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Improvements in swine herd biosecurity reduce the incidence risk of porcine reproductive and respiratory syndrome virus in breeding herds in the Midwestern United States

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OBJECTIVE
Porcine reproductive and respiratory syndrome (PRRS) is a significant disease of swine. The purpose of this study was to determine whether application of a comprehensive, science-based approach to breeding herd biosecurity, known as next-generation biosecurity (NGB), could reduce PRRS incidence risk across a large commercial production company.

ANIMALS
Pigs (381,404 sows across 76 breeding herds).

METHODS
From 2009 to 2020, the annual incidence risk of PRRS in sow farms managed by the same company averaged 33%, ranging from 20% to 50%. To measure the effect of NGB on PRRS incidence risk, a retrospective cohort study was conducted from July 1, 2021, to June 30, 2023, across breeding herds managed by the same company. During the analysis, 2 groups of herds emerged: those that implemented protocols for all phases of NGB (NGB COMPLETE), and those that implemented all described protocols of biosecurity except for air filtration (NGB INCOMPLETE).

RESULTS
During the 2-year assessment period, 56 breeding herds were classified as NGB COMPLETE, while 20 herds were NGB INCOMPLETE. The PRRS incidence risk in NGB COMPLETE herds was 8.9% as compared to 40.0% in NGB INCOMPLETE herds. From disease year 1 (July 1, 2021, to June 30, 2022) and disease year 2 (July 1, 2022, to June 30, 2023), system-wide PRRS incidence risk was 8.6% and 9.2%, respectively. The association between NGB status and PRRS incidence risk for the 2-year period was statistically significant at a *P* value of .006.

CLINICAL RELEVANCE
Results of the present report provided evidence that improvements in biosecurity result in lower PRRS incidence risk under large-scale commercial swine production conditions.

Keywords: pigs, PRRS, next generation, biosecurity, commercial production

Porcine reproductive and respiratory syndrome (PRRS) is a devastating disease of pigs, resulting in loss of production, reduced animal welfare, and economic losses estimated at $660M/y to the US swine industry.[1] PRRS is caused by PRRS virus (PRRSV), a single-stranded enveloped RNA virus that was first identified in 1991.[2] PRRSV is classified in the genus *Arterivirus* and is a member of the family *Arteriviridae*.[3] PRRSV undergoes genetic change as it replicates within pigs and spreads throughout populations, which results in the regular emergence of new variants that often display enhanced pathogenicity and ability to spread.[4,5] Recent variants demonstrating these features include PRRSV 184, PRRSV 174, and PRRSV 144 lineage L1C.[6–8] In addition to enhanced virulence, other characteristics such as the improved ability to spread via the airborne route have been described.[8] PRRSV is now known to be endemic in pig populations across 5 continents, and only African swine fever virus can rival its clinical and economic significance throughout the global swine industry.[9]

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In an effort to advance control of PRRS, a recent publication[10] challenges US swine veterinarians to help farmers to eliminate PRRSV from breeding herds and prevent reinfection through improvements in biosecurity. It had been shown that PRRSV could be eliminated from infected breeding herds; however, reinfection was a frequent event, particularly when herds were located in regions of dense swine production.[11] A recent publication[12] demonstrates that advances in biosecurity, specifically air filtration and the use of feed mitigants in breeding herd diets, could reduce the frequency of PRRSV infection. Application of these technologies, in conjunction with existing biosecurity measures, has been termed *next-generation biosecurity* (NGB).[10,12] NGB is defined as the implementation of a comprehensive set of science-based biosecurity protocols that target select direct and indirect routes of PRRSV transmission that have been validated experimentally.[12] The direct routes of PRRSV transmission targeted by NGB consist of infected breeding stock and contaminated semen.[13,14] Protocols employed to reduce the risk of PRRSV entry to the breeding herd via these routes involve the quarantining and testing of incoming genetic stock originating from a documented naïve genetic source, along with the use of semen from a PRRSV-naïve artificial insemination center.[15,16] NGB also targeted the indirect routes of PRRSV transmission by managing mechanical/fomite-based risks, such as contaminated transport, personnel boots, and coveralls and contaminated supplies,[17–19] through the use of validated protocols for transport sanitation, personnel shower in/out, and supply entry.[20–22] In addition to the mitigation of mechanical risk, NGB also focuses on the ability of PRRSV to infect farms via the airborne route and through contaminated feed,[18,23,24] through the application of validated air filtration protocols and the use of feed additives capable of inactivating PRRSV in breeding herd diets.[23,24] Therefore, the objective of the study reported here was to compare the ability of NGB to reduce PRRS incidence risk. It was hypothesized that following application of all aspects of NGB, PRRS incidence risk in breeding farms managed by the Pipestone System would be reduced as compared to reported levels of PRRSV incidence risk across the company since 2009.

