Porcine Epidemic Diarrhea; Epidemiology

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Outline

- National PED Incidence project
- Production impact
- Time to stability
- Impact of infected neighboring herd
- Swine Health Monitoring Project (SHMP)
National PED Incidence Project

• Voluntary convenience sample of U.S. sow herds
  – 15 participating systems with 680 sow farms & 2.3 million sows

• Weekly report of change in sow herd status

• Started in October 2013
  – added 5 months of retrospective data.
EWMA-Smoothed Incidence of PEDv in 680 Breeding Herds
Time To Baseline Production

Dane Goede, Bob Morrison
Production Impact of PEDv

- n = 18 herds
- Avg TTBP = 5.9 wks
- 95% CI TTBP = 4.2-7.6
- Avg Loss in Pigs/1000 sows = 1688
- 95% CI pigs/1000 sows = 1077-2299
- Avg Loss in weeks of production = 3.9 wks
- 95% CI wks lost = 2.0 – 5.8 wks
“Classic” PED

- $n = 86$ herds
- Avg TTBP = 7.4 wks
- 95% CI = 1.7-13
- Avg lost 2,501/1000 sows
- 95% CI = 64-4,939
Mild PED strain?

- n = 3 herds
- Avg TTBP = 3 wks
- Avg Lost 938/1,000 sows
  - 496, 982, 1,335
Comparison

- $n = 86$ herds
- Avg TTBP = 7.4 wks
- Avg lost 2,501/1,000 sows

- $n = 3$ herds
- Avg TTBP = 3 wks
- Avg lost 938/1,000 sows
Growing pigs -
Pattern was repeated in other sites in the next two weeks.

Peak consumption occurred about 4 day prior to reported clinical signs.

PED observed on 11-2-13, and confirmed two days later by lab.

It took 10 days to get back to that level and 14 days to get back to their potential.

PED observed on 11-2-13, and confirmed two days later by lab.
Time To Stability

Mike Murtaugh, Dane Goede, Bob Morrison
Time To Stability

- 40 sow herds

- Environmental swabbing 4-10 weeks after last feedback

- Pigs / litters >10 weeks.
Site Classification Guideline for PED Virus
Bob Morrison (P.I. Swine Health Monitoring Project), Matt Ackerman, Joe Connor

Sow Farms
I – Infected and shedding virus
II – Stable – weaned pigs are negative for PED
   - Herd is free of clinical signs of PED
   - At least 4 consecutive samples of piglet feces collected as often as weekly from farrowing are PCR negative.
     o Each sample must represent 30 litters between 7 days of age and weaning (95/10).
     o Collect 1 Swiffer sample per litter. Bias the litters towards younger parity sows and/or have any diarrhea. Swab diarrhea when evident.
     o You may pool up to 5 swabs (litters) together for PCR testing.

III – Provisionally negative
   - Herd is free of clinical signs of PED and at least 60 gilts have been introduced and have remained free of clinical signs of PED for at least 60 days.
   - These sentinel gilts should have no known history of prior PED infection.
   - Serum test is negative on at least 30 gilts present in sow herd for at least 60 days.
   - Ongoing monthly testing of gilt litters is encouraged

IV – Negative
   - Herd has no clinical history of PED virus
     Or
   - Herd was provisionally negative, has had no clinical evidence of PED virus for at least 6 months and gilts entering herd have no history of PED infection and have remained free of clinical signs.
II – Stable – weaned pigs are negative for PED

• Herd is free of clinical signs of PED
• At least 4 consecutive samples of piglet feces collected as often as weekly from farrowing are PCR negative.
  – Each sample must represent 30 litters between 7 days of age and weaning (95/10).
  – Collect 1 Swiffer sample per litter. Bias the litters towards younger parity sows and/or have any diarrhea. Swab diarrhea when evident.
  – You may pool up to 5 swabs (litters) together for PCR testing.
% PCR +'ve and average Ct of positives for environmental swabs / week x 5 farms
PED PCR Ct values by area sampled post-exposure (5 herds)

- Boot Area
- Common Hallway
- Young Pig Mat
- Door Knob
- Load Out Chute
- Medicine Room
- Wean Pig Mat

Weeks Post-Exposure:
- Week 4
- Week 5
- Week 6
- Week 7
- Week 8

Environment:
- Environment
- Environment
- Environment
- Environment
- Environment
- Environment
Time-to-Stability

