Pertussis Epidemiology and Vaccination in the United States

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Centers for Disease Control and Prevention

NCIRS Pertussis Meeting
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BACKGROUND AND OVERVIEW
Pertussis Surveillance and Reporting

• Nationally notifiable
• Clinical (Probable) case
  – Cough ≥2 weeks AND
  – One among paroxysms, whoop, post-tussive vomiting
• Confirmed case
  – Culture OR
  – Clinical case and PCR positive OR
  – Clinical case and epi-linked to confirmed case
Pertussis Immunization in the US

- Infants (1997)
  - DTaP at 2, 4, 6 months
- Toddler (1992)
  - DTaP at 15-18 months
- Pre-school (1992)
  - DTaP at 4-6 years
- Adolescent/adult (2005)
  - Single Tdap preferred at 11-12 years
DTaP coverage among children aged 19 through 35 months

CDC National Immunization Survey
Reported pertussis cases – 1922-2010

Number of cases

Year

SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System and 1922-1949, passive reports to the Public Health Service
Annual incidence by state, 2009

2009 incidence 5.5

Source: CDC National Notifiable Disease Surveillance System, 2009
CDC Wonder Population Estimates (Vintage 2009)
Annual incidence by State, 2010*

2010* incidence 8.97

Incidence is per 100,000 population
CDC Wonder Population Estimates (Vintage 2009)
EMERGENCE OF DISEASE AMONG 7-10 YEAR-OLDS
Pertussis incidence by age group - 1990-2009

Incidence (per 100,000)

Source: CDC National Notifiable Disease Surveillance System, 2009
CDC Wonder Population Estimates (Vintage 2009)
Proportion of all pertussis cases contributed by children aged 7-10 years
Pertussis cases by age – 2002-2005

2002

Cases vs. Age (years)

2003

Cases vs. Age (years)

2004

Cases vs. Age (years)

2005

Cases vs. Age (years)
Pertussis cases by age – 2006-2009

2006

2007

2008

2009
Incidence rate ratios of pertussis among children aged 7-10 years – 1990-2009

In 2005, 7-10 year old cohort includes aP vaccine recipients

Source: CDC National Notifiable Disease Surveillance System, 2009
CDC Wonder Population Estimates (Vintage 2009)
Waning Immunity by Vaccine Type

Mean Annual Pertussis Cases by Birth Cohort

Cases/# of Birth Cohorts in Each Age Year

Age (years)

- 1992-1999
- 2000-2008
Ongoing Evaluations of DTaP Series

- **California DTaP Vaccine Effectiveness Assessment**
  - Case-control design using provider-verified immunization data

- **Registry Assessment: Duration of Protection**
  - Mergers of immunization registries and surveillance databases
Primary Objectives:

- Assess overall VE of DTaP following the complete childhood series
- Determine duration of protection by assessing VE at specific time points post vaccination
CA VE Assessment
Participating Counties

Alameda  Riverside
Del Norte  San Diego
El Dorado  San Luis Obispo
Fresno  Santa Cruz
Madera  Santa Clara
Marin  Sonoma
Merced  Stanislaus
Orange
CA VE Case Control Design

- Cases & controls 4-10 yrs at illness onset or enrollment
- Reported pertussis cases in 15 CA counties
- Unmatched controls, from case-patient providers (3:1)
- In-person collection of vaccine history data
- Analysis: logistic regression, adjusted for cluster sample design
**CDPH Case Definition for Pertussis**

- **Clinical case definition:** Cough ≥2 weeks AND paroxysms, inspiratory whoop, or posttussive vomiting

<table>
<thead>
<tr>
<th>Status</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| Confirmed (47.6%) | - Culture positive + cough any duration  
                      - PCR positive + clinical case definition  
                      - Epi-Link + clinical case definition    |
| Probable (8.3%)   | - Meets clinical case definition                                              |
| Suspect (23.5%)   | - PCR confirmed + cough any duration  
                      - Epi-Link + cough any duration + other symptom |

* Status pending (19.0%) or Missing (1.7%)
Interim Results
# CA VE Timing of 5th Dose

<table>
<thead>
<tr>
<th>Received 5 DTaP doses</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>668 (69.2)</td>
<td>2151 (75.5)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age at 5th Dose</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>436 (65.2)</td>
<td>1456 (67.7)</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>204 (30.5)</td>
<td>594 (27.6)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6 (0.9)</td>
<td>20 (0.9)</td>
<td></td>
</tr>
<tr>
<td>7+</td>
<td>8 (1.2)</td>
<td>13 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>14 (2.1)</td>
<td>68 (3.2)</td>
<td></td>
</tr>
</tbody>
</table>
## CA VE Interim Analysis *
### Overall VE Estimates

