Epidemiology of Pertussis in Australia –
The effect of vaccination and cocooning

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National Centre for Immunisation Research and Surveillance
22 million people

24,000 pertussis notifications annually

100 cases per 100,000 people
Rate of infant pertussis deaths, by country, 2003-2012

Death rate per 1,000,000 in 2003-2012
Death rate per 1,000,000 at peak year

Rate per million

Australia  Canada  England and Wales  United States
Diagnostic method

- Historically
  - culture, clinical

- 1996
  - serology

- 2004
  - PCR hospitals

- 2008
  - PCR community
Vaccination Schedule and coverage

- **1975**: DTPw 3,4,5 mth + 15-18 mth booster
- **1978**: 15-18 mth booster removed
- **1982**: DTPw 2,4,6 mth
- **1985**: 18 mth booster reintroduced
- **1994**: DTPa at 18 mth + 4 yr
- **1997**: 4-5 yr booster introduced
- **1999**: DTPa for all doses
- **2003**: 18 mth booster removed
- **2008**: dTpa 15-17 yr
- **2013**: dTpa cocoon dose

- **1975 - 1978**: 3-dose DTP coverage ~70%
- **1978 - 1982**: 85-90%
- **1982 - 1994**: 92%

Colors:
- Green = funded
- Red = removed
- Blue = recommended
Age-specific notification rates of pertussis, Australia, 1995–2014

Source: National Notifiable Diseases Surveillance System (NNDSS)
Impact of adolescent vaccination
The impact of adolescent pertussis immunization, 2004–2009: lessons from Australia

Helen E Quinn & Peter B McIntyre

Objective To compare the impact of three strategies for delivering a booster dose of adult-formulated tetanus–diphtheria–pertussis (Tdap) vaccine to adolescents in Australia. These comprise: (i) administering Tdap to: a one-year age cohort; (ii) administering Tdap to the entire high school and to subsequent entrant cohorts; and (iii) administering Tdap to the entire high school but without continuing to immunize entrant cohorts.

Methods A series of ecologic analyses of pertussis notifications during epidemic periods in relevant age cohorts were conducted. The primary outcome measure was the incidence rate ratio (IRR), calculated by dividing pertussis incidence after the introduction of Tdap delivery programmes by pertussis incidence during the most recent pre-programme epidemic.

Findings During the epidemic period of 2008–2009, the national-level IRR among age cohorts targeted for Tdap was 0.6 (95% confidence interval, CI: 0.6–0.7), but among other age cohorts it was 1.1 (95% CI: 1.1–1.2). Only the jurisdiction that implemented strategy 2 (Western Australia) experienced sustained decreases in pertussis notifications in both adolescents and infants under 6 months of age (IRR: 0.4; 95% CI: 0.3–0.6) until 2009.

Conclusion If confirmed by longer experience in Australia and elsewhere, a broad school-based catch-up programme followed by immunization of school entrants may be the optimum strategy for the implementation of adolescent Tdap programmes.
The impact of adolescent pertussis immunization, 2004–2009: lessons from Australia

Helen E Quinn & Peter B McIntyre

- Ecological study comparing notification rates before and after program implementation
  - targeted and non-targeted adolescents
- Original data 2005 - 2009
- Impact on targeted cohorts only
- Extension of analysis up to 2012

Evidence that Australian adolescent pertussis vaccination program has benefited adolescents

<table>
<thead>
<tr>
<th>Regional group by program type*</th>
<th>Incidence Rate Ratio comparing epidemic periods pre- versus post-program (95% CI)</th>
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<tbody>
<tr>
<td></td>
<td>Age cohort targeted by program</td>
</tr>
<tr>
<td>ACT/ SA/ Victoria</td>
<td>0.9 (0.86 to 1.01)</td>
</tr>
<tr>
<td>New South Wales</td>
<td>0.9 (0.82 to 0.91)</td>
</tr>
<tr>
<td>Western Australia</td>
<td>0.4 (0.39 to 0.49)</td>
</tr>
<tr>
<td>Queensland</td>
<td>0.7 (0.65 to 0.77)</td>
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* Regional groups were based on program delivery characteristics.
N/A - All West Australian adolescents had been targeted by the program by the epidemic
Evidence that Australian adolescent pertussis vaccination program has benefited adolescents

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<thead>
<tr>
<th>Regional group by program type*</th>
<th>Incidence Rate Ratio comparing epidemic periods pre- versus post-program (95% CI)</th>
<th>Infants aged &lt;6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age cohort targeted by program</td>
<td>Age cohort not targeted by program</td>
</tr>
<tr>
<td>ACT/ SA/ Victoria</td>
<td>0.9 (0.86 to 1.01)</td>
<td>2.2 (2.05 to 2.38)</td>
</tr>
<tr>
<td>New South Wales</td>
<td>0.9 (0.82 to 0.91)</td>
<td>1.6 (1.52 to 1.72)</td>
</tr>
<tr>
<td>Western Australia</td>
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Vaccine effectiveness in young children
Duration of Protection After First Dose of Acellular Pertussis Vaccine in Infants

WHAT’S KNOWN ON THIS SUBJECT: Waning effectiveness of 5 doses of acellular pertussis vaccines is well documented after 6 years of age, but data are lacking for fewer doses in younger children.