Methods

Selection of breeding herds and historical PRRS incidence risk

NGB was developed for breeding herds in the Pipestone System, which is currently the third-largest breeding herd inventory in the US. The Pipestone System included breeding herds located across several states in the Midwestern US, including Minnesota, Iowa, South Dakota, North Dakota, Indiana, Illinois, Missouri, Kansas, and Wisconsin. From 2009 to 2020, the annual incidence risk of PRRS across Pipestone System breeding herds averaged 33%, with an annual range of 20% to 50%, as determined by the Morrison Swine Health Monitoring Project (MSHMP), administered by the University of Minnesota College of Veterinary Medicine.[25] The MSHMP was developed by the late Dr. Bob Morrison, a faculty member on the University of Minnesota College of Veterinary Medicine swine group, to monitor PRRS cumulative incidence risk throughout the US swine industry.[26] Initiated in 2009, the MSHMP is a voluntary initiative in which producers and veterinarians share new cases of breeding herd PRRSV infection status weekly to contribute to the understanding, in quantitative terms, of PRRS epidemiological dynamics and, ultimately, to support its control in the US. The MSHMP has characterized the incidence risk over the last 14 years, allowing project participants and industry stakeholders to understand viral occurrence trends, and now is a well-documented and widely recognized means of monitoring PRRSV incidence risk over a large segment of the US swine industry.[27,28] Due to the high Pipestone System incidence risk of PRRS and the subsequent economic impact of frequent PRRS outbreaks, farmers and lenders requested action, resulting in the development of NGB. During the study period, all breeding herds in the Pipestone System were involved in the process.

Ethical review

Following IACUC review, it was determined that an ethical review of the farms reported was not needed, as this study was data based. In addition, Pipestone has permission to use site data for research and publication as part of the management contracts.

Details of NGB protocols

As described earlier, NGB protocols targeted select direct and indirect routes of PRRSV infection **(Figure 1)**.

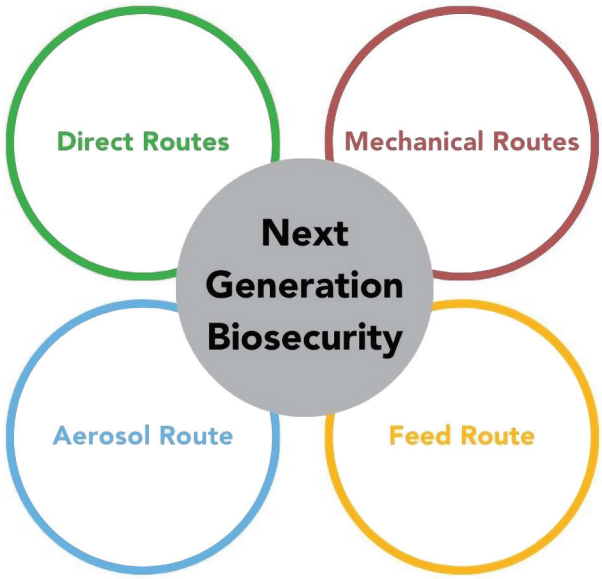

Figure 1—The relationship of the selected routes of direct and indirect PRRSV transmission targeted by the next-generation biosecurity approach.

Protocols targeting direct routes (eg, infected pigs and contaminated semen) focused on the quarantine and testing of incoming breeding stock from a validated PRRSV-naïve source and the use of validated PRRSV-free semen from PRRSV-naïve boars housed in an artificial insemination center. Upon arrival to the breeding herd, incoming gilts, approximately 24 days of age, were placed into a designated quarantine room. The quarantine room was located on the same site, directly connected to the breeding herd facility; however, it had its own personnel and supply entry points and its own air filtration system and slurry pit. Immediately upon arrival to the quarantine room, oral fluid samples were collected from all pens of gilts (1 rope/pen) and tested for the presence of PRRSV RNA by PCR.[29] This process was repeated on day 14 after arrival. If both sets of samples were determined to be PRRSV PCR negative, the quarantine was lifted, and the gilts entered the herd. Regarding semen, the company worked with several artificial insemination centers that practiced strict biosecurity based on published data and used daily blood swab testing of collected boars to ensure a PRRSV-negative status following testing by PCR.[16,30]

