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Production impact & time to stability in sow herds infected with porcine epidemic diarrhea virus (PEDV)

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ABSTRACT

PEDV was first detected in United States in May, 2013. The virus spread through the swine industry and was reported in 30 US states by June, 2014 (Morrison and Goede, 2014). There are limited data describing the impact on production in sow farms. Veterinarians attempt to control the virus in sow herds with a program that stimulates herd immunity. There are no data on how long it takes with this control program to achieve a stable state of consistently produce weaned pigs that are not infected with the virus. This study involved participants and data from an existing program called the Swine Health Monitoring Project. Veterinarians were invited to share production data from 429 herds infected with PEDV. These data, in conjunction with diagnostic reports, were used to estimate the time required for the herd to produce PEDV PCR negative pigs and the production loss. Of the 429 infected herds that achieved the stable state of weaning PEDV PCR negative pigs, the median time was 28 weeks, ranging from 7 to 64 weeks. A median of 2.7 piglets/inventoried sow were not weaned and the average time required to recover to baseline production was 10 weeks in 183 herds. Herd infected in quarters 3 or 4 of the year had approximately twice the negative impact. These data are valuable for veterinarians in advising clients on the anticipated impact and time to re-achieve a stable state with regards to PEDV.

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1. Introduction

New cases of PEDV have spread extensively within the United States since the first diagnosed farm was confirmed in April, 2013 (Stevenson et al., 2013). The virus spread through the country being detected in 30 states and approximately 50% of the US swine breeding herds by June 30, 2014 (Morrison and Goede, 2014; Morrison and Goede, 2015). The original US PEDV strain can cause up to 100% suckling piglet mortality (Pensaert and Yeo, 2006).

PEDV is an enveloped, single stranded, positive sense RNA virus of the genus *Alphacoronaviridae* in the family *Coronaviridae* similar to transmissible gastroenteritis virus (TGEV) (Hofmann and Wyler, 1989; Stevenson et al., 2013). The two viruses infect swine of all ages with identical clinical effects of watery diarrhea and vomiting, but can be differentiated via RT-PCR testing of fecal material and environmental samples. Aside from the identified US strains of PEDV with reported similarly severe clinical impact, a variant of PEDV characterized by a large deletion in the spike gene (S-INDEL variant) has been detected (Oka et al., 2014; Vlasova et al., 2014). Cases of infection with the S-INDEL variant of PEDV (also identified as OH851) have resulted in apparent milder clinical impact and faster return to baseline production than original US PEDV clades (Goede et al., 2015). The S-INDEL variant was initially identified by whole-genome sequencing due to the unexpected observation of low mortality and rapid time to stability in some herds diagnosed with PEDV by RT-PCR.

Efforts to control the virus after infection include a whole-herd exposure program inspired by the same feedback exposure methods used to eliminate TGE virus from breeding herds (Geiger and Connor, 2013). This program includes "loading" the breeding herd with as many gilts as capacity allows, closing the herd to any more introductions and then exposing all present through the feedback program in an attempt to infect all sows at the same time. The goal is to stimulate sufficient herd immunity, such that in conjunction with aggressive environmental cleaning and restricted movement of sows and pigs, the virus is eliminated from the premises. After whole herd exposure to PEDV via feedback of intestinal and fecal material, the sows' immunity (Gerber et al., 2014) reduces the 100% morbidity of watery diarrhea and 50–100% pre-weaning mortality that is seen during an acute outbreak in naïve herds (Pensaert and Yeo, 2006). While the long term goal at a sow herd might be to eliminate the virus, a shorter term goal in all herds is to wean pigs that

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are not infected. Holtkamp et al. (2011) attribute the term "stable" to herds infected with Porcine Reproductive and Respiratory Syndrome virus (PRRSV) where pigs are PCR negative at weaning but there is insufficient diagnostic evidence to indicate that the herd is free of the virus. Linhares et al. (2014) proposed the term "time to stability" (TTS) as being the time from last known exposure of the sow herd to PRRSV until there was 4 consecutive samples of at least 30 weaned pigs that tested PCR negative. This same goal of stability has been adopted for PEDV. After clinical signs subside, veterinarians typically test piglets' feces for the presence of PEDV by PCR (Chen et al., 2014) with the goal being to wean PEDV negative pigs as soon as possible after the herd is infected. Whereas the programs have been anecdotally successful at controlling clinical signs, these methods and their success as measured by time to stability have not been reported.

Similarly, Linhares et al. (2014) measured time for herds to recover performance back to the level achieved before PRRSV infected the herd. They quantified the loss as pigs not weaned and described the parameter as "time to baseline performance" (TTBP). This has not been reported for PEDV. Also, given the identical clinical signs between original PEDV strains and the S-INDEL variant, it is important to compare TTS and TTBP between the S-INDEL variant PEDV and the original strain.

The objectives of this study were to determine TTS and TTBP in a sample of sow herds infected with PEDV.

