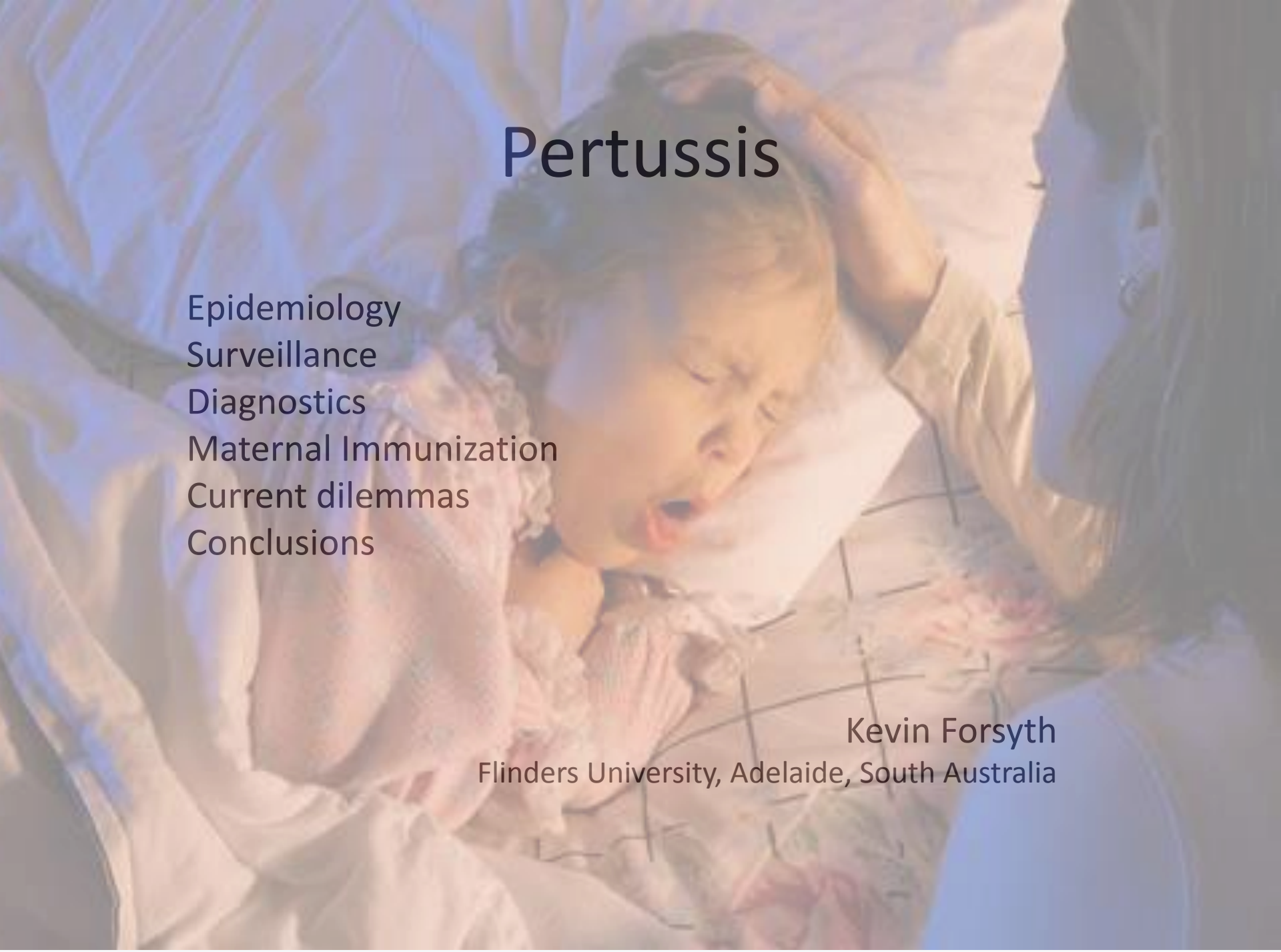


Pertussis

Epidemiology
Surveillance
Diagnostics
Maternal Immunization
Current dilemmas
Conclusions

Kevin Forsyth
Flinders University, Adelaide, South Australia

How worried should we be about the whooping cough epidemic?

