Herd- and litter-level factors associated with the incidence of diarrhea morbidity and mortality in piglets 1 to 3 days of age

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Summary: *We used National Swine Survey data collected by the National Animal Health Monitoring System (NAHMS) to identify litter and herd factors associated with the risk of diarrhea morbidity and mortality in 1- to 3-day-old piglets. A total of 28,266 litters in 703 herds, monitored for producer-observed health events during 1990, were included in our analysis. The average rate of diarrhea morbidity among 1- to 3-day-old piglets was approximately one new case per day for a producer with an average inventory of 100 piglets. Diarrhea mortality averaged approximately one death every 10 days for the same-sized herd. Both diarrhea morbidity and mortality were lower among herds that vaccinated sows against* Escherichia coli. *The risk of diarrhea morbidity and mortality was higher among litters in which the sow experienced health problems within 3 days postfarrowing. This suggests that the use of* E. coli *vaccines, along with careful observation of the postpartum sow for health problems and appropriate intervention practices, might reduce the occurrence of diarrhea morbidity and mortality in 1- to 3-day-old piglets.*

Diarrhea is a common cause of mortality in neonatal pigs.[1,2] It has become an economically important disease as producers continue to intensify their use of farrowing facilities.[3] A survey conducted by the United States Department of Agriculture (USDA) National Animal Health Monitoring System (NAHMS) Animal and Plant Health Inspection Service (APHIS) Veterinary Service (VS) found diarrhea to be the most common cause of preweaning morbidity, and an important cause of preweaning mortality.[4,5] We hypothesized that differences in specific management practices may greatly influence the risk of disease. We used data from the NAHMS National Swine Survey to identify litter- and herd-level factors associated with the risk of diarrhea morbidity and mortality in 1- to 3-day-old piglets. At this age, most piglet diarrhea is associated with *E. coli* infections.[6] A subsequent report examines similar risk factors for diarrhea morbidity and mortality in piglets 4–14 days of age (see page 105 of this issue).

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Methods

Source of the data

A total of 28,266 litters in 703 herds were monitored at 1–3 days of age for disease events as part of the USDA:APHIS:NAHMS National Swine Survey.[4] Swine producers voluntarily participated in the program after they were selected using the multiple-frame sampling technique of the National Agricultural Statistics Service. Due to the sampling scheme, the 18 states from which our study population was selected represented 84% of United States swine operations and 95% of the hogs in the United States. A detailed description of the selection process, the study population, and the data collection techniques is presented elsewhere.[4,5]

The NAHMS National Swine Survey monitored each participating herd for a 3-month period. The surveys were administered between December 1989 and March 1991. A random selection of farrowing rooms was used for farms with more than 100 expected farrowings. State and federal Veterinary Medical Officers visited the farms monthly during the monitoring period to collect data and administer four questionnaires to the producers to obtain information regarding general characteristics of the herd. Producers also recorded litter information onto standardized diary cards for each sow that farrowed during the 3-month monitoring period. To provide accurate estimates of the number of new cases, producers were instructed to record all health events only on the day that they were first observed, even though a pig might be sick for several consecutive days. Only piglets that were dead before 4

days of age were included as mortalities in this study. Detailed descriptions of the producer questionnaires and the diary cards used to collect the data are presented elsewhere.[4,5]

For analysis, these outcomes were expressed as an incidence density; i.e., the number of piglets in the litter or herd sick or dead of a given cause divided by the total number of piglet days at risk of being sick or dying of that cause. Using incidence density to analyze our data allowed us to account for the changes in the population sizes of individual litters and herds that resulted from fostering activity and piglet death losses. The incidence densities we used reflect that, in this study, a piglet by definition could only have diarrhea once in the first 3 days of life; once a piglet was recorded as having diarrhea, it was removed from the denominator. Also, if a piglet died, it was then no longer at risk of the disease. Although this makes intuitive sense, often in more traditional measurement techniques, these cases are not removed from the population at risk.

Litter-level management variables were developed from the sow diary cards that producers used to record litter information. Herd-level management variables were developed from information obtained with the four producer questionnaires. Herd-level variables were distinguished from litter-level variables to allow us to identify the level at which a management decision should be made to decrease the incidence of diarrhea. Management variables were included as putative causes of diarrhea if we believed there was a plausible biological relationship prior to analysis. These management variables generally apply to all pigs in the herd or litter, and therefore, any inferences regarding risk also apply to the herd or litter rather than to the individual animal.