2. Materials and methods

All herds enrolled in the Swine Health Monitoring Project (SHMP) that were infected with PEDV after April 2013 when the virus was detected in United States through July 2014 were eligible to participate in this study and were included in analysis regardless of vaccine product use. Briefly, this SHMP project represents a convenience sample of 910 sow herds including a total of approximately 2.3 million sows. Veterinarians represent each herd and voluntarily report diagnostic status for PRRSV and PEDV on a weekly basis (Tousignant et al., 2015). Of the 910 herds in SHMP, 863, 538 and 491 participate in sharing diagnostic results for PEDV, PRRSV or both, respectively.

Diagnostic records were not audited and veterinarians' reports were assumed to be accurate. This included the diagnosis of PEDV, monitoring the requested sample size after PEDV infection and characterizing the sow herd status for PRRSV.

Of the 863 sow herds enrolled in the Swine Health Monitoring Project for PEDV, 454 (53%) had been infected and were included in the assessment of TTS. Following the guidelines for PRRSV (Holtkamp et al., 2011), herds were declared "stable" by the veterinarian after finding 4 consecutive samples of at least 30 litters to be PCR negative for PEDV. Time to achieve stability was determined as the number of weeks from reported initial infection until the last week of achieving 4 consecutive negative samples.

To evaluate production impact, all veterinarians were invited to share production records and 190 herds participated. Pigs weaned per week was the key outcome compared before and after PEDV infection was detected. Statistical process control methods were used as described by Linhares et al. (2014). Briefly, 26 weeks of performance data prior to the onset of clinical signs of PEDV were collected as the control period to determine baseline production for each farm ("in control" level of production). Baseline was estimated by calculating the arithmetic mean of weekly number of piglets weaned throughout the control period. Two methods were used to determine TTBP. The time for the exponentially-weighted moving average (EWMA) of weaned pigs/week (lambda = 0.40) to return to 100% of previous production was used to accurately describe herds exhibiting lengthy return to baseline after initial rapid response. Comparatively, the time for the EWMA to return to within 99% confidence limits (3σ) of the baseline production was used as a standard method to evaluate return to an acceptable baseline range of production. (De Vries and Reneau, 2010).

Net loss of weaned pigs was calculated as a measure of production impact for each TTBP calculation method. Net loss was defined as the baseline expected production minus the area under the curve of weekly piglet weaning numbers from week 0 post-diagnosis to re-achieving baseline production plus the number of piglets weaned off in the first week of infection. Early weaning of piglets immediately after detection of the PEDv outbreak in farrowing became typical practice shortly into the nationwide epidemic in an attempt to save as many piglets as possible through weaning onto solid food and into a clean environment. This early weaning is thought to prevent exacerbation of diarrhea by milk product maldigestion and by removing piglets from rapidly-increasing viral challenge in the environment. This net loss was then standardized by herd size to "piglets lost per 1000 sows" for comparison among herds.

There were only 5 herds in the SHMP database confirmed to be infected with S-INDEL variant. To increase the sample size for comparing production impact with herds infected with the Original strain, 5 other sow herds confirmed to be infected with S-INDEL variant were recruited through contacts with veterinarians involved in the study. All remaining 185 herds were assumed to have been infected with original strain of US PEDV. Veterinarians reporting sample sequences and by considering the timing of early infections in the US epidemic participating in the study before sequencing was widely available, lead us to believe that approximately 5% of these herds could have potentially been S-INDEL cases.

Risk factors potentially associated with TTS and production loss included herd inventory, quarter of the year when the herd was infected with PEDV and PRRS infection status when the herd was infected with PEDV. PRRSV infection status was analyzed as infected (status 1) vs pooled herd statuses of stable, provisionally negative or negative (status 2, 2 v, 3, 4). Herds confirmed to be infected with S-INDEL variant were compared to herds presumed to be infected with the original PEDV strain.

Standard testing guidelines were recommended to participating veterinarians highlighting that 4 negative sampling rounds including 30+ litters sampled would be used to determine stability. Few production companies tested differently than the recommended sampling. One company used 3 negative sampling rounds to determine stability and 2 others that we are aware of, sampled variable numbers of litters, but never less than 15.

Descriptive and analytic statistics were conducted using Statistix v10.0 software (Analytical Software, Tallahassee, FL). Frequency distributions of TTBP, net piglet loss and TTS were tested for normality with Shapiro–Wilk test. Testing for association between TTBP, net loss and TTS and respective risk factors were conducted using Spearman rank correlations and Kruskall–Wallis ANOVA.

3. Results

Of the 454 herds that were infected with PEDV, 429 achieved stability. The TTS distribution differed significantly from normal ($p < 0.001$, Fig. 1). The average and median TTS were 29.5 and 28.0 weeks, respectively and values ranged from 7 to 64 weeks.

The 429 herds had an average inventory of 3025 sows ranging from 500 to 12,410 sows. Of these sow herds, 80.9% were farrow to wean commercial sow units, 3.5% were farrow to feeder commercial sow units, 12.8% had finishing pigs on site, 2.6% were multiplier sow herds, and 0.2% were genetic nucleus farms. Geographically, 47.1% of the herds are in Southeast region, 38.9% are in the Midwest region, and 14.0% are in the Southern panhandle region.