A thorough understanding of PRRS virus persistence and transmission is critical for successful eradication or control programs.

In many chronically infected herds, uncontrolled circulation of PRRS virus occurs in the breeding herd. Getting the breeding herd into a PRRS-stable status is the first step in controlling the infection. Stable breeding herds are defined as those herds that have no evidence of sow-to-sow or sow-to-piglet transmission.

Unstable breeding herds are frequently a result of the introduction of poorly acclimatized or exposed gilts.

Closing a breeding herd to new introductions for a period of 60 to 180 days is thought to provide a sufficient period to achieve stability. During this period, all negative animals should have an opportunity to become infected and subsequently result in a population of immune animals with negligible amounts of resident PRRS virus circulation.

Partial depopulation, all-in all-out pig flow, and use of PRRS vaccines can all be helpful in establishing stability on a farm.

Eradication programs have been customized to specific farm or production systems and have resulted in complete elimination of the virus. A variety of techniques have been used in these eradication programs but all start with the fundamental process of achieving stability in the breeding herd.
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5. Persistently infected breeding herds contain clusters of PRRS virus-infected animals, but the extent of shedding is limited. Diagnostic samples collected during whole-herd testing procedures suggested that PRRS virus-infected animals tended to cluster together in small groups. Figure 1 provides an example of an endemically infected breeding herd where all sows were tested on a single day, their location recorded, and their PRRS virus status determined by ELISA serology and virus detection (Dee et al. 2000a). Previously exposed and/or infected animals appeared to cluster in small groups or reside as single reactors randomly located throughout the gestating population. Section A contained 3 sows (shaded boxes) that were virus-positive at the time of sampling.

6. Genetically diverse strains of PRRS virus can co-exist in a single infected farm Molecular sequencing of PRRS virus nucleic acid recovered over a 12-month period from a chronically infected farm indicated that unrelated strains of PRRS virus could co-exist and circulate within a farm (Dee et al., 2001a).

7. The prevalence of PRRS virus-positive carrier sows in an infected breeding herd is low A recently published field study attempted to estimate the percentage of carrier sows within an infected field population (Bierk et al., 2001a). Results indicated that the level of persistently infected breeding animals was low in the population sampled (1 out of 60 animals or 1.7%). In this herd, the infected animal was detected during the ninth month following closure. Experimental infection of pregnant sows at day 95 with the virus recovered from this sow resulted in the production of both clinically affected and unaffected (but virus-positive) fetuses.

8. Tonsil biopsy is not an effective ante-mortem method for identifying persistently infected sows While tonsillar scrapings appear to be an effective method for detecting PRRS virus-infected weaned pigs, results from a recently published study indicated that the technique, when applied to breeding animals, resulted in a number of problems. These included the inability to consistently collect good quality tonsil samples and occasional injury to the animal (Bierk et al., 2000b). Furthermore, it often resulted in false negative results.

9. PRRS virus can persist in sows and persistently infected animals can shed virus to naïve contacts An experimental model demonstrated that PRRS virus negative sows could be infected with the virus after exposure to sows that had been infected 49, 56, and 86 days earlier.

10. Vertical and horizontal transmission of PRRS virus occurs by a number of routes Besides semen, PRRS virus transmission has been documented to occur through saliva, mammary secretions, and via the transplacental route, all of which are potential routes for sow-to-sow and sow-to-piglet transmission prior to weaning (Christianson et al., 1992; Wagstrom et al., 1998; Wills et al., 1997b). Vertical transmission from sow to piglet has also been documented to occur at a low frequency (3.7%) in clinically normal lactating populations (Dee and Philips, 1999).

11. Mechanical transmission of PRRS virus can occur via contaminated fomites and needles Mechanical vectors documented to spread the virus include contaminated coveralls, boots, and needles (Otak et al., 2001a,b). Although farm personnel do not appear to serve as carriers, virus has been recovered from the palmar surface of hands following contact with experimentally infected pigs (Otak et al., 2001b).

Determining the Pattern of Viral Infection

In today's industry, swine production systems are a series of interdependent populations: breeding/gestation/lactation, nursery, finishing, and the replacement pool. A fundamental principle of PRRS control is understanding the pattern of virus transmission within an infected production system through the use of serologic profiling. Serologic profiling is the process of monitoring infectious agents in populations by following changes in the levels of serum antibodies. It has been shown that PRRS virus may limit its spread to a specific population within the herd, for example the nursery (Dee and Joo, 1994b). Therefore, it is important to determine the pattern of viral transmission within an individual farm on a population or "stage of production" basis in order to determine which methods of control have the greatest chance of success.
Farm Classification: Understanding the PRRS Status of an Infected Farm

The classification of infected farms may be based on clinical signs, diagnostic results, or production data. Dee proposed a classification system to assist in the determination of the correct intervention strategy for control of the disease (Zimmerman et al., 1998). Four classes of farms were described:

The negative farm - An uninfected farm, as determined by clinical observations and diagnostic results.

