destination?
- When were these animals delivered to the farm and where did they come from?
- Does this producer care for other livestock?
- How many employees work at this site?
- Do the employees have livestock at home?
- Is equipment shared between sites or with neighbors?
- Does the producer grind his own feed or when was the last delivery of feed?
- Have there been any foreign visitors to the farm?
- Have any employees recently visited a foreign country?
- Are employees permitted to consume meat in the livestock buildings?

When the FADD arrives, communication will continue between the FADD, the veterinarian, and the producer. Many questions will need to be answered during the investigation. Be assured that there will be a constant stream of communication to keep those involved informed of the procedures and timeframe for sample testing.

Risk Communication

Risk communication is a two-way, interactive process that has been occurring throughout the risk assessment between the facility owner, risk assessor (veterinarian), the employees and other interested parties. Information has been collected, the analysis has occurred, and now information needs to be delivered to those affected by the risk assessment and risk management plan.

One of the major barriers to effective risk communication is inadequate planning and preparation. Before designing an educational program, it is important to consider who is best suited to communicate the message, what message will be most effective, and when and where the information should be communicated.

In large operations, the biological risk management plan may be formulated by upper management, and some employees may not understand the importance of the plan. Risk management plans must be understood, supported, and adopted by every employee for effective implementation. Because many employees may not understand disease transmission routes and the chain of events involved in disease spread, this communication can be difficult and employees may not fully appreciate the significance of the measures they are asked to follow.

Characteristics of effective risk communication:

- It must be adapted to meet the needs of the audience. If bilingual information is required, make sure it is provided;
- It should present the important information in more than one way (appeal to both visual and auditory learners);
- Keep sessions focused to a maximum of three main points and 45 minutes maximum;
- Sessions are more valuable if they are timely and the participants can apply the new information immediately;
- Sessions should cover what, when, where, how, by whom, and why;
- Give participants the opportunity to take ownership of the production process and the ramifications of decisions that impact their area. They should be actively engaged in the question at hand so that they share information, and most importantly provide input so that decisions become a collective agreement.
- Schedule meetings earlier in the day. Meetings at the end of the working day are less effective.

Educational programs that inform employees and other affected individuals of the risk assessment and management plan can take many forms, and may include:

- Face to face/group meetings (one of the best communication forms if the presenter and participants have open dialogue);
- Newsletter, fliers or bulletin;
- Videos, CD's, PowerPoint presentations or web-based instruction;
- Posted signs or information panels placed at key locations on the farm (break rooms, shower /changing rooms);
- Employee questions and suggestions (question/answer board, suggestion box, question period during meetings, etc.);

- Mentoring of new employees by experienced employees;
- Recognition or incentive program that rewards employees when BRM goals are reached (this has been used on some farms focused on farrowing rates, and preweaning mortality).

Educational programs should not be limited to one form. Facility owners may incorporate many of the above mentioned education forms to create a program that fits the needs of their facility. To help the veterinarian facilitate communication, there are handouts about each of the routes of transmission with various applicable diseases provided on the Center for Food Security and Public Health website (www.cfsph.iastate.edu) to educate producers about the risk of zoonotic, endemic and foreign animal diseases. The reports that can be printed based on the answers to the assessment question provide a visual tool to the strengths and weaknesses for the various routes of transmission on a swine farm. The final report graphs that are generated are meant as a visual aid to illustrate potential areas of action. The various risk factors identified have not been quantified or prioritized. It should not be interpreted as an arbitrary number which is required for a facility or veterinarian to “pass,” or even that comparable scores for two different facilities mean they face equal risk. The reports should be used to identify if a particular area seems to represent a disproportionate risk and help track progress over time through continued assessments. The management recommendations are made to minimize circumstances that could potentially result in the spread of infectious diseases.

Proper communication of the risk management plan is of utmost importance for effective infectious disease control. When communication is effective and efficient, disease spread can often be minimized and controlled. However, few management plans are successful if records are not kept or some form of biosecurity audit performed so that compliance can be verified and progress can be measured. Part of the risk communication process should include helping to ensure that a monitoring system is put in place to measure progress.

Conclusion

Biological risk management (BRM) is an essential part of all swine operations regardless of their size or mode of operation. Disease risk can never be completely eliminated, but BRM is a great approach to minimizing the possibility, as well as the consequences, of a new disease introduction or the spread of disease within a farm. Each operation has different strengths and weakness, but while keeping in mind the different routes of transmission, you can work with your veterinarian in figuring out the prioritization for your particular operation. Being aware of the different routes of

transmission will also serve as a reminder that there are more diseases out there than just PRRSV. A full awareness of all risks is critical in mitigating threats of endemic, emerging, and foreign animal diseases. Submitting surveillance samples which test for diseases also raises our awareness to a national level. For example, 14,666 samples were tested for CSF during 2010 as part of the CSF Surveillance Program. Testing included samples from both domestic and feral swine (personal communication). Surveillance of the U.S. swine herd is just as important as surveillance performed on the farm. While surveillance will help to identify a disease affecting one or more herds, practicing good BRM will give each producer the best chance of keeping that disease out of their herd. As we continue to learn about transmission routes of diseases, the BRM practices on each operation will need to be adjusted. The BRM is a working document that needs to be adjusted as new information is provided.

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