WHAT THIS STUDY ADDS: In 2- to 3-month-old infants, 1 dose of the diphtheria–tetanus–acellular pertussis vaccine gave significant protection against hospitalized pertussis. The effectiveness of 3 doses decreased from 84% between 6 and 11 months to 59% after 3 years.

OBJECTIVE: Data on the effectiveness of the diphtheria–tetanus–acellular pertussis (DTaP) vaccine in the first 4 years of life are sparse. We evaluated the vaccine effectiveness (VE) of 1 and 2 doses of DTaP among children aged 2 months to <4 years.

abstract

Duration of Protection After First Dose of Acellular Pertussis Vaccine in Infants

**Authors:** Helen E. Quinn, PhD, MAE, Thomas L. Snelling, BMBS (Hons), Grad Dip Clin Epid, Kristine K. Macartney, MBBS, BMedSci, MD, and Peter B. McIntyre, MBBS, PhD

**WHAT'S KNOWN ON THIS SUBJECT:** Waning effectiveness of 5 doses of acellular pertussis vaccines is well documented after 6 years of age, but data are lacking for fewer doses in younger children.

- Matched case control study
- National data 2005 - 2009
- 2 month - 3 year olds
- Dose based analysis
- Hospitalised and non-hospitalised

# Vaccine effectiveness in infants, aged 2–11 months

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Doses</th>
<th>Notified* VE (95% CI)</th>
<th>Hospitalised VE (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–3</td>
<td>1</td>
<td>53.7 (43.8 to 61.9)</td>
<td>55.3 (42.7 to 65.1)</td>
</tr>
<tr>
<td>4–5</td>
<td>2</td>
<td>75.3 (65.7 to 82.3)</td>
<td>83.0 (70.2 to 90.3)</td>
</tr>
<tr>
<td>6–11</td>
<td>2</td>
<td>80.8 (73.5 to 86.1)</td>
<td>81.3 (63.4 to 90.5)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>83.5 (79.1 to 87.0)</td>
<td>85.0 (75.0 to 91.0)</td>
</tr>
</tbody>
</table>

* Notified cases include those hospitalised, not hospitalised and of unknown hospitalisation status
Vaccine effectiveness in children, aged 1–3 years

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Doses</th>
<th>Notified VE (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>79.2 (75.0 to 82.8)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>70.7 (64.5 to 75.8)</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>59.2 (51.0 to 66.0)</td>
</tr>
</tbody>
</table>

* Notified cases include those hospitalised, not hospitalised and of unknown hospitalisation status
Waning vaccine effectiveness of 3 doses of DTPa

Note: Effectiveness (solid line) and pointwise 95% confidence intervals (dotted lines) were estimated from the best fitting fractional polynomial transformation of the age*vaccine interaction, being a third degree cubic polynomial
ICD-coded pertussis hospitalisations in persons aged ≥12 months, Australia, 1995–2013

Source: AIHW National Hospital Morbidity Database
Comorbidities among children presenting to the Children’s Hospital at Westmead with pertussis, 2007–2012

- Cardiorespiratory (57%), immunodeficiencies (11%) and chromosomal abnormalities (8%)
- Cases aged ≥12 months with comorbidities
  - More likely to be hospitalised for ≥2 days (OR: 12.6, 95% CI: 5.9–27.0)
  - 7 of the 9 cases requiring ICU admission had a comorbidity
ICD-coded pertussis hospitalisations in infants aged <12 months, Australia, July 1995 - June 2014

Source: AIHW National Hospital Morbidity Database
Percentage of total pertussis deaths in infants <12 months, by month of age, Australia, 1967–2014

Source: AIHW National Mortality Database and NNDSS
In light of the current outbreak, parents and GPs are asked to bring the first dose forward to six weeks of age to provide earlier protection.
Early first dose

- Estimated to reduce pertussis hospitalisations by 9% for infants aged <1 year in Australian setting

- Rapid uptake in some states of Australia
  - 50% of infants had dose 1 at 6-7 weeks of age within 6 months of announcement

- Progressive uptake in other states
  - Continued after epidemic
  - December 2014 dose 1 national coverage 70% at 6-7 weeks of age
  - Not an official schedule point

Cumulative age at onset and death for pertussis in infants <12 months of age, Australia, 1999–2013