Mary-Rose MacColl *The Australian* April 28, 2012 12:00AM

Dana McCaffery, who died from whooping cough at four weeks. *Source:* Supplied

Epidemiology of Pertussis

- Pertussis remains endemic worldwide.[1]
  - Estimated 50 million cases and 300,000 deaths each year.
- Pertussis is an important public health problem, even in countries with sustained high vaccination coverage.[2–4]
  - Incidences vary widely from <0.1/100,000 in Japan to 150/100,000 in Australia.
- Worldwide, infants bear the greatest disease burden and mortality, making disease prevention an important public health goal.
  - Hospitalization rate for infants <12 months of age are higher at 38.8 per 100,000 population compared with those <16 years old at 2.6 per 100,000.[5]
  - Of 809 hospitalizations for pertussis in California in 2010, most occurred in infants younger than 3 months; all 10 deaths occurred in this age group.[6]

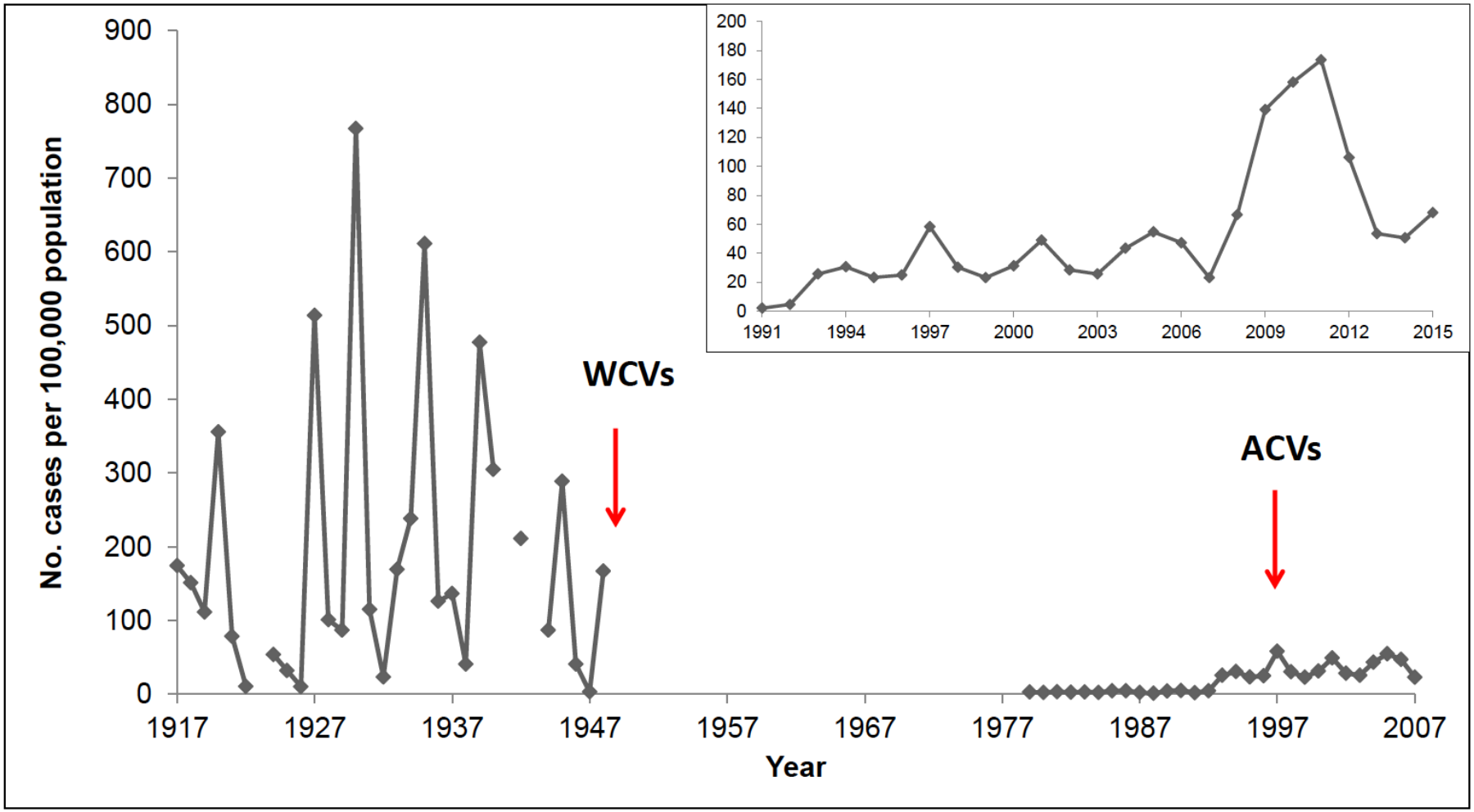
1. Libster R, Edwards KM. *Expert Rev Vaccines.* 2012;11:1331–46. 2. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18. 3. Crowcroft NS, Pebody RG. *Lancet.* 2006;367:1926–36. 4. Sato H, Sato Y. *Clin Infect Dis.* 1999;28(Suppl 2):S124–S130. 5. Heininger U, et al. *Pediatr Infect Dis J.* 2014;33:147–151. 6. Winter K, et al. *J Pediatr.* 2012;161:1091–6.