After these practices were in place, the focus turned to mitigating mechanical (fomite-based) routes of PRRSV transmission. This included transport sanitation, which involved the removal of organic material (feces, shavings, etc), followed by washing, disinfection, drying of trailers, and auditing.[20] Personnel entry required a shower-in and shower-out procedure and use of farm-designated clothing and footwear.[21] Finally, a designated area to manage supply entry using validated decontamination and downtime protocols was implemented.[22] The next step was implementation of an air filtration system designed to reduce the risk of airborne PRRSV entry to breeding herds, involving negative pressure ventilation, minimum efficiency reporting value, 14 fiberglass filters (Camfill Farr), and strategies to minimize retrograde movement of external airflow into the facility.[18,23,24] A filtration compliance technician was assigned to each breeding herd to inspect and maintain the air filtration system. In addition, subsets of filters were removed at designated times, sent to a third-party laboratory (LMS Technologies), and tested to measure airflow and fractional efficiency changes over time. A standardized auditing procedure was also implemented to monitor personnel compliance with mechanical and aerosol biosecurity protocols, involving unannounced visits to all breeding herds by trained personnel twice each month. A monetary bonus was applied to herd personnel based on positive audit results and the ability to maintain a PRRSV-negative status. Finally, based on experimental evidence of the ability of PRRSV transmission through feed,[24] products validated to reduce the risk of PRRSV were added to the diets of all breeding herds. Approved products were based on data from published studies and included organic acid-based products (Guardian at 0.44%/ton; Alltech), organic acid products with methionine analogs (Activate DA at 0.5%/ton; Novus International), or formaldehyde-based products (SalCURB at 0.275%/ton; Kemin).[24]

Study design and analysis

To measure the effect of NGB on PRRS incidence risk, a retrospective cohort study was conducted during the period of July 1, 2021, to June 30, 2023, across all breeding herds within the Pipestone System, including existing herds and any new herds that joined the company during this time. A retrospective approach was taken, as the review of historical records involving PRRSV infections across company farms over the 2-year period provided the data for the analysis. Herds were classified either as NGB COMPLETE (ie, all aspects of the NGB protocol had been applied) or NGB INCOMPLETE (ie, mechanical and feed-based protocols that lacked air filtration had been implemented). The summary statistics for herd size were calculated with the median and range. The count of new PRRSV introductions into farms was determined for each disease year, and the incidence risk was calculated for each NGB category by state as well as for the overall time period across all breeding herds. Incidence risk was chosen as the measure of the disease occurrence, as Pipestone stakeholders were interested in knowing the risk of a new introduction throughout the study period rather than knowing how quickly herds would become infected. In addition, stakeholders were also interested in being able to conduct benchmarking, and the incidence risk would be comparable to the national MSHMP PRRS incidence risk. Regarding the entry of new PRRSV variants, a new PRRSV introduction to any company breeding herd was defined in 1 of 3 ways: (1) a PRRSV recovered from swine samples that was not derived from a modified-live PRRSV vaccine, (2) a PRRSV identified as the initial introduction to a previously naïve herd or, (3) a PRRSV variant having > 2% heterology based on the nucleic acid sequencing of the open reading frame 5 region as compared to historical sequences identified in the herd.[31]

For the statistical analysis, all herds in the Pipestone System were included in the denominator, and if a single herd was infected more than once during the disease year, the farm was counted only once in the numerator. A Pearson χ^2 test (Stata 161C; StataCorp LLC) for association between NGB status (COMPLETE vs INCOMPLETE) and disease status (new PRRSV introduction or not) for the 2-year period using a level of significance of 0.05 was used. Each farm was only counted once in this analysis even if they became infected with different strains of PRRSV more than once in the time period.