Statistical analysis

The multiple logistic regression model[7] was used to estimate the relationships between the management variables and diarrhea morbidity and mortality. We conducted separate analyses for herd-level and litter-level data. Management variables that had simple associations ($P < .10$) with diarrhea morbidity and mortality at the initial screening were used to develop the logistic regression models. We constructed the models using a backward elimination procedure with criteria to leave the model set at $P < .01$. We attempted to account for the resulting underestimate of variability of animals within herds and litters by using intraherd correlation coefficients[8] to adjust the model test statistics.[9,10] The intraherd correlation coefficient measured the clustering of morbidity and mortality within the herd and allowed us to determine which factors were associated with the outcome after we removed the clustering. The adjusted test statistics were used to determine management variables to remain in the final models. We adjusted for the state in which the herd was located and the time of year in which the herd was monitored for all analyses. Biologically reasonable interactions were tested for the management variables in the final model.

Incidence densities are measured in animal-time units. For example; a denominator of 100 piglet-days could represent 100 piglets observed for 1 day or four piglets observed for 25 days. As another example, six pigs each living for 3 days would contribute 18 pig days to the denominator for mortality; so would nine piglets each living for 2 days. Incidence densities express the reality that not all piglets present at the start of the study period will be alive and well throughout the observation period.

Herd-level variables are management decisions that are made to apply to the entire herd (e.g., the producer decides to vaccinate the herd for TGE). They are also factors that can only be applied at the herd level (e.g., the herd is considered free of TGE).

Litter-level variables are management decisions that are made to apply within a herd only to certain litters (e.g., only parity-one sows are vaccinated for *E. coli*) or they may represent variations from the herd-level decision (e.g., the producer usually castrates at 1 day of age but this litter didn't get castrated until day 5 of age). For factors that can be measured at the herd and litter level, the litter-level variable will be more accurate.

Results

Diarrhea morbidity among litters averaged nine cases per 1000 piglet-days at risk while mortality averaged one case per 1000 piglet-days at risk (Table 1). There was wide variability in litter management routines (Table 2). Four percent of sows experienced health problems in the first 3 days postfarrowing. Breeding herd variables are presented in Table 3. Routine herd-level preventive practices also varied widely (Table 4).

Table 1

Mean, median, and range of incidence densities[a] (%) of diarrhea[b] morbidity and mortality among 1- to 3-day-old piglets born in 28,266 litters in 703 herds.

	Mean	Median	Range
Diarrhea morbidity			
Litter level	0.9	0	0 to 100
Herd level	1.0	0	0 to 29
Diarrhea mortality			
Litter level	0.1	0	0 to 75
Herd level	0.1	0	0 to 5.6

[a] Incidence density is defined as the number of piglets in the litter or herd with diarrhea divided by the total number of piglet days at risk. The result is multiplied by 100 and expressed as a percentage.

[b] As observed and reported by the participating producers.

The final litter-level risk factor models included sow health problems and clipping teeth (Table 5). Sow health problems that occurred in the farrowing facility resulted in an increased ($P < .01$) risk of both diarrhea morbidity and mortality among piglets in the litter. Clipping teeth of piglets in the litter at 1–3 days of age was associated with a lower ($P < .01$) risk of diarrhea mortality. No other litter-level risk factors were associated with the risk of diarrhea morbidity and mortality at 1–3 days of age.

The final herd-level risk factor models included only *E. coli* vaccination (Table 6). Herds that reported vaccination of sows with

an *E. coli* vaccine had lower ($P < .01$) incidence densities of both diarrhea morbidity and mortality in piglets 1–3 days old. Other herd-level risk factors were not associated with the risk of diarrhea morbidity and mortality during this period.

Discussion

The litter size found in this study of 9.9 piglets born alive is typical of that reported in other observational studies.[11-13] In this study, 0.9 cases of diarrhea per 100 piglet-days were observed within the first 3 days of life. Diarrhea mortality was 0.1 cases per 100 piglet-days (Table 1). When these outcomes are expressed as a proportion of the piglets born alive, the respective morbidity rate is 2.6% and the mortality rate is 0.3%.