Reported NNDSS pertussis cases: 1922-2013*

*2013 data are provisional.

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

Incidence of pertussis in Australia



Hall, R. 2003. *Commun Dis Intell* 17:226-236; National Notifiable Diseases Surveillance System

Thanks to Ruiting Lan

Figure 55: Notifications and notification rates for pertussis, Australia, 1993 to 2012

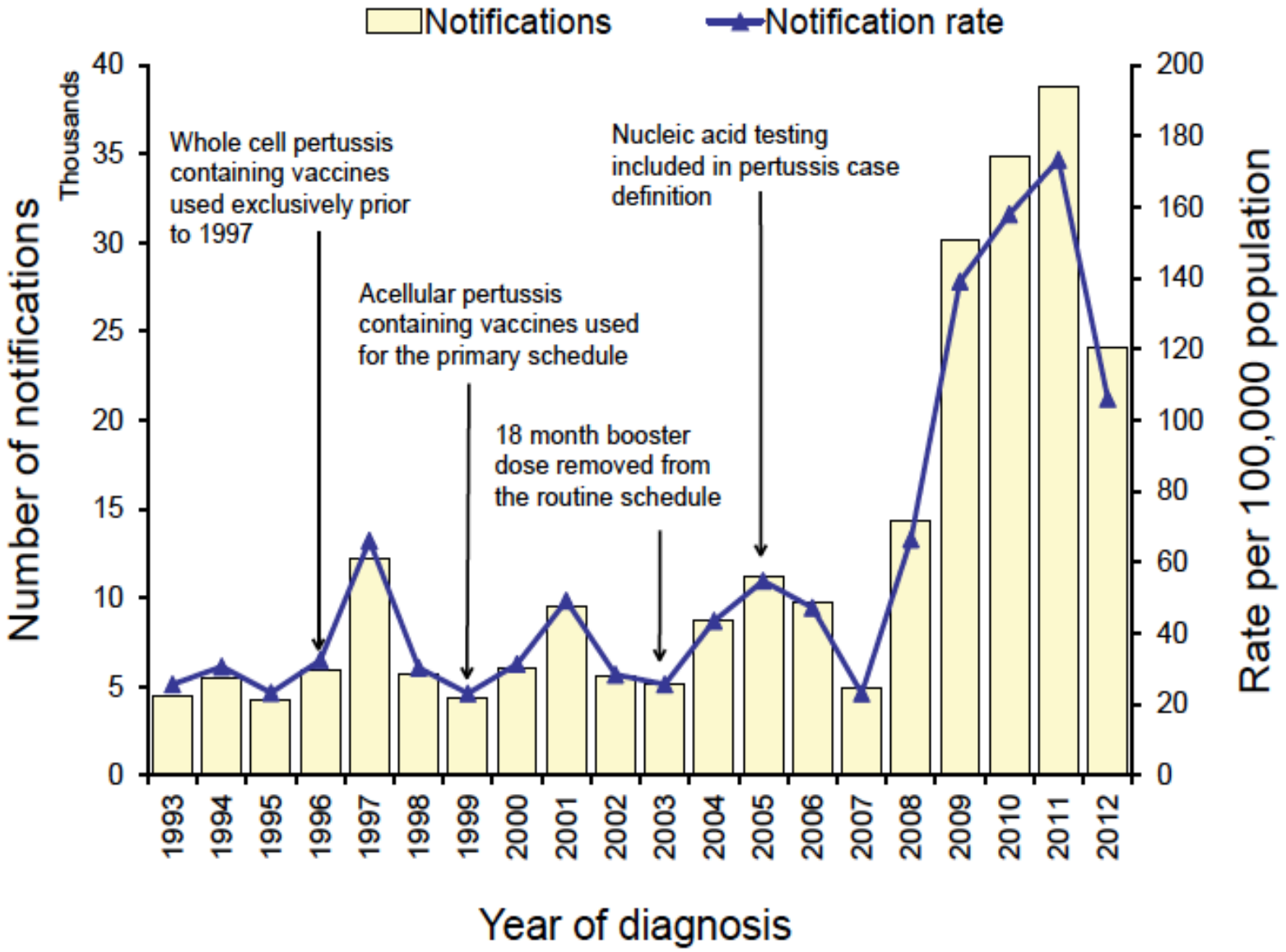
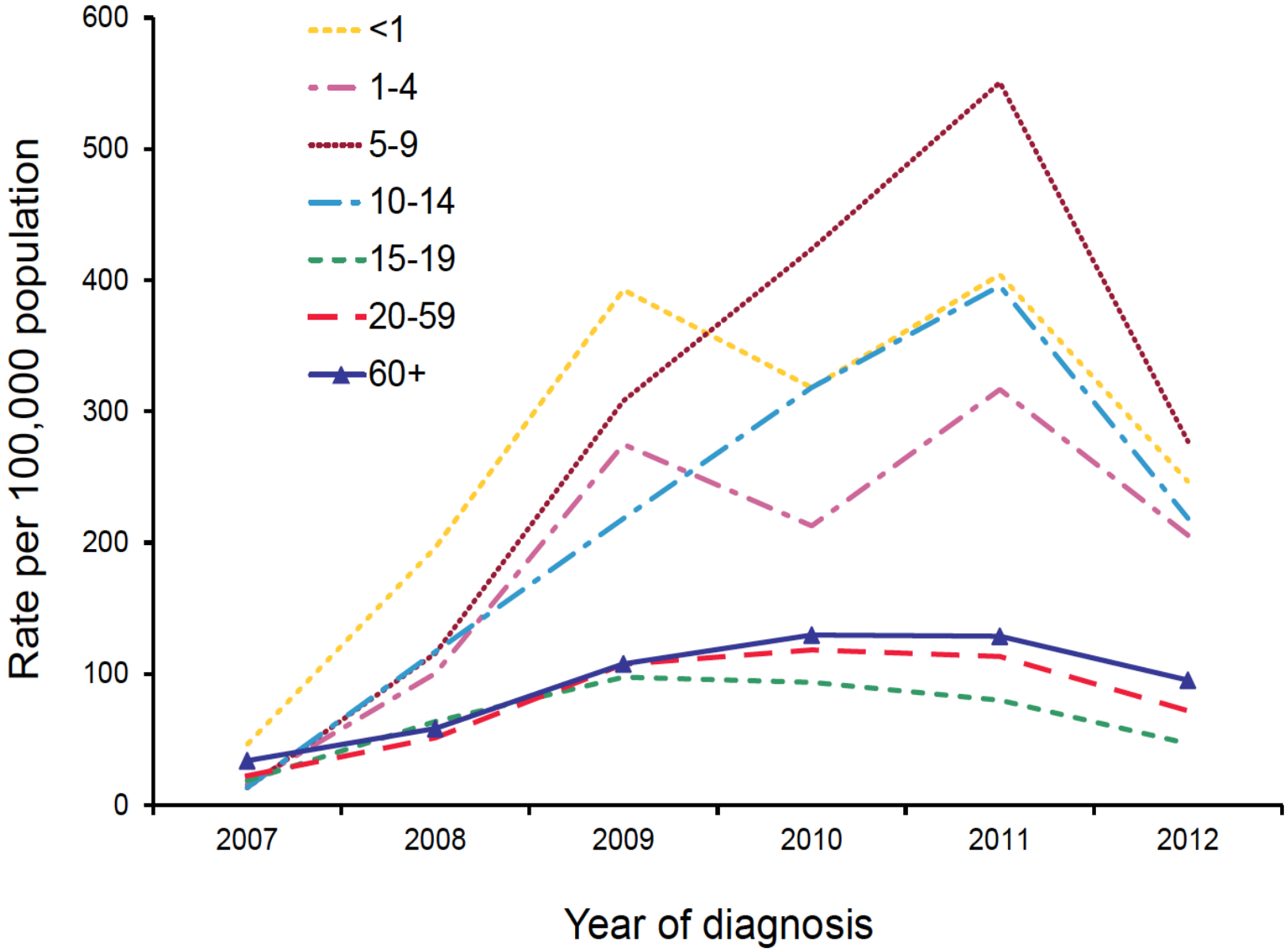