In addition, to understand whether there was any difference in the area density of swine farms surrounding the participating breeding herds, all neighboring swine herds to the best of our knowledge were identified within an 8.3-km radius of each breeding herd via Google Earth, version 7.3.2.5776, and Map Developers (mapdevelopers.com). This distance was selected based on published data regarding the ability of PRRSV to be transported via aerosols out to and beyond this distance.[32] In conjunction with mapping, site inspections by approved and trained Pipestone personnel were conducted around each participating breeding herd to validate whether the sites did or did not house pigs and the

types of sites (eg, breeding herd, wean-to-market facility) in the respective area. In addition, whether each site was owned and/or managed by Pipestone was also recorded. This practice had been in place across the Pipestone System for more than 12 years. The evaluation of area density around these herds was calculated twice a year, including regular updates, including site inspections during the 2 years of the study. During this 2-year assessment, the difference in the mean number of neighboring swine herds within an 8.3-km radius of NGB COMPLETE herds and NGB INCOMPLETE herds was analyzed by Mann-Whitney *U* test (Statistics Kingdom), with the level of significance set at 0.05. Following the analysis, data were graphed to depict the overall PRRS incidence risk across all farms in the Pipestone company during disease year 1 compared to all farms in disease year 2. Graphs were constructed using Microsoft Excel (Microsoft Corp) in accordance with the format used by the MSHMP.

Results

Herds were categorized into 1 of 2 groups—specifically, herds that implemented all phases of the NGB approach and herds that had implemented all protocols (direct, mechanical, and feed) but had not applied an air filtration system. For reporting the results and analysis, the former group was classified as NGB COMPLETE, while the latter was classified as NGB INCOMPLETE. The 2-year evaluation involved a total of 321,013 and 381,404 sows housed across 69 and 76 breeding sites, respectively. Two "disease years" were evaluated in the study, defined as July 1, 2021, to June 30, 2022 (disease year 1), and July 1, 2022, to June 30, 2023 (disease year 2). Disease year 1 involved 69 breeding herds, 48 of which had incorporated biosecurity protocols across all direct and indirect routes and were designated as NGB COMPLETE. In contrast, 21 herds implemented protocols mitigating mechanical and feed risks, but were unable to implement an air filtration system due to cost and/or facility age and design, and these were designated as NGB INCOMPLETE. Disease year 2 involved 76 breeding herds, 56 of which were NGB COMPLETE and 20 of which were NGB INCOMPLETE.

Characteristics of NGB COMPLETE and NGB INCOMPLETE herds, including breeding herd inventory, herd distribution across US states, number of new wild-type PRRSV introductions across each group, and incidence risk of PRRS, are summarized **(Tables 1 and 2)**. Comparing the 2 groups, the median herd size of NGB COMPLETE herds was 5,727 sows (range, 1,387 to 12,000 sows). In comparison, the median herd size of NGB INCOMPLETE herds was 3,102 (range, 1,362 to 6,219 sows). During the study period, the incidence risk of PRRS across all herds in the company was 8.6% in disease year 1 and 9.2% in disease year 2. These data are displayed graphically **(Figure 2)**.

Table 1—A descriptive summary of breeding herd statistics and porcine reproductive and respiratory syndrome incidence risks by state from July 1, 2021, to June 30, 2023, in herds that used all components of next-generation biosecurity.

State	No. of breeding herds	No. of sows	New PRRSV introductions	PRRS incidence risk	Mean	Range	SD	95% CI	Median
Iowa	6	24,425	1	16.7%					
Illinois	2	9,356	0	0.0%					
Indiana	2	16,109	0	0.0%					
Minnesota	13	52,201	4	30.8%					
Missouri	6	32,276	0	0.0%					
South Dakota	22	142,809	0	0.0%					
Wisconsin	2	11,364	0	0.0%					
Kansas	3	24,500	0	0.0%					
Total	**56**	**313,040**	**5**	8.9%	5,590	1,387–12,000	2,153	5,014–6,166	5,727

PRRS = Porcine reproductive and respiratory syndrome. PRRSV = PRRS virus.

Table 2—A descriptive summary of breeding herd statistics and porcine reproductive and respiratory syndrome incidence risks by state from July 1, 2021, to June 30, 2023, in herds that did not use all components of next-generation biosecurity.

State	No. of breeding herds	No. of sows	New PRRSV introductions	PRRS incidence risk	Mean	Range	SD	95% CI	Median
Iowa	5	12,018	6*	100.0%					
Illinois	5	17,961	1	20.0%					
Minnesota	2	8,818	0	0.0%					
Missouri	1	2,958	0	0.0%					
North Dakota	1	5,498	0	0.0%					
South Dakota	5	19,555	1	20.0%					
Kansas	1	1,556	0	0.0%					
Total	**20**	**68,364**	**8**	40.0%	3,418	1,362–6,219	1,389	2,768–4,068	3,102

*One farm in Iowa broke with 2 difference PRRSV variants in this time period, but the farm was counted only once for the incidence risk calculation.

PRRS = Porcine reproductive and respiratory syndrome. PRRSV = PRRS virus.