- 13 Sites have achieved stability with an average time-to-stability of 24 weeks post infection.
- Stability: 4 consecutive tests of fecal swabs/swiffers from 30 litters as close as 1 week apart
Endemic PED; Clinically active or PCR +’ve 16 weeks after last feedback

- System 1 – 6/22 (27%)
- System 2 – 6/25 (24%)
- System 3 – 3/11 (27%)
- System 4 – 5/6 (83%)
- System 5 – 14/36 (39%)
- Average – 34/100 (34%)

6 herds - PCR +
4 herds - 4-10%
1 herds - 10%
3 herds - 3%
Lateral Spread

Dane Goede, Andrea Beam, Charles Haley, Andres Perez, Peter Davies, Bob Morrison
Investigative team

- U of Minnesota:
  - Dane Goede, Peter Davies, Andres Perez, Bob Morrison
- USDA epidemiologists:
  - Andrea Beam, Charles Haley, Brian McCluskey, Bruce Wagner
- NPB & AASV
  - Paul Sundberg & Harry Snelson
- Participants:
  - OK cluster
  - NC whole state
  - Case / control

Preliminary analysis
Objective

• To determine if “my” farm is at increased risk of PED virus infection if my neighbor’s farm is infected.
Conclusions

- **Density**
  - Risk of infection increases with density.
  - Distance to neighbor is diluted at high density.
- **Rendering service**
  - OR 1.19 / visit or 7.1x in last 2 weeks
- **Birds, rodents & feral animals**
  - OR 6-10 x in last 2 weeks
- **Not significant**
  - Recent manure application
PEDv Samples

- **Birds (n = 12)**
  - No positive samples for PEDv found to date in/on feces, feet, beaks

- **Flies (n = 5)**
  - 1/5 samples found PCR positive (Ct 30.44)
    - 30 flies saturated with 10 ml media & compressed to extract sample

- **Compost (n = 3)**
  - 1 of 3 samples found PCR positive

- **Lagoons (n = 7)**
  - PEDv was detected in 4/4 positive farms’ lagoons as early as 1 day post-infection (Ct 22.64 – 27.41) and was PCR negative in 3/3 negative farms’ lagoons.

- **Lagoons at now-stable sites (n = 6)**
  - PEDv was detected in 6/6 now-stable sites’ lagoons (Ct 28 – 35)
  - Bio-assay yielded live PED in 1/4 lagoons
PEDv in air outside barns

- 64 air samples collected around acutely infected sow and finishing barns at varying distances.
  - 11 PCR +’ve (60 ft, ½ mi, 1 mi, 3 mi, 10 mi)
    - All samples around 36-38 Ct
  - All samples negative on bioassay
    - Virus may have been inactivated through the air
Air from experimentally challenged pigs

- 10 x 8 week old pigs challenge-exposed in isolation unit with PEDv. Had significant diarrhea.
- Air samples collected twice a day using the cyclonic air collector.
- 2/3 samples tested by bioassay.
Air samples were positive (Ct 16) on bioassay.
OK cluster

• Data collected from all sites
  – Farm ID
  – Company
  – Location (geocoordinates)
  – Capacity
  – Cause of infection (lateral vs pig movement)

• Spatial Analysis on entire cohort performed
  – 90 positive sites out of 222 total
Analysis of OK farms

• Spatial analysis of 90 +’ve / 222 sites
  – “Provides some support to the hypothesis of airborne spread since direction of disease spread appears to correlate with wind direction.”
NC - farm characteristics and spatial features as risk factors for PEDv infection

• 2,071 sites were followed from 7/1/2013 – 1/27/2014 for PEDv occurrence.

• Available data:
  – Company, production type, total capacity, geographic coordinates and PEDv status
• 327 / 2,071 (15.8%) farms became infected with PEDv by unknown mechanisms (lateral) during the observation period.
• 286 / 2,071 (13.8%) became infected by vertical movement.

