Protecting Public Health by Limiting Influenza: A Virus Spread in Pigs at Agricultural Fairs

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The Ohio State University
Background

• Pigs play a critical role in the ecology and epidemiology of influenza A viruses infecting humans.

• Interspecies transmission received considerable publicity following the emergence of the influenza A (H1N1)pdm09 virus.

Solid lines between species: Confirmed inter-species transmission

Solid lines within species: Intra-species maintenance cycle

Dotted lines between species: Suspected interspecies transmission
Changes in Nomenclature

• Swine Influenza Virus
• Influenza A Virus in Swine (IAV-S)

• Pandemic influenza A (H1N1) 2009 virus
  • Influenza A (H1N1)pdm09

• Animal-origin influenza viruses identified in humans
  • “Variant” denoted with a “v”
Agricultural Fairs

Unique swine-human interface

- Non-commercial swine (youth education programs)
- Multi-source pigs
- High people:pig ratio (~150 million people)
- Pigs and people comingled for a prolonged period of time
Public Health Importance

306 documented human cases of H3N2v across 10 states during the summer of 2012
80% of the cases from two states
- 138 cases in Indiana
- 107 cases in Ohio

16 hospitalizations and one fatality
Jhung et al., Clin Infect Dis. 2013 Dec;57(12):1703-12

Majority of the cases had prolonged direct or indirect exposure to swine (exhibiters or their family members)
Linked to 14 of Ohio’s agricultural fairs
7 participating in surveillance project
Sampling Methods

Weights

Entry
4-36 hours

Shows

Exhibition Period
3-10 days

Sale

Departure
4-36 hours
Agricultural Fairs

Agricultural fairs have been held in the U.S. since 1811

- Family events
- Celebration of agricultural heritage and achievement
- Agricultural education
Percent of fairs/exhibitions ≥ 1 pig IAV positive

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio</td>
<td>20.0%</td>
<td>18.8%</td>
<td>27.3%</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>(3/15)</td>
<td>(3/16)</td>
<td>(6/22)</td>
<td>(10/40)</td>
</tr>
</tbody>
</table>

Percent of sampled pigs testing IAV positive (all fairs)

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.4%</td>
<td>10.8%</td>
<td>17.7%</td>
<td>19.3%</td>
</tr>
<tr>
<td></td>
<td>(40/299)</td>
<td>(34/315)</td>
<td>(81/459)</td>
<td>(161/834)</td>
</tr>
</tbody>
</table>

Percent of sampled pigs testing IAV positive (positive fairs)

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>72.7%</td>
<td>56.7%</td>
<td>57.8%</td>
<td>68.8%</td>
</tr>
<tr>
<td></td>
<td>(40/55)</td>
<td>(34/60)</td>
<td>(81/140)</td>
<td>(161/234)</td>
</tr>
</tbody>
</table>
Policy Working Group

- American Association of Swine Veterinarians
- Centers for Disease Control and Prevention
- Council for State and Territorial Epidemiologists
- International Association of Fairs and Exhibitions
- Minnesota Center for Influenza Research and Surveillance
- National Assembly of State Animal Health Officials
- National Association of State Public Health Veterinarians
- National Pork Board
- National Swine Registry
- USDA, APHIS, VS
- USDA, NIFA, Youth & 4-H

It is estimated that 150 million people visit agricultural fairs each year in North America. Agricultural exhibitions provide valuable educational venues for the public. Equally important, the exhibition of swine is an important learning opportunity for thousands of youth exhibitors, 4-H and FFA members across the United States. Seeing swine for these youth at their county or state fair is the culmination of many months of work dedicated to the care and training of their animal.

Pigs can be infected with human, swine and avian origin influenza A viruses. While rare, influenza A viruses can spread from pigs to people and from people to pigs, but it usually requires close contact between pigs and people. This has happened in different settings, including agricultural fairs. When people are infected with swine origin influenza A viruses, it is termed as a variant virus infection and denoted with a “V” after the subtype (e.g. H3N2v). In the past 5 years, cases of influenza A H3N2v, H1N2v and H3N2v have been associated with swine exhibitions. In 2011 there were 12 cases of H3N2v reported from 5 states. In 2012 there were a total of 309 cases of H3N2v identified in 12 states. The majority of cases reported exposure to pigs prior to onset of illness and were exhibitors and others in close contact with pigs at agricultural fairs. Sixteen of these individuals were hospitalized and one death was reported. Eleven of the 16 hospitalized cases, as well as the person who died, were people considered to be at high-risk for complications from influenza infections. People at high-risk include children younger than 5 years of age, people 65 years of age and older, pregnant women and people with certain long-term health conditions (like asthma, diabetes, heart disease, chronic respiratory diseases, weakened immune system, and neurological or neurodevelopmental conditions.)