First DTPa dose

- Cumulative age at onset
- Cumulative age at death

Age (weeks)

Cumulative percentage

0 1 2 3 4 5 6 7 8 9 10 11 12
Vaccination Schedule

1975: DTPw 3,4,5 mth + 15-18 mth booster
1978: DTPw 2,4,6 mth
1982: 18 mth booster reintroduced
1985: DTPa at 18 mth + 4 yr
1994: 4-5 yr booster introduced
1997 1999: DTPa for all doses
2003: 18 mth booster removed
2008: dTpa 15-17 yr
2013: State-based cocoon programs
2015: dTpa cocoon dose

Legend:
- Green = funded
- Red = removed
- Blue = recommended
- Turquoise = state-funded
The cocoon strategy
Commenced March 2009
Parents, grandparents and other regular carers of infants aged <12 months

Commenced June 2009
Parents of infants aged <6 months

Commenced January 2011
Parents, grandparents and carers of infants aged <7 months
Location for vaccination

Mother vaccination timing relative to birth

Parental Tdap Boosters and Infant Pertussis: A Case-Control Study

AUTHORS: Helen E. Quinn, PhD, MAE,a,b Thomas L. Snelling, BMBS, PhD,c,d Andrew Habig, MBBS, MPH,a Clayton Chiu, MBBS, MPH, TM,a,b Paula J. Spokes, RN, MIPH,e and Peter B. McIntyre, MBBS, PhD,a,b

aNational Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, and bDiscipline of Paediatrics and Child Health, University of Sydney, Children’s Hospital at Westmead, Westmead, Australia; cTelethon Institute for Child Health Research, University of Western Australia, Subiaco, Australia; dMenzies School of Health Research, Charles Darwin University, Casuarina, Australia; and eNew South Wales Ministry of Health, North Sydney, Australia

WHAT’S KNOWN ON THIS SUBJECT: Parental reduced antigen diphtheria-tetanus-acellular pertussis (Tdap) vaccination is difficult to implement, and empirical data on its impact is limited to a single hospital-based study in Texas, which found no reduction in infant pertussis hospitalization.

WHAT THIS STUDY ADDS: In New South Wales, Australia, a case-control study found both parents receiving Tdap ≥4 weeks before disease onset was associated with a significant reduction in risk of early infant pertussis and suggestive of persistent protection in subsequent pregnancies.

KEY WORDS
pertussis, vaccine, effectiveness, cocooning, immunisation

ABBREVIATIONS
ACIR—Australian Childhood Immunisation Register
CI—confidence interval
NCIMS—Notifiable Conditions Information Management System
# Parental Tdap Boosters and Infant Pertussis: A Case-Control Study

**Authors:** Quinn HE, PhD; Mares T; Thomas L; Spillane J; Quinn HE, et al.


## Table

<table>
<thead>
<tr>
<th>Factor</th>
<th>Cases N (%)</th>
<th>Controls N (%)</th>
<th>Adjusted odds ratio (95% CI)</th>
<th>VE (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother vaccination status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not vaccinated prior to disease onset</td>
<td>91 (42)</td>
<td>207 (35)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>at least 4 weeks prior to disease onset</td>
<td>47 (22)</td>
<td>189 (32)</td>
<td>0.52 (0.26 to 1.02)</td>
<td>48 (-2 to 74)</td>
</tr>
<tr>
<td>within 4 weeks of disease onset</td>
<td>55 (25)</td>
<td>111 (19)</td>
<td>0.97 (0.47 to 1.99)</td>
<td>3 (-99 to 53)</td>
</tr>
<tr>
<td><strong>Mother + Father vaccination status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both not vaccinated prior to disease onset</td>
<td>65 (33)</td>
<td>160 (29)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Both at least 4 weeks prior to disease onset</td>
<td>26 (13)</td>
<td>138 (25)</td>
<td>0.49 (0.27 to 0.90)</td>
<td>51 (10 to 73)</td>
</tr>
</tbody>
</table>

* Adjusted for health-care safety-net eligibility, education level, breast-fed infant, resident father, infant vaccination status, age of resident children.
The impact of parental postpartum pertussis vaccination on infection in infants: A population-based study of cocooning in Western Australia

Dale Carcione a, *, Annette K. Regan a, b, Lauren Tracey a, Donna B. Mak a, c, Robyn Gibbs a, Gary K. Dowse a, Max Bulsara d, Paul V. Effler a, b

a Communicable Disease Control Directorate, Department of Health, Perth, WA, Australia
b School of Pathology and Laboratory Medicine, University of Western Australia, Perth, WA, Australia
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ABSTRACT