<table>
<thead>
<tr>
<th>Production type</th>
<th>PEDv status</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>Positive-Vertical</td>
<td>Positive-Lateral</td>
<td>Total</td>
</tr>
<tr>
<td>Sows only</td>
<td>139</td>
<td>2</td>
<td>78</td>
<td>219</td>
</tr>
<tr>
<td>Sows and growing pigs</td>
<td>71</td>
<td>5</td>
<td>42</td>
<td>118</td>
</tr>
<tr>
<td>Boar stud</td>
<td>18</td>
<td>0</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Growing pigs only</td>
<td>1,230</td>
<td>279</td>
<td>206</td>
<td>1,715</td>
</tr>
<tr>
<td>Total</td>
<td>1,458</td>
<td>286</td>
<td>327</td>
<td>2,071</td>
</tr>
</tbody>
</table>

• Of the 327 laterally infected (cases) sites:
  – Median capacity 3,600 head
  – Median distance to nearest +’ve 1.4 miles
Three analyses:

1. Whole state, all sites from 3 companies, no biosecurity questionnaire.

2. Case / control with questionnaires

3. Following sites selected as controls and having biosecurity questionnaire.
1. Whole state, 3 companies

- Company (1, 2, 3)
- Production type
- Site capacity
- Distance:
  - to nearest +’ve farm
  - farm density
  - Interaction of nearest +’ve and density
- Multivariable logistic regression
• Production type
  – Sow farms had 8.8 x higher odds than farms with growing pigs only.
  – Sow farms & growing pigs had 5.8 x higher odds than farms with growing pigs only.

• Capacity
  – Sites with $\geq$ 2,000 head had 2.5 x higher odds than farms with < 2,000 head.
Density, prevalence of PEDv & proximity to infected site

<table>
<thead>
<tr>
<th>Density</th>
<th>Prevalence</th>
<th>Odds of being +’ve if within 4 miles of neighbor +’ve site</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; =5 sites / 25 mi²</td>
<td>5.60%</td>
<td>ref</td>
</tr>
<tr>
<td>6-10 sites / 25 mi²</td>
<td>12.90%</td>
<td>1.6, 0.9 - 2.8</td>
</tr>
<tr>
<td>&gt;= 11 sites / 25 mi²</td>
<td>28.70%</td>
<td>5.8, 3.4 - 10.2</td>
</tr>
<tr>
<td>All farms</td>
<td>18.30%</td>
<td></td>
</tr>
</tbody>
</table>

OR = Odds Ratio, 95% CI = 95% Confidence Interval
Effect of density

- ≤ 5 sites / 25 mi² – OR 1.19 / mile closer to +’ve starting at 15 miles away.
- 6-10 sites / 25 mi² – OR 1.10 / mile closer
- > 11 sites / 25 mi² – Not significant
2. Case / Control

- All farms with confirmed PEDv infection as of October 23, 2013 were cases (n=155). For each case farm, two control farms:
  - one matched on company, production type and site capacity (n=45 pairs).
  - one geographically matched (nearest neighboring uninfected farm), regardless of company, production type, capacity (19 pairs).
Questionnaires

• Case farm - biosecurity practices with all questions referring to the 2 week period before PEDv clinical signs began.

• Control farm - the 2 week period between September 27 and October 4 (2 wks before our cases started).

• Also, company level questionnaire on biosecurity practices.
Site questionnaire

• 3 pages; 30-45 minutes
• Herd management practices (2 wks previous)
  – Site visitors
  – Borrowing equipment
  – Manure application
  – Pig additions
  – Live pig removals
  – Loading / unloading area
  – Staff at this site
  – Dead pig disposal
  – Pests & wildlife
  – Nothing on feed (lateral spread was objective)
Company questionnaire

• 2 pages; 30-45 minutes
• Herd management practices
  – Transport biosecurity
  – Pest & wildlife control
  – Staff
  – Visitors
  – Ventilation, air filtration & access to outside
45 cases / company controls matched on production type & capacity

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI OR</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renderer visited farm in last 2 weeks</td>
<td>7.1</td>
<td>0.7-72.8</td>
<td>0.099</td>
</tr>
<tr>
<td>Wildlife other than birds (e.g., rats, mice, raccoons) was seen in the pig buildings in last 2 weeks</td>
<td>6.0</td>
<td>1.7-22.0</td>
<td>0.006</td>
</tr>
</tbody>
</table>

• Multivariable conditional logistic regression
### 19 cases / nearest neighbor controls

- **Limitation** - small sample size did not permit multi-variable statistical model.