These cases led to the formation of the Swine Exhibitions Zoonotic Influenza Working Group that has developed a set of measures to minimize influenza virus transmission between swine, from people to swine, and from swine to people at swine exhibitions. Influenza viruses are unpredictable and their impact and circulation can vary by year. It may not be possible to prevent all transmission of influenza viruses at swine exhibitions. The measures described here are offered for careful consideration depending on the needs of the specific exhibition and can be implemented in part or in total. They are not intended to supersede federal, state, or local regulations. These measures were formulated based on current evidence and the collective knowledge of the Swine Exhibitions Zoonotic Influenza Working Group. It is expected that this document will be updated regularly as additional information becomes available.

The suggested measures have been organized to address activities before, during, and after swine exhibitions. Measures are further divided into actions that may minimize risk to swine and risk to humans, although there is significant overlap between these two groups.
Potential Mitigation Strategies
What are “exhibition swine”? 

- Swine that are shown for evaluation of the animal or the handler.
- Swine can be shown at multiple times, across multiple locations, in exhibitions open to any age competitor. Examples: 4-H and FFA projects

<table>
<thead>
<tr>
<th></th>
<th>Exhibition Swine</th>
<th>Commercial Swine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of industry</td>
<td>1 million</td>
<td>66 million</td>
</tr>
<tr>
<td>Humans that are exposed</td>
<td>Naïve (?)</td>
<td>Continually exposed</td>
</tr>
<tr>
<td>Size of farm</td>
<td>Small (?)</td>
<td>$\bar{x} = 1,044$ head</td>
</tr>
<tr>
<td>Biosecurity plan</td>
<td>(?)</td>
<td>Yes</td>
</tr>
<tr>
<td>Population integrity</td>
<td>Low, multiple exhibitions (?)</td>
<td>High</td>
</tr>
</tbody>
</table>
Geographic distribution of influenza A(H3N2) variant virus cases, by county, United States, July–September 2012, and number of pigs by county (2007).

Jhung et al., Clin Infect Dis. 2013;57:1703-1712
Determine the geographical distribution of exhibition swine

- Six states participated: Illinois, Indiana, Iowa, Michigan, Missouri, and Ohio

- Fair organizers and state animal health officials reported total number of exhibition swine attending fairs on a county basis during 2013.

- The reported swine per county were interpolated to the geometric centroid of each county.

- A continuous spatial distribution developed using inverse distance weighting based on 15 neighbors.
Total swine inventory

Exhibition swine per county fair

Bliss N. et al, JAVMA (in press)
Exhibition swine

Modified from Jhung et al. Clin Infect Dis, 2013

Human cases with total swine
# 2013 Genotypes

<table>
<thead>
<tr>
<th></th>
<th>PB2</th>
<th>PB1</th>
<th>PA</th>
<th>HA</th>
<th>NP</th>
<th>NA</th>
<th>MP</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1-G1</td>
<td></td>
<td></td>
<td></td>
<td>H1δ1</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G2</td>
<td></td>
<td></td>
<td></td>
<td>H1δ1</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G3</td>
<td></td>
<td></td>
<td></td>
<td>H1δ2</td>
<td></td>
<td>N2-02</td>
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<td></td>
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<tr>
<td>H1-G4</td>
<td></td>
<td></td>
<td></td>
<td>H1γ</td>
<td></td>
<td>N1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G5</td>
<td></td>
<td></td>
<td></td>
<td>H1γ</td>
<td></td>
<td>N1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G6</td>
<td></td>
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<td></td>
<td>H1γ</td>
<td></td>
<td>N1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G7</td>
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<td></td>
<td></td>
<td>H1γ</td>
<td></td>
<td>N1c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G8</td>
<td></td>
<td></td>
<td></td>
<td>H1γ</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1-G9</td>
<td></td>
<td></td>
<td></td>
<td>H1γ</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H3-G1</td>
<td></td>
<td></td>
<td></td>
<td>H3</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H3-G2</td>
<td></td>
<td></td>
<td></td>
<td>H3</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H3-G3</td>
<td></td>
<td></td>
<td></td>
<td>H3</td>
<td></td>
<td>N2-02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nelson et al., J Infect Dis, 2016
PB2