The mortality rate we observed in this study is lower than what has previously been reported. Other researchers have suggested that 0.9% to 1.4% of 1- to 3-day-old piglets die from diarrhea.[14,15] We expect that some piglets that develop diarrhea during the neonatal period will die later, hence our estimate of mortality due to neonatal diarrhea is conservative.

Table 3

Description and distribution of breeding herd variables among 28,266 litters

Variable	Mean	Median	Range
Litter size	9.9	10	0 to 21
Sow parity	3.1	3	1 to 19
Days in facility pre-farrow	5.8	4	0 to 125

Table 2

Description and distribution of litter-level management variables among 28,266 litters monitored at 1–3 days of age

Variable	Description	Categories of response	Percent of litters
Vaccinate piglets (1– 3 days)	Any vaccination of piglets in the litter at 1 to 3 days of age	No Yes	93.2% 6.8
Clip teeth (1–3 days)	Clip teeth of piglets in the litter at 1 to 3 days of age	No Yes	24.5 75.5
Dock tails (1–3 days)	Dock tails of piglets in the litter at 1 to 3 days of age	No Yes	40.8 59.2
Castrate (1–3 days)	Castrate male piglets in the litter at 1 to 3 days of age	No Yes	84.1 15.9
Iron 1–3 days)	Supplemental iron given to piglets in the litter at 1 to 3 days of age	No Yes	34.1 65.9
Foster in (1–3 days)	At least 1 piglet fostered into the litter when the litter is 1 to 3 days of age	No Yes	78.2 21.8
Foster out (1–3 days)	At least 1 piglet fostered out of the litter when the litter is 1 to 3 days of age	No Yes	81.8 18.2
Vaccinate sow	Any vaccination of the sow in the farrowing facility prior to farrowing	No Yes	88.4 11.6
Deworm sow	Deworm the sow in the farrowing facility prior to farrowing	No Yes	80.9 19.1
Treat sow for mange/lice	Mange/lice-treat sow in the farrowing facility prior to farrowing	No Yes	84.0 16.0
Feed sow antibiotics	Antibiotics fed to the sow in the farrowing facility	No Yes	91.8 8.2
Farrowing problems	Sow had problems farrowing the litter	No Yes	97.8 2.2
Sow health problems	Health problems of the sow in the farrowing facility prior to farrowing	None Milk problems All other[a]	96.0 2.7 1.3

a The category of "all other" sow health problems includes producer-reported health problems classified as respiratory system, lameness, scours, other known, or unknown.

None of the piglet processing procedures (castration, clipping canine teeth, tail docking, and iron injections) were associated with increased rates of neonatal diarrhea. However, litters in which the piglets' canine teeth were clipped during the first 3 days of life (i.e., 75% of the litters in this study) had a lower rate of diarrhea mortality (Table 2). These sharp canine teeth can cause skin abrasions on the head of piglets, leading to septicemia and/or exudative epidermitis. The sow's udder may also be lacerated, resulting in mastitis and poor milk letdown.[20,21]

Typically, the cause of mortality in preweaned piglets is multifactorial.[14-19] We believe it is essential to understand the multifactorial causes of preweaning diarrhea. Often piglets that are weak and do not regularly nurse develop diarrhea. Similarly, piglets that are chilled often develop diarrhea, become dehydrated and hypoglycemic. These piglets may die of starvation or trauma because they are laid on by the sow.

Piglets nursing sows with concurrent illness were more likely to develop diarrhea and die.[1,2,22] Four percent of the sows in the study had health problems within 3 days of farrowing; 69% of these were milk related (including mastitis, agalactia, and poor milking) (Table 2). In our study, piglets nursing sows with milk-related problems were 2.6 times more likely to have diarrhea and