#### Table

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<thead>
<tr>
<th>Description</th>
<th>OR</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removed cull sows/gilts/boars</td>
<td>46</td>
<td>0.001</td>
</tr>
<tr>
<td>Saw rats, mice, raccoons, etc in barns</td>
<td>19</td>
<td>0.001</td>
</tr>
<tr>
<td>Mild, moderate or severe problem with birds</td>
<td>10</td>
<td>0.04</td>
</tr>
<tr>
<td>Moderate or severe problem with rodents</td>
<td>25</td>
<td>0.004</td>
</tr>
<tr>
<td>Number of visits from renderer (per visit increase)</td>
<td>1.19</td>
<td>0.05</td>
</tr>
</tbody>
</table>
3. Following 101 herds selected as controls (having biosecurity questionnaire)

- 36 / 101 became +’ve

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<tr>
<td>Sows only</td>
<td>18</td>
<td>15</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Sows and growing pigs</td>
<td>10</td>
<td>6</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Growing pigs only</td>
<td>37</td>
<td>15</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>65</strong></td>
<td><strong>36</strong></td>
<td><strong>101</strong></td>
<td></td>
</tr>
</tbody>
</table>
Following 101 sites

<table>
<thead>
<tr>
<th>Description</th>
<th>Hazard Ratio</th>
<th>SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Had employees who are not family</td>
<td>0.31</td>
<td>1.55</td>
<td>0.004</td>
</tr>
<tr>
<td>Buried mortalities on site</td>
<td>6.03</td>
<td>1.82</td>
<td>0.001</td>
</tr>
<tr>
<td>Had 1 or more visits from a building contractor</td>
<td>3.86</td>
<td>1.80</td>
<td>0.006</td>
</tr>
</tbody>
</table>

- Multivariable Cox proportional hazards model
Study limitations

• Recall bias (questioned up to 3 months later).
• Biosecurity practices probably changed over the 3 months.
• Busy people volunteering their time.
Conclusions – Am I at increased risk if neighbor’s herd is infected?

• Density
  – Risk of infection increases with density.
  – Distance to neighbor is diluted at high density.

• Rendering service
  – OR 1.19 / visit or 7.1x in last 2 weeks

• Birds, rodents & feral animals
  – OR 6-10 x in last 2 weeks

• Not significant
  – Recent manure application,
Bio-assay of PED PCR Positive Feed Samples

Four PED PCR positive pig feed samples from two different sources were recently tested for viability in bio-assay. The samples’ origins are as follows:

- Sample A: Unopened, sealed bag of feed stored at the infected site
- Sample B: Retained at feedmill #1 from the same lot as Sample A
- Sample C: Retained at feedmill #2
- Sample D: Feed collected from an on-site bulk bin

All samples were inoculated via gavage into 10 day-old piglets daily for 3-5 days depending on the size of the original sample. On top of inoculations, samples A and D were also fed daily as a ration.

None of the above samples tested positive for live PED virus. This conclusion is based on lack of visible severe diarrhea (sporadic, mild diarrhea was observed), no significant decrease in Ct values from inoculation (via 1 sample t-test) and no evidence of infection on samples collected at necropsy (PCR and IHC negative).

Update of PED in Canada

Canadian efforts to determine the source of PED outbreaks have resulted in the preliminary bio-assay results of 10 feed samples from the first infected farm in Canada including 5 complete feed and 5 porcine plasma that were PED PCR positive. Some clinical signs (a couple of pigs with a little diarrhea out of 12) were seen in the porcine plasma group and only the porcine plasma fed pigs are producing PEDV RNA in their feces in significant quantities in daily rectal swabs. The Canadian Food Inspection Agency has concluded that the porcine plasma contained infectious PED virus particles. However, the pigs being fed complete feed did not appear to be producing the virus.

These results are preliminary as the groups will continue to be followed and tested for antibodies in coming weeks.

New, non-PED Coronavirus detected in pigs with Diarrhea

A novel coronavirus (designated Swine Delta Coronavirus, or SDCV) has been detected in swine feces from four different swine farms in Ohio. These farms showed clinical signs similar to those caused by PED and TGE (also coronaviruses). Three of the four farms were positive for both PED and SDCV whereas the fourth was only positive for the SDCV. This virus is distinct from PED and TGE viruses and is closely related to a coronavirus detected in Hong Kong in 2012.

The implications of this virus are yet unknown as further studies are needed to determine if it is the cause of diarrhea in affected pigs.
Summary

• National PED Incidence project

• Production impact

• Time to stability

• Impact of infected neighboring herd

• Swine Health Monitoring Project (SHMP)
Acknowledgements

• Veterinarians
  – Mary Battrell, Scanlon Daniels, Luc Dufresne, Ian Levis, Chad Smith, Matthew Turner

• Producers
  – Seaboard, Iowa Select & study participants

• Lateral spread data analysis
  – Andrea Beam, Charles Haley, Brian McCluskey

• Financial support
  – National Pork Board, UMN Swine Disease Eradication Center (SDEC)