Key
- commercial/non-H3-G1
- commercial/H3-G1
- exhibition/non-H3-G1
- exhibition/H3-G1

Nelson et al., J Infect Dis, 2016
Conclusions

• Frequent introduction of IAVs from commercial swine populations.
  • Extent of viral exchange between commercial and exhibition swine was unexpected

• Reassortment between viruses co-circulating in exhibition swine further increases viral diversity.

• Exchange of viruses between exhibition swine in Indiana and Ohio.
<table>
<thead>
<tr>
<th>State</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio</td>
<td>20.0%</td>
<td>18.8%</td>
<td>27.3%</td>
<td>25%</td>
<td>36.1%</td>
<td>18.2%</td>
</tr>
<tr>
<td>Indiana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41.6%</td>
<td>63.6%</td>
</tr>
<tr>
<td>(15/36)</td>
<td>(14/22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.3%</td>
<td>6.3%</td>
</tr>
<tr>
<td>(1/7)</td>
<td>(1/16)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.2%</td>
<td></td>
</tr>
<tr>
<td>(2/9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>(0/10)</td>
<td>(0/10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Virginia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>(0/1)</td>
<td>(0/1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kentucky</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1/1 (100%)</td>
<td></td>
</tr>
<tr>
<td>(0/1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0/1)</td>
<td>(1/1) (100%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>20.0%</td>
<td>18.8%</td>
<td>27.3%</td>
<td>26.8%</td>
<td>31.0%</td>
<td>30.1%</td>
</tr>
<tr>
<td>(3/15)</td>
<td>(3/16)</td>
<td>(6/22)</td>
<td>(11/41)</td>
<td>(31/100)</td>
<td>(22/73)</td>
<td></td>
</tr>
</tbody>
</table>
Objectives
Objectives

1. Determine the prevalence of influenza A virus in exhibition swine during arrival at agricultural fairs.

2. Characterize the on-farm management practice used for exhibition swine and identify where exhibition swine are located geographically.
   
   • Determine the risk factors associated with bringing a swine infected with influenza to a fair.
• During 2014, nine agricultural exhibitions (Exhibitions A-I) located in Indiana and Ohio were enrolled.

• Exhibition swine entering the fair were sampled during the first time they could be uniquely identified by ear tag.
Methods

Snout wipes collected

Samples placed in viral transport media and frozen

Sample RNA screened via rRT-PCR for influenza A virus

rRT-PCR positive (Ct ≤ 35) samples inoculated for virus isolation on MDCK cells
<table>
<thead>
<tr>
<th>Fair</th>
<th>Exhibition A</th>
<th>Exhibition B</th>
<th>Exhibition C</th>
<th>Exhibition D</th>
<th>Exhibition E</th>
<th>Exhibition F</th>
<th>Exhibition G</th>
<th>Exhibition H</th>
<th>Exhibition I</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. swine exhibited at fair</td>
<td>2,149</td>
<td>424</td>
<td>377</td>
<td>465</td>
<td>523</td>
<td>367</td>
<td>274</td>
<td>597</td>
<td>286</td>
</tr>
<tr>
<td>No. swine tested</td>
<td>382</td>
<td>419</td>
<td>359</td>
<td>445</td>
<td>523</td>
<td>367</td>
<td>274</td>
<td>492</td>
<td>286</td>
</tr>
<tr>
<td>No. (%) rRT-PCR positive</td>
<td>21 (5.50%)</td>
<td>144 (34.37%)</td>
<td>16 (4.45%)</td>
<td>6 (1.35%)</td>
<td>1 (0.19%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. (%) Virus Isolation positive</td>
<td>6 (1.57%)</td>
<td>43 (10.26%)</td>
<td>1 (0.28%)</td>
<td>2 (0.45%)</td>
<td>1 (0.19%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>5,462</td>
<td>3,547</td>
<td>188 (5.30%)</td>
<td>53 (1.49%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exhibition B:

- Sampled in chute
- rRT-PCR positive: 144
- Isolates recovered: 43

Key:
- ● H1N1
- ○ H3N2
- ★ H1H3 N1N2
Exhibition E:

- Pigs sampled in pen prior to weigh-in.
- rRT-PCR positive: 1
- Isolates recovered: 1

Key:
- ● H1N1
- ○ H3N2
- ★ H1H3 N1N2
Conclusions

• The frequency of influenza virus isolation was low among arriving swine.