Table 4

Description and distribution of herd-level variables among 703 swine herds

Variable	Description	Categories of response	Percent of herds
Decision maker	Primary decision maker for the swine operation	Operator	71.1
		Hired manager	7.7
		Partners	21.2
Operation type	Type of swine operation	Farrow to finish	78.2
		Feeder pig	18.6
		Breeding stock	2.8
All-in–all-out	All-in–all-out management of farrowing facility	No	45.5
		Yes	54.5
Wash sows	Wash sows prior to entry into farrowing facility	No	62.6
		Yes	37.4
Supplement milk	Provide supplemental milk to piglets	No	95.9
		Yes	4.1
Supplement creep	Provide supplemental creep feed to piglets	No	17.8
		Yes	82.2
TGE-free herd	Herd considered free of TGE	No	83.5
		Yes	16.5
Vaccinate TGE	Breeding herd vaccinated for TGE	No	71.8
		Yes	28.2
Vaccinate *E. coli*	Breeding females vaccinated for *E. coli*	No	48.1
		Yes	51.9
Vaccinate Rotavirus	Breeding females vaccinated for rotavirus	No	82.2
		Yes	17.8
Clip teeth	Clip teeth of piglets	No	13.5
		Yes	86.5
Dock tails	Dock tails of piglets	No	14.2
		Yes	85.8
Iron	Supplemental iron given to piglets	No	7.7
		Yes	92.3
Treat navels	Navels of piglets treated with iodine	No	67.9
		Yes	32.1
Consultant	Operation uses the services of a consultant	No	52.1
		Yes	47.9
Farrowing facility	Type of farrowing facilities utilized	Total confinement	85.5
		Other building	14.9
		Hut	5.5

3.4 times more likely to die than piglets nursing healthy sows (Table 5). Piglets that do not get adequate nutrition during the first few days of life become hypoglycemic, are reluctant to get up to nurse, and typically scour and then die. This may represent concurrent morbidity in sows and piglets. Piglets nursing sows with other health problems were 4.9 times more likely to experience diarrhea and die (Table 5). For example, when TGE outbreaks occur in seronegative herds, sows go off feed and vomit, have diarrhea, and become agalactic.

In herds in which producers vaccinate their sows against enterotoxigenic *E.coli*, piglets were one third as likely to have diarrhea than those not using the vaccine. This agrees with Fairbrother,[3] who stated that maternal vaccination is one of the most effective methods of controlling morbidity and mortality due to *E.coli* in the neonatal pig. *Escherichia coli* vaccination may be a surrogate measure of other good management techniques used to decrease preweaning diarrhea. However, none that were measured in this study were associated with our outcome measurements. Although no diagnostic tests were used to determine the cause of the diarrhea, we believe that discussion of *E. coli* is warranted. Enterotoxigenic *E.coli* is the most common causative agent for diarrhea in 1- to 3-day-old piglets.[6,24] *Escherichia coli* is identified as the causative agent in half of the neonatal diarrhea submissions to diagnostic laboratories.[1] It typically affects piglets from 2 hours to 4 days of age.[3]

Escherichia coli diarrhea is not caused by the *E. coli* organism alone, but is in fact the result of multiple causative factors; usually, unsanitary environments, chilling, and milk deprivation are required in addition to the organism to cause disease in piglets. It is likely that piglets ingest the organisms, which then multiply in the intestinal tract.[1] Enterotoxigenic *E.coli* adhere to the intestinal epithelium and produce enterotoxins which result in a secretory diarrhea.[1] The piglets develop diarrhea and become dehydrated. Mortality is caused by dehydration and metabolic acidosis.[1,3]

Vaccines contain fimbriae from more than 90% of the enterotoxigenic *E. coli* cultured from scouring piglets.[6] The fimbrial antigens found in swine vaccines include F4 (K88), K99, F5, F6 (987P), and may include F1 (type 1 pili). These vaccines provide passive lacteal immunity. The antibodies from the colostrum and milk bind to the fimbrial receptors and prevent the fimbriae from interacting with receptors on the intestinal epithelial cells.[6] In 1991, there were an estimated 7.7 million sows in the

Table 5

Final models[a] for estimating adjusted odds ratios for the incidence density of diarrhea morbidity and mortality for piglets aged 1–3 days in 28,266 litters

Diarrhea morbidity

Variable	Odds Ratio[b]	95% CI (OR)
Sow health problems		
None	1.0	—
Milk problems	2.6 **	1.1 to 5.9
All other[c]	4.9 **	1.9 to 12.9

Diarrhea mortality

Variable	Odds Ratio[b]	95% CI (OR)
Sow health problems		
None	1.0	—
Milk problems	3.4 **	1.3 to 9.1
All other[c]	5.0 **	1.5 to 16.5
Clip teeth (1–3 days)		
No	1.0	—
Yes	0.45**	0.26 to 0.79

a State in which the herd was located, and the quarter in which the herd was monitored were adjusted for in the model, but the resulting odds ratios are not shown.

b For categorical variables, the odds ratio is for each exposure category versus the reference category with OR=1.0.

c Includes producer-reported health problems classified as respiratory system, lameness, scours, other known, or unknown.