<table>
<thead>
<tr>
<th>Model **</th>
<th>Case (n)</th>
<th>Control (n)</th>
<th>VE, %</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall VE, All Ages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 dose</td>
<td>53</td>
<td>24</td>
<td>Ref</td>
<td>--</td>
</tr>
<tr>
<td>5 doses</td>
<td>668</td>
<td>2151</td>
<td>85.9</td>
<td>75.6 - 91.9</td>
</tr>
<tr>
<td>Overall VE, All Ages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 dose</td>
<td>53</td>
<td>24</td>
<td>Ref</td>
<td>--</td>
</tr>
<tr>
<td>4 doses, 4th dose after age 4</td>
<td>32</td>
<td>74</td>
<td>80.4</td>
<td>62.5 - 89.8</td>
</tr>
</tbody>
</table>

* VE estimates are preliminary and based on interim data.

** Adjusted for County and provider clustering.
CA VE Interim Analysis *
Time Since 5\textsuperscript{th} Dose VE Estimates

<table>
<thead>
<tr>
<th>Model **</th>
<th>Case (n)</th>
<th>Control (n)</th>
<th>VE, %</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time since 5\textsuperscript{th} dose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 doses</td>
<td>53</td>
<td>24</td>
<td>Ref</td>
<td>--</td>
</tr>
<tr>
<td>&lt; 12 months</td>
<td>56</td>
<td>458</td>
<td>94.5</td>
<td>90.5 – 96.8</td>
</tr>
<tr>
<td>12 – 23 months</td>
<td>55</td>
<td>403</td>
<td>93.8</td>
<td>90.1 – 96.2</td>
</tr>
<tr>
<td>24 – 35 months</td>
<td>76</td>
<td>375</td>
<td>90.8</td>
<td>84.3 – 94.6</td>
</tr>
<tr>
<td>36 – 47 months</td>
<td>108</td>
<td>303</td>
<td>83.9</td>
<td>72.9 – 90.4</td>
</tr>
<tr>
<td>48 – 59 months</td>
<td>141</td>
<td>290</td>
<td>78.0</td>
<td>59.9 – 87.9</td>
</tr>
<tr>
<td>60+ months</td>
<td>220</td>
<td>322</td>
<td>69.1</td>
<td>43.0 – 83.2</td>
</tr>
</tbody>
</table>

* VE estimates are preliminary and based on interim data.

** Adjusted for County and provider clustering.
Registry Assessment: Objective

- Investigate waning of immunity in the five years post 5th DTaP dose through evaluation of incidence rates and risk of pertussis.
Registry Assessment: Data Sources

Statewide Pertussis Surveillance (NNDSS)
- Jan 1, 1998 – Oct 31, 2010
- Confirmed & probable cases

Immunization Registry
- 5 DTaP doses
- 5th dose between 4-6 years

Linkage

Population to date
- Minnesota cohort
- 353 cases
- Total N=199,643
Registry Assessment: Cohort Analyses

- **Incidence rates**
  - Incidence rates of pertussis for each year following the 5\(^{th}\) DTaP dose (up to 5 years time-since)

- **Risk**
  - Risk ratios calculated using longitudinal modeling
  - 1 year post-vaccination referent group
  - Adjusts for repeated measures correlation structures
Preliminary Risk Ratios and Incidence Rates for Pertussis by Year of Follow-up post 5th Dose DTaP - Minnesota 2010

* Risk Ratios Calculated with 1 year post 5th dose as referent
# Relationship between CA VE Estimates and MN Estimates of Risk

<table>
<thead>
<tr>
<th>Time (months)</th>
<th>CA VE (%)</th>
<th>Vaccinated Susceptibles (N) *</th>
<th>VS Ratio</th>
<th>MN Model RR</th>
<th>Predicted Cases (N) **</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12</td>
<td>94.5</td>
<td>3,850</td>
<td>Ref</td>
<td>Ref</td>
<td>18</td>
</tr>
<tr>
<td>12 – 23</td>
<td>93.8</td>
<td>4,340</td>
<td>1.13</td>
<td>1.29</td>
<td>24</td>
</tr>
<tr>
<td>24 - 35</td>
<td>90.8</td>
<td>6,440</td>
<td>1.67</td>
<td>1.78</td>
<td>33</td>
</tr>
<tr>
<td>36 - 47</td>
<td>83.9</td>
<td>11,270</td>
<td>2.93</td>
<td>2.44</td>
<td>45</td>
</tr>
<tr>
<td>48 - 59</td>
<td>78.0</td>
<td>15,400</td>
<td>4.00</td>
<td>3.95</td>
<td>72</td>
</tr>
<tr>
<td>60 +</td>
<td>69.1</td>
<td>21,630</td>
<td>5.62</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Based on birth cohort size of 70,000