• Exhibition swine movement and corralling activities are likely to enhance pathogen transmission during exhibitions.

• Focus should be placed on mitigating influenza A virus spread during swine exhibitions rather than attempting to completely preclude entry of the influenza A virus infected swine.
Survey of on-farm practices

• A 24 question survey was administered to the adults accompanying the swine exhibitors at the fairs.
• 480 surveys were collected, over the nine exhibitions with 5,462 swine.
  • 52 of the surveys dropped from study
• Surveys were associated with swine sampled upon entry.
  • Surveys that were not associated with individual pigs were used for descriptive data.
Descriptive data findings: swine herd

- Most survey participants reported not having swine year round.
- Obtained swine from an off-farm source (75.4%).
  - Most sales occurring between March and April (84.3%).
- Exhibition swine were raised in small herds (median, 6; range 1-6500).
- The same location as other livestock (66.5%).
  - Cattle (53.5%)
  - Poultry (32.6%)
  - Goats (32.4%)
  - Horses (27.3%)
  - Sheep (24.8%)
  - Other (llamas, buffalo, rabbits, etc.) (11.7%)
Descriptive data findings: movement

• Participants reported showing swine at an average 3.38 exhibitions during 2014.
  • (median 2; range 0-50)

• Brought swine back to the farm from an average from 2.88 exhibitions.
  • (median 2; range 0-40)

• Number of exhibitions attended by an individual pig averaged 2.19.
  • (median 1; range 0-30)

• Average travel time from loading to exhibition for these pigs was 3.20 hours.
  • (median 2 hours; range 5 minutes – 24 hours)
Exhibition swine management

• Half of the premises (48.6%) implemented some form of isolation for returning swine.

• Contact with swine or the environment of swine, other than their own, occurred at least once a week at 45.2% of the premise of the participant.

• Commercial swine production was reported at 13.3% of the premises as where the exhibition swine were raised.
<table>
<thead>
<tr>
<th>Description</th>
<th>Odds Ratio</th>
<th>P value</th>
<th>95% confidence interval</th>
<th>Number of rRT-PCR events</th>
</tr>
</thead>
<tbody>
<tr>
<td>At least one swine testing IAV positive via rRT-PCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of swine on premise January 1st, 2014</td>
<td>0.999</td>
<td>0.936</td>
<td>0.996 – 1.001</td>
<td>11</td>
</tr>
<tr>
<td>No. of swine on premise the day prior to attending exhibition</td>
<td>0.999</td>
<td>0.976</td>
<td>0.993 - 1.001</td>
<td>15</td>
</tr>
<tr>
<td>Maximum no. of swine on premises in 2014</td>
<td>1.000</td>
<td>0.789</td>
<td>0.998 – 1.068</td>
<td>15</td>
</tr>
<tr>
<td>No. of exhibitions attended by swine from premise in 2014</td>
<td>0.952</td>
<td>0.651</td>
<td>0.775 – 1.068</td>
<td>15</td>
</tr>
<tr>
<td>No. of exhibitions that swine returned to premise in 2014</td>
<td>1.053</td>
<td>0.234</td>
<td>0.956 – 1.142</td>
<td>14</td>
</tr>
<tr>
<td>Open houses/sales hosted on premise were people would come into contact with swine</td>
<td>3.933</td>
<td>0.035</td>
<td>1.097 – 13.064</td>
<td>6</td>
</tr>
<tr>
<td>New swine were directly mixed into existing herd on premise</td>
<td>2.131</td>
<td>0.266</td>
<td>0.603 – 6.966</td>
<td>15</td>
</tr>
<tr>
<td>Swine were obtained from an off-farm source</td>
<td>0.457</td>
<td>0.247</td>
<td>0.140 – 2.100</td>
<td>15</td>
</tr>
<tr>
<td>Distance from premise to closest commercial farm</td>
<td>0.948</td>
<td>0.682</td>
<td>0.751 – 1.201</td>
<td>15</td>
</tr>
<tr>
<td>Other livestock were raised on same premise as swine</td>
<td>0.627</td>
<td>0.562</td>
<td>0.185 – 2.255</td>
<td>6</td>
</tr>
<tr>
<td>The total time, in minutes, swine were on trailer during transportation to exhibition</td>
<td>1.001</td>
<td>0.153</td>
<td>0.999 – 1.003</td>
<td>15</td>
</tr>
<tr>
<td>No. of exhibitions attended by individual swine in 2014</td>
<td>0.943</td>
<td>0.635</td>
<td>0.748 – 1.092</td>
<td>21</td>
</tr>
<tr>
<td>No. of exhibitions that was planned to be attended by individual swine after current exhibition</td>
<td>0.858</td>
<td>0.794</td>
<td>0.387 – 1.333</td>
<td>9</td>
</tr>
<tr>
<td>Individual swine was reported as receiving a vaccination to influenza</td>
<td>2.828</td>
<td>0.143</td>
<td>0.773 – 15.606</td>
<td>3</td>
</tr>
</tbody>
</table>
Risk Factor