The stable/inactive farm - "Stable" refers to a lack of virus transmission in the breeding herd. "Inactive" refers to the lack of clinical signs of PRRS in a weaned pig population. Thus, a stable/inactive farm has an infected adult population that is not actively shedding virus to piglets prior to weaning, and in which farrowing and nursery performance has returned to levels of productivity similar to those seen prior to infection.

The stable/active farm – In a stable/active farm, performance of the breeding herd is satisfactory, but there is evidence of active infection and clinical disease in pigs after weaning. Serologic profiling indicates seroconversion in the late nursery or finishing periods. At weaning, due to the lack of virus transmission within the gestating or lactating sow population, piglets are of excellent health, with high levels of colostral immunity. Two to 3 weeks post weaning, colostral immunity decreases and infection occurs with the source of virus being older, previously infected pigs. Virus is spread by mixing older, poor-growing pigs with younger pigs, by short distance aerosol spread, or by fomite transmission from room-to-room.

The unstable farm – Unstable herds may have recently experienced an acute outbreak or they may be persistently infected. In either case, clinical signs and losses are present in both the breeding herd and weaned pig populations. Serologic evidence of recent exposure to PRRS virus is detected throughout all populations. Clinical signs of PRRS virus are common at all stages of production.

In addition to herd profiling, it may be useful to submit tissues or whole animals to a diagnostic laboratory for pathological, bacterial, and virological examination. It is important to identify the components of the clinical disease process. This

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includes understanding the pathology involved, identifying concurrent bacterial and viral infections that contribute to the problem, and demonstrating the presence of PRRS virus.

A Review of Current Control Strategies

Once the classification of a PRRS virus-infected farm has been determined, it is possible to determine which strategies may be applicable for controlling the pattern of viral spread and reducing the clinical effect of the disease. With our current tools and knowledge, the goal in most cases is to establish stable/inactive status. Prior to implementing control strategies, it is important to review the available options. The following section will provide an overview of techniques, protocols, and products currently in use.

Gilt development & isolation/acclimatization

Prior to dealing with post-weaning PRRS, it is critical to stabilize the breeding herd. Strategies such as partial depopulation or piglet vaccination are not effective unless infection of the piglet is prevented prior to weaning (Dee and Joo, 1994b). A potential reason for persistent viral shedding within the breeding herd population is the introduction of naive or actively infected seedstock. This practice perpetuates the formation and maintenance of subpopulations of susceptible and/or recently infected sows within chronically infected herds (Dee et al., 1995a; Dee et al., 1995b).

A gilt developer facility is helpful for successfully preparing gilts for entry into an infected farm. Gilt developer facilities may be nursery and/or finishing buildings. They may be located on the sow site, but location on an alternate site is highly preferable. Regardless of the arrangement, they function under all-in/all-out (AIAO) pig flow practices. Gilts may be introduced as weaned piglets or a range of ages from 2 to 5 months of age. The purpose of the gilt developer facility is to prepare animals for PRRS virus infection prior to entry into the breeding herd (Dee, 1997a, 1997b).

Gilt development programs generally consist of 3 periods: the isolation period, the acclimatization period, and the recovery period. The length of each period may range from 30 to 60 days, depending on the age at which the pig is purchased, the PRRS history of the source and receiving herds, and the type and size of facility available. The isolation period consists of serologic testing (day 1 to 2) to determine the PRRS virus infection status of the incoming animals. If the choice is made to vaccinate against PRRS, it should be done shortly after arrival. The acclimatization period starts 30 days after gilts enter the developer facility. The purpose of acclimatization is to expose new animals to the farm-specific strain of PRRS virus. Finally, a period of recovery is implemented to reduce the risk of introducing actively infected gilts into the breeding herd. Sources of field virus (nursery pigs, cull sows) are removed from the development facility at this time, and the gilt population is allowed to recover for at least a 30 day period prior to entry into the gilt pool.

Partial depopulation

Partial depopulation is an adjustment in pig flow to interrupt horizontal transmission of PRRS virus and is an effective means for controlling post-weaning PRRS or eliminating virus from the weaned pig population (Dee and Joo, 1994b; Dee et al., 1997c; Dee et al., 1997d). Partial depopulation is based on the principle that virus circulation exists in a specific stage of production, i.e. the nursery or finisher, but is absent in the breeding herd. This specific pattern of spread is critical for success, since infection of piglets prior to weaning results in the introduction of infectious animals to the nursery or grow-finish populations. The advantages of partial depopulation are a minimal disruption in pig flow and low cost. The disadvantage of partial depopulation is that the technique depends on an absence of virus transmission in the breeding herd. In addition, it may be logistically difficult to implement in large (≥ 1,000 sows) herds, and it requires a temporary off-site facility to house depopulated pigs. In some cases, partial depopulation may need to be repeated every 1 to 2 years.

All-in/all-out pig flow (AIAO)

All-in/all-out (AIAO) pig flow has been effective at controlling a variety of respiratory pathogens in weaned pigs, including Mycoplasma hyopneumoniae and Actinobacillus pleuropneumoniae (Scheidt et al., 1995). AIAO consists of dividing buildings into individual rooms and allowing for thorough cleaning and disinfection of facilities between groups of pigs. This technique is very effective at reducing the horizontal spread of pathogens from older, infected animals to those recently placed in the finishing stage. While AIAO does not directly control the transmission of PRRS virus, it does reduce the impact of concurrent bacterial infections.

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The basis of AIAO is strict control over movement of animals. The mixing of older, slower growing, poor-doing pigs with younger animals is places the younger animals at a greater risk of becoming infected with PRRS virus and other pathogens. Furthermore, solid dividing walls and individual room ventilation needs to be established to provide separate air spaces and prevent fence-line contact of younger and older pigs. Ideally, age spread within rooms should not exceed two weeks. While individual pit compartments have been established in certain cases, this does not appear to be necessary if the aforementioned principles are followed.

**Vaccination**

The purpose of vaccination is to produce an immune response that will protect against clinical disease. Vaccination will not stop infection. For this reason, PRRS vaccine labels in the U.S. typically describe the product as “an aid in the reduction” of clinical disease associated with PRRS virus. Due to the necessity of cell-mediated immunity to control PRRS, modified-live virus (MLV) vaccines appear to be more efficacious than killed preparations (SA Dee, unpublished data). It is important to develop farm-specific vaccination programs, based on individual farm diagnostic data, rather than promote standardized protocols.

In the U.S., currently available modified-live vaccines (MLV) include Ingelvac® PRRS™ and Ingelvac® ATP™ (Boehringer-Ingelheim Animal Health, Inc., St. Joseph Missouri). Both are approved for use in pigs 3 weeks of age or older and gilts or sows 3 to 4 weeks prior to breeding. Modified live vaccines are not approved for use in PRRS virus-negative herds, pregnant females, or breeding age boars. Combination vaccine products have also been brought to the market recently, including PRRS virus and Haemophilus parasuis, PRRS virus, Haemophilus parasuis, and Erysipelothrix rhusiopathiae, and PRRS virus, parvovirus, and Leptospira interrogans spp.

A number of controlled studies have demonstrated safety and efficacy of MLV PRRS vaccines against homologous and heterologous viral challenge (Gorczyca et al., 1994, 1995, 1996; Henry and Tokach, 1996; Hesse, 1996a, 1996b; Mengeling et al., 1996). Side effects of modified live virus vaccines have been reported following administration, including shedding to contact controls, a short-term reduction in fertility following vaccination of naive sows prior to breeding, transplacental infection of the fetus following vaccination during the third trimester of gestation, and transmission through semen. The use MLV vaccines is discouraged in negative herds where spread of the virus could be detrimental to sale or export of PRRS negative breeding stock (Mengeling et al., 1995; Shin et al., 1995; Torrison et al., 1996).

Inactivated (killed) PRRS virus vaccines are available, as well. A commercial inactivated virus preparation for use in gestating sows was released in 1997 (PRRomiSe™, Bayer Corporation). In addition, autogenous PRRS vaccines, i.e., vaccines produced from virus isolated from a swine herd and intended for use only in the herd from which the virus was isolated, are available (Bayer Corporation; Immttech Biologics). At present, information is lacking on the performance of inactivated vaccine products.

Development of new vaccine products is currently an area of active research. Undoubtedly, as our knowledge of PRRS virus and the components of protective immunity improve, subunit, recombinant, and/or genetically engineered vaccines will emerge.

**Prevention of PRRS Virus Infection**

Despite the fact that PRRS virus infection is widespread throughout the world, uninfected herds still exist. While all routes of virus introduction into a naive herd are not completely understood at this time, the primary sources are infected pigs and semen (Dee, 1992; Swenson et al., 1994). For that reason, it is critical to routinely isolate and test breeding stock intended for introduction into PRRS virus-negative herds. Farms that have never experienced the disease should purchase replacement stock from known negative sources that carry out a regular schedule of herd monitoring. Communication with the veterinary practitioner associated with the source farm should take place prior to purchase.

Ideally, isolation facilities should be located on another farm site and visited at the end of the working day. Following the arrival of new stock, all animals should be serologically tested on days one and 14 following entry into the isolation building. Isolation periods should be at least 30 days in length to allow sufficient time to obtain laboratory results prior to animal introduction. If diagnostic results indicate that incoming stock is infected, all animals should be removed from the premise and marketed.

**Elimination of PRRS Virus**

Elimination of PRRS virus from swine herds has been completed successfully. The major obstacle to
PRRS eradication is the ability of the virus to establish persistent infection in swine. PRRS virus is an Arterivirus and persistent infection is a characteristic common to viruses within this group (Plagemann and Moennig, 1992). Studies have described the ability of sows to harbor persistent PRRS virus and shed to naive contact control sows for up to 86 days post inoculation (Bierk et al., 2001c). Wills et al. (1997a) described isolation of virus from the tonsils of infected pigs for as long as 157 days after inoculation. Persistence of the virus has been described in boars, with the shedding of PRRS virus in semen detected out to 92 days post inoculation (Christopher-Hennings et al., 1995; Swenson et al., 1994)

Several strategies have been applied to PRRS virus elimination, including whole herd depopulation-repopulation, test and removal, herd closure, and partial depopulation.

**Whole herd depopulation-repopulation**

Whole herd depopulation-repopulation has been widely used in the industry. It has been proven effective not only for elimination of a wide range of pathogens, but as a method to enhance genetic improvement (Leman, 1988). While it is possible to eliminate PRRS virus using this strategy, maintaining the farm PRRS virus-free in the long term obviously depends on the status of the incoming replacement stock. It is essential to purchase PRRS virus-free stock, and a representative sample of animals from each incoming group of animals should be tested during the repopulation.

**Test and removal (T & R)**

Successful elimination of PRRS virus by test and removal has been described in a number of commercial seedstock farms (Dee and Molitor 1998, Dee et al., 2000a, 2001b). At present, all farms summarized in these papers remain free of PRRS virus 2 to 3 years following completion of the protocol. The primary focus of this strategy is to test all breeding animals, identify carriers, remove them from the herd, and prevent vertical transmission of PRRS virus. Analysis of sera using ELISA for the detection of antibodies along with PCR for the detection of viral protein are used in combination to identify previously exposed, potentially infected animals. While highly effective, T&R does have certain disadvantages, including a high diagnostic cost ($10 U.S. per sow tested), extensive labor on testing days, and does result in premature removal of potentially PRRS virus-negative sows due to the inability of the ELISA to distinguish chronic carriers from those previously infected that have cleared the virus. Finally, due to a lack of differential tests, it is impossible to distinguish vaccinated animals from infected animals. Therefore, its effectiveness in vaccinated herds is unknown at this time.

**Herd closure**

Herd closure is an alternative to T&R (Torremorell and Christianson, 2001). This protocol is based on preventing the entry of replacement gilts for an extended period (4 to 8 months), isolating the infection to within the endemically infected breeding herd, and removing carriers over time following normal culling procedures. This procedure does have several advantages, including preservation of genetic material and reduced labor when contrasted with T&R. The main disadvantage of herd closure is the economic loss due to extended breeding periods without the availability of gilts and the impact this has on herd parity distributions. While these issues can be dealt with using an off-site breeding project, this also results in extra cost (labor, facilities, etc).

**Partial depopulation**

Partial depopulation (PD) is an effective means for eliminating PRRS virus from endemically infected weaned pig populations in farms that employ segregated production, in conjunction with a program of elimination of the virus within the breeding herd. Obviously, if infected pigs are continually introduced to the nursery secondary to horizontal and/or vertical transmission from dam to offspring, PD will fail.

**Summary**

Porcine reproductive and respiratory syndrome has been a source of frustration to pork producers and veterinarians since it first appeared and it continues to be so today. Progress has been made in understanding PRRS virus epidemiology, improving the accuracy of the diagnostic testing procedures, and devising cost-effective control measures. Although many questions remain unanswered, increased knowledge in these areas has improved our ability to prevent, control, and/or eradicate PRRS. Even so, prevention, control, and eradication of PRRS virus using the current control strategies, diagnostic tests, and vaccines is not easily accomplished. Reasons for this include:

1. The ability of the virus to produce long-term carriers (persistent infection).
2. The viruses’ tendency for mutation and/or recombination, resulting in the production of new, diverse strains.

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3. A lack of information regarding non-swine routes of viral transmission.

Current diagnostic assays, including PCR, cannot reliably and rapidly identify persistently infected carrier animals. The ability of the virus to undergo genetic change and for multiple strains of PRRS virus to co-exist in farms challenges the ability of commercially available vaccines to provide immunity across different strains. Finally, if eradication is achieved, herds are vulnerable to re-infection with PRRS virus through the introduction of carrier animals or by “area spread” of the virus via currently unidentified routes of entry. Therefore, eradication should not be undertaken lightly. The economic effects of PRRS can be minimized through the application of management strategies, and profitability can be maintained despite the presence of the virus in the herd.

References


Dee SA. 1992. Investigation of a nationwide outbreak of PRRS using a telephone survey. American Association of
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