** Based on birth cohort size of 70,000 and MN model
**Vaccine Effectiveness**

**DTaP Waning Each Year After Vaccination**

<table>
<thead>
<tr>
<th>Year post-vaccination</th>
<th>MN RR</th>
<th>MN</th>
<th>MN</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>5.5</td>
<td>94.5</td>
<td>94.5</td>
</tr>
<tr>
<td>1</td>
<td>1.29</td>
<td>7.1</td>
<td>92.9</td>
<td>93.8</td>
</tr>
<tr>
<td>2</td>
<td>1.78</td>
<td>9.8</td>
<td>90.2</td>
<td>90.8</td>
</tr>
<tr>
<td>3</td>
<td>2.44</td>
<td>13.4</td>
<td>86.6</td>
<td>83.9</td>
</tr>
<tr>
<td>4</td>
<td>3.95</td>
<td>21.7</td>
<td>78.3</td>
<td>78</td>
</tr>
</tbody>
</table>

*Based on cohort size = 100*
Summary and Future Directions

- Modest waning of immunity contributing to emergence of pertussis among school-aged children
- Completing observational and modeling assessments of factors contributing to pertussis resurgence
- Expanding and maximizing benefits of immunization program
- Assessing immunology/vaccinology
Thank You

For more information please contact Centers for Disease Control and Prevention
1600 Clifton Road NE, Atlanta, GA 30333
Telephone, 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov       Web: www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.
## Reported pertussis-related deaths by age-groups - 1980-2009*

<table>
<thead>
<tr>
<th>Age-Group</th>
<th>1980-1989¹</th>
<th>1990-1999¹</th>
<th>2000-2009²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1 month</td>
<td>38</td>
<td>68</td>
<td>119</td>
</tr>
<tr>
<td>2-3 month</td>
<td>11</td>
<td>16</td>
<td>56</td>
</tr>
<tr>
<td>4-5 month</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6-11 month</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1-4 years</td>
<td>13</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5-10 years</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>11-18 years</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>&gt;18 years</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>77†</strong></td>
<td><strong>103</strong></td>
<td><strong>195</strong>*</td>
</tr>
</tbody>
</table>

*2009 Data are provisional

² National Notifiable Diseases Surveillance System, CDC, 2009*

† Includes one case with unknown age

See Poster #94
Average Pertussis Case Fatality Rate, by State 2000 - 2010

Source: CDC National Notifiable Disease Surveillance System, through 2010 provisional data.
PREVENTION AND EVALUATION
Promoting “cocooning” to protect infants
ACIP considering expanded recommendations (poster 81)
Reported pertussis incidence by age group - 1990-2009

SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System
Number of reported pertussis cases by diagnosis* - 1990 – 2009**

See Posters 91 - 93

*Data collection for PCR and epi-link began in 1995.
**2009 Data are provisional
TDAP IMPLEMENTATION AND EVALUATION
Proportion of reported pertussis cases by age group - 1990-2009

Source: CDC National Notifiable Disease Surveillance System, 2009
CDC Wonder Population Estimates (Vintage 2009)
Tdap coverage among adolescents aged 13-17 years – 2006-2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>10.8</td>
</tr>
<tr>
<td>2007</td>
<td>30.4</td>
</tr>
<tr>
<td>2008</td>
<td>40.8</td>
</tr>
<tr>
<td>2009</td>
<td>55.6</td>
</tr>
</tbody>
</table>

Tdap Vaccine Effectiveness

- Bridging studies of ADACEL and BOOSTRIX\(^1\)
  - 85-89%
- APERT study\(^2\)
  - 92% (95% CI: 32.0-99.0)
- Australia\(^3\) – screening method
  - 78.0% (95% CI: 60.7-87.6)
- St. Croix outbreak\(^4\) – case-control study
  - 65.6% (95% CI: 35.8-91.3)
- MN case-control study (poster #80)
  - 72.3% (95% CI: 38.8-87.4)

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\(^1\) Schmitt HJ et al. JAMA 1996;275:37-41; Gustafsson LH et al. NEJM 1996;334:349-355
Incidence of reported pertussis - 1990-2008

CDC unpublished data
Accelerated decline of pertussis
Rate ratios of pertussis incidence among adolescents 11-18 years, 1990-2008

CDC unpublished data