- Participants that hosted and open house or sale had 3.93 times the odds of having an IAV positive pig compared to the odds of participants that did not host an open house or sale.
  - 95% CI: 1.1 – 13.01
  - p = 0.035

- An open house/sale is an event hosted, prior to the fair, for other people at the farm to purchase swine.

- We think that this is identifying is the professional showmen.
**Exhibition swine management**

<table>
<thead>
<tr>
<th></th>
<th>Vaccinated</th>
<th>Not vaccinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pig with reported vaccination status</td>
<td>62.74% (197/314)</td>
<td>37.26% (117/314)</td>
</tr>
<tr>
<td>No. of rRT-PCR positive samples</td>
<td>7.77% (15/193)</td>
<td>2.88% (3/104)</td>
</tr>
<tr>
<td>No. of virus isolates</td>
<td>33.33% (5/15)</td>
<td>33.33% (1/3)</td>
</tr>
</tbody>
</table>

- 62.7% of swine were reported as vaccinated for influenza
- Having a reported vaccination status did not protect for influenza

Vaccination of swine, may repress clinical signs of disease without preventing infection or transmission

Conclusion

• The exhibition swine industry is composed of a diverse mixture of farm types and management practice differed from commercial swine production.

• There exists an interaction between commercial and exhibition swine industries. Although this is still poorly defined, this helps us to understand the viral gene flow between these two swine populations.
Shorten swine exhibitions

“Shorten the total time pigs are on the exhibition grounds, ideally exhibition swine should be on the exhibition grounds no more than 72 hours.”

-Measures to Minimize Influenza Transmission at Swine Exhibitions

Objective:

Validate the recommendation of limiting swine exhibitions to 72 hours to prevent zoonotic transmission of IAV-S.
Results

• 6,810 pigs sampled

• 948 (13.9%) were detected as positive during the course of study.

• IAV was detected in the pigs at 7 (44%) of the 16 fairs
  • Sustained IAV transmission at 5 of the 7

• Within those 5 events, the proportion of pigs testing positive for IAV at the conclusion of fairs was 49%.

• If the exhibitions had ended at 72 hours, the proportion of positive pigs would have been <18%.
Percent of swine testing positive for influenza A virus

Hours Post Arrival

0 24 48 72 96 120 144 168

Fair A 15
Fair B 15
Fair C 15
Fair A 14
Fair B 14
Fair D 14
Fair E 14
Accelerated Spread
Accelerated Spread

Fair 1: Virus Isolation and PCR Results

- Pigs
- Surface A
- Surface B
- Surface C
- Virus Isolation
Summary

• Exhibition swine are a small population relative to the commercial swine industry
  • Unique management practices
  • Unique exposure to humans and other pigs

• Largely unstudied interface between commercial and exhibition swine is important

• IAV continues to circulate in the exhibition swine
  • Reassortment continues to occur

• 72 hour recommendation is valid
  • Altered management practices might help where 72 hours is not achievable.
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