During a pertussis epidemic in 2011–2012 the Western Australian (WA) Department of Health implemented a ‘cocooning’ programme, offering free pertussis-containing vaccine (dTpa) to new parents. We assessed the impact of vaccinating parents with dTpa on the incidence of pertussis infection in newborns. Births in WA during 2011–2012 were linked to a register of parental pertussis vaccinations and to notified reports of laboratory-proven pertussis in children ≤6 months of age. Parents who received dTpa during the four weeks after their child's birth were defined as ‘vaccinated postpartum’.
<table>
<thead>
<tr>
<th>Factor</th>
<th>N</th>
<th>Rate per 1,000 (95% CI%)</th>
<th>Adjusted hazard ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother + Father vaccination status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both not vaccinated prior to disease onset</td>
<td>45</td>
<td>2.0 (1.6 to 2.9)</td>
<td>1</td>
</tr>
<tr>
<td>Both vaccinated within 28 days from birth</td>
<td>23</td>
<td>1.9 (1.3 to 2.9)</td>
<td>0.91 (0.55 to 1.53)</td>
</tr>
<tr>
<td><strong>Mother vaccination status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not vaccinated prior to disease onset</td>
<td>49</td>
<td>2.1 (1.6 to 2.7)</td>
<td>1</td>
</tr>
<tr>
<td>Vaccinated within 28 days from birth</td>
<td>69</td>
<td>2.3 (1.9 to 3.0)</td>
<td>1.19 (0.82 to 1.72)</td>
</tr>
</tbody>
</table>

*maternal age, geographic region of birth, timing of birth and number of siblings
Post-partum vaccination did not reduce pertussis disease in infants <6 months of age
Source of infection
## Risk of pertussis associated with children in household

<table>
<thead>
<tr>
<th>Resident children</th>
<th>Adjusted odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aged 1 years</td>
<td>1.55 (0.85 to 2.82)</td>
</tr>
<tr>
<td>Aged 2 years</td>
<td>1.81 (1.15 to 2.86)</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Aged 12–17 years</td>
<td>1.12 (0.63 to 1.97)</td>
</tr>
</tbody>
</table>

### Vaccination status for children in household

- **3 doses** – 93%
- **4 doses** – 85%

Source of infection studies

- **Study 1**
  - January to May 2009
  - Source: siblings 36%, parents 24%
  - Majority of sibling sources aged 3-4 years

- **Study 2**
  - January 2008 to December 2012
  - Source: siblings 51%, parents 32%
  - Majority of sibling sources aged 3-4 years and vaccinated

Lessons from recent Australian epidemiology

- Adolescent vaccination benefits those who are vaccinated
- Waning immunity occurs in young children without a booster in the second year of life
- Vaccination at 6 weeks acceptable
  - but not enough to prevent infant deaths and severe disease
- Indirect protection from cocooning can provide limited protection
  - timing of vaccination critical
  - source of infection an issue
Vaccination Schedule

- **1975**: DTPw 3,4,5 mth + 15-18 mth booster
- **1978**: DTPw 2,4,6 mth
- **1982**: 18 mth booster reintroduced
- **1985**: DTPw 3,4,5 mth + 15-18 mth booster
- **1994**: DTPa for all doses
- **1997**: 4-5 yr booster introduced
- **1999**: DTPa for all doses
- **2003**: 18 mth booster removed
- **2008**: dTpa antepartum or cocoon dose
- **2013**: dTpa ≥65 years
- **2015**: 18 mth booster reintroduced
- **2016**: State-based antepartum programs

Legend:
- **Green** = funded
- **Red** = removed
- **Blue** = recommended
- **Teal** = state-funded
Pertussis notification rates, Australia, 2011–September 2015

Notification rate per 100,000

Month and Year

NSW
VIC
others
To: Women and Children’s Health, Infectious Diseases Physicians, Infection Control Practitioners, Western Sydney LHD and Children’s Hospital Westmead

From: Public Health Unit

Date: 11 November 2015

Re: INFANT PERTUSSIS ALERT

Dear colleagues

There has been a steady increase in pertussis notifications in Western Sydney, and across NSW since late 2014. In 2014, a total of 414 notifications of pertussis were notified to the Western Sydney Public Health Unit. For 2015 (year to date), we have had 1294 notifications so far. While illness has been reported in all age groups from 0 to 85+ years, the majority of cases have been in school-aged children (5-14 year olds). Of concern, recently there have been notifications of illness in infants under 6 months of age, and history of a coughing illness in families of women in their last month of pregnancy.

The high risk groups for pertussis include:
- Women in their last month of pregnancy
- Babies <6 months of age
- Health care or childcare workers, working with women in their last month of pregnancy and babies <6 months of age.

It is important that any coughing illness amongst patients, staff and visitors in high risk areas (Neonatal ICU, Paediatric ICU, Birthing/Maternity units, Ante- and Post-Natal Clinics)
Acknowledgements

- Peter McIntyre
- Melina Georgousakis
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