** $P < .01$ as assessed using Wald's test adjusted for intraherd clustering.

Table 6

Final models[a] for estimating adjusted odds ratios for the incidence density of diarrhea morbidity and mortality for piglets aged 1–3 days in 703 herds

Diarrhea morbidity

Variable	Odds Ratio[b]	95% CI (OR)
***E. coli* vaccination**		
No	1.0	—
Yes	0.34 **	0.22 to 0.56

Diarrhea mortality

Variable	Odds Ratio[b]	95% CI (OR)
***E. coli* vaccination**		
No	1.0	—
Yes	0.38 **	0.23 to 0.63

a State in which the herd was located, and the quarter in which the herd was monitored were adjusted for in the model, but the resulting odds ratios are not shown.

b For categorical variables, the odds ratio is for each exposure category versus the reference category with OR=1.0.

** $P < .01$ as assessed using Wald's test adjusted for intraherd clustering.

Odds ratios: The odds of a litter having diarrhea if it was also subjected to that particular management variable compared to litters not subjected to that management variable. The management variables with the highest odds ratios have the most influence on diarrhea morbidity and mortality.

United States, and 16.8 million doses of *E.coli* vaccine were manufactured in the United States for use in swine.[6] Typically, the vaccine is administered to gilts twice before farrowing and to sows once before farrowing. In this study, 51.9% of producers routinely used *E.coli* vaccines.

Considerably fewer producers (28%) vaccinated the sows for transmissible gastroenteritis (TGE) and rotavirus (18%). Vaccines against TGE typically induce a poor rate of seroconversion and a poor level of protective immunity to the piglets (0%–70% mortality).[24,25] Diarrhea caused by rotavirus is commonly mild and lasts only 2–3 days in uncomplicated cases.[26]

Immunity to colibacillosis is due to antibodies preventing the organisms from multiplying, adhering to the epithelium, and neutralizing enterotoxins.[1,23] The colostrum contains nonspecific bactericidal factors and specific IgA antibodies, which inhibit growth of the *E.coli* organisms. Colostrum also contains high levels of IgG, which could play some role in preventing enterotoxigenic *E. coli* diarrhea at 1-3 days of age.[3] But even with adequate colostrum intake, without regular ingestion of lactogenic antibodies, the piglet is susceptible to *E.coli* infections.[1,23] Factors that decrease the production of colostrum and milk in the sow, including:

- agalactia,
- mastitis,
- systemic disease, or
- insufficient teats

will result in an increased susceptibility to diarrhea in the piglet.[1,3]

We found that vaccinating sows against *E.coli* was associated with reduced rates of diarrhea morbidity and mortality in 1- to 3-day-old piglets. Clipping piglets' teeth within 3 days of birth was associated with lower diarrhea mortality. We also found that concurrent health problems in the sow resulted in a greater risk of diarrhea morbidity and mortality in neonatal piglets. This illustrates the importance of carefully observing postpartum sows. Perhaps piglets born to sows not capable of nursing should be fostered onto another sow. The other potential risk factors examined, while not associated with diarrhea morbidity and mortality in this study (as they are defined in this study), might still play important roles within individual herds.

Implications

- Diarrhea morbidity and mortality in piglets was lower among herds in which sows were vaccinated against *E. coli*.
- Higher rates of diarrhea morbidity and mortality occurred in litters in which the sow had health problems. Interventions such as cross-fostering may be appropriate when sick sows are identified.
- Specific piglet processing procedures, such as clipping teeth, docking tails, administering iron, or castrating within 3 days of birth were not associated with increased risk of diarrhea morbidity and mortality during the first 3 days of life. Studies of diarrhea incidence in piglets aged 4–14 days suggest that castration in the 1–3 day period may be associated with a higher incidence of diarrhea in the 4–14 day period (see pp. 105–112).

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