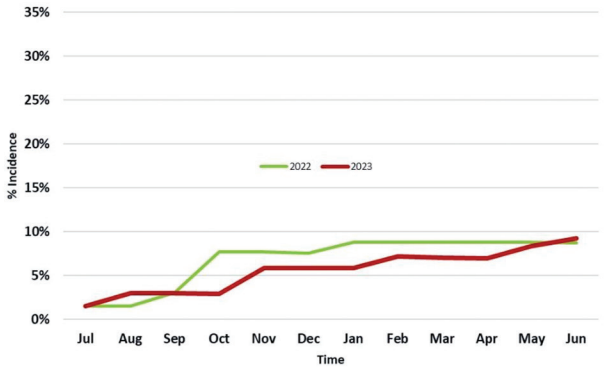

Figure 2—Comparison of PRRSV incidence risk across all herds in the Pipestone company during the 2 disease years involved in the case study. The green line represents disease year 1 (July 1, 2021, to June 30, 2022) involving 69 breeding herds, while the red line represents disease year 2 (July 1, 2022, to June 30, 2023) involving 76 breeding herds.

In year 1, 3 out of 48 NGB COMPLETE herds experienced new wild-type PRRSV introductions, for an incidence risk of 6.3%. In contrast, 3 out of 21 NGB INCOMPLETE herds experienced new wild-type PRRSV introductions, for an incidence risk of 14.3%. In disease year 2, novel infections occurred in 2 out of 56 NGB COMPLETE herds (3.6%), while 5 infections were observed in 20 NGB INCOMPLETE herds (25.0%). Across the 2 disease years, 1 NGB COMPLETE herd and 1 NGB INCOMPLETE herd experienced 2 new PRRSV introductions, 1 in each year. A χ^2 test for association between NGB status and disease status for the 2-year period resulted in a statistically significant association between NGB status and disease burden (*P* value = .006). Across the 13 new wild-type PRRSV introductions, open reading frame 5 sequence heterology ranged from 9% to 14% as compared to historical variants, or 100% heterologous if it was the initial infection of a naïve herd. Finally, during this 2-year assessment, the median number of neighboring swine herds within an 8.3-km radius of NGB COMPLETE herds and NGB INCOMPLETE herds was calculated and determined to be 2.0 and 2.0 respectively. This difference was not significant (*P* = .6085) based on the Mann-Whitney *U* test.

Discussion

In the introduction, it was hypothesized that PRRS incidence risk would be reduced following the implementation of all NGB aspects of NGB as compared to historical levels of incidence across company farms. The results of this retrospective cohort study supported the hypothesis and suggest that the concept of NGB, while not perfect, is fundamentally sound and has significantly advanced the science and practice of swine herd biosecurity over the past several years. This is further evidence describing sustainable PRRS control across a large commercial swine production system in the US, which supports previously published experimental data.[12]

Strengths of the study included the description of a biosecurity process within a single production system that encompasses a wider degree of protocol implementation than what is currently being used in the global industry. Based on the authors' experience, this approach has not yet been applied at this level. In addition, the size and scope of the production system described in the paper, the consistency of the biosecurity protocol application across each herd in the system, the assessment of the protocols over multiple years, and the ability to collect accurate data on area swine density that surrounded each breeding herd are novel strengths of the study and have not been described in the published literature. The issue of surrounding farm density is very important, as differences in area density could have easily biased the performance of the biosecurity protocols. Further, we have seen in some other recent work that the state where the farm is located matters, but the reason for the association with location was not determined.[12] However, based on the long-standing, continuous process of validating pig density around Pipestone System breeding herds and the use of multiple means of assessment (mapping and physical inspection), the authors are confident that the surrounding herd density is accurate and that this variable did not influence the results reported in the paper. Regarding limitations, this study focused only on the breeding herd, and clearly programs designed to biosecure the wean-to-finish segment of the pork production chain need to be developed. Furthermore, since this is a field study, whether herds in each group across both study periods were being challenged equally could not be determined.

In closing, based on the information from this study, we believe the practice of NGB has merit and, when appropriate (based on facility design, financial status of the enterprise, and personnel discipline within the herd), should be considered for adaption across the global swine industry to improve the control of PRRS and other domestic diseases as well as to enhance preparation for the impending challenge of transboundary diseases, such as African swine fever.

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Disclosures

The authors disclose a conflict of interest, as the Guardian feed additive described in the study was developed by Pipestone and sold to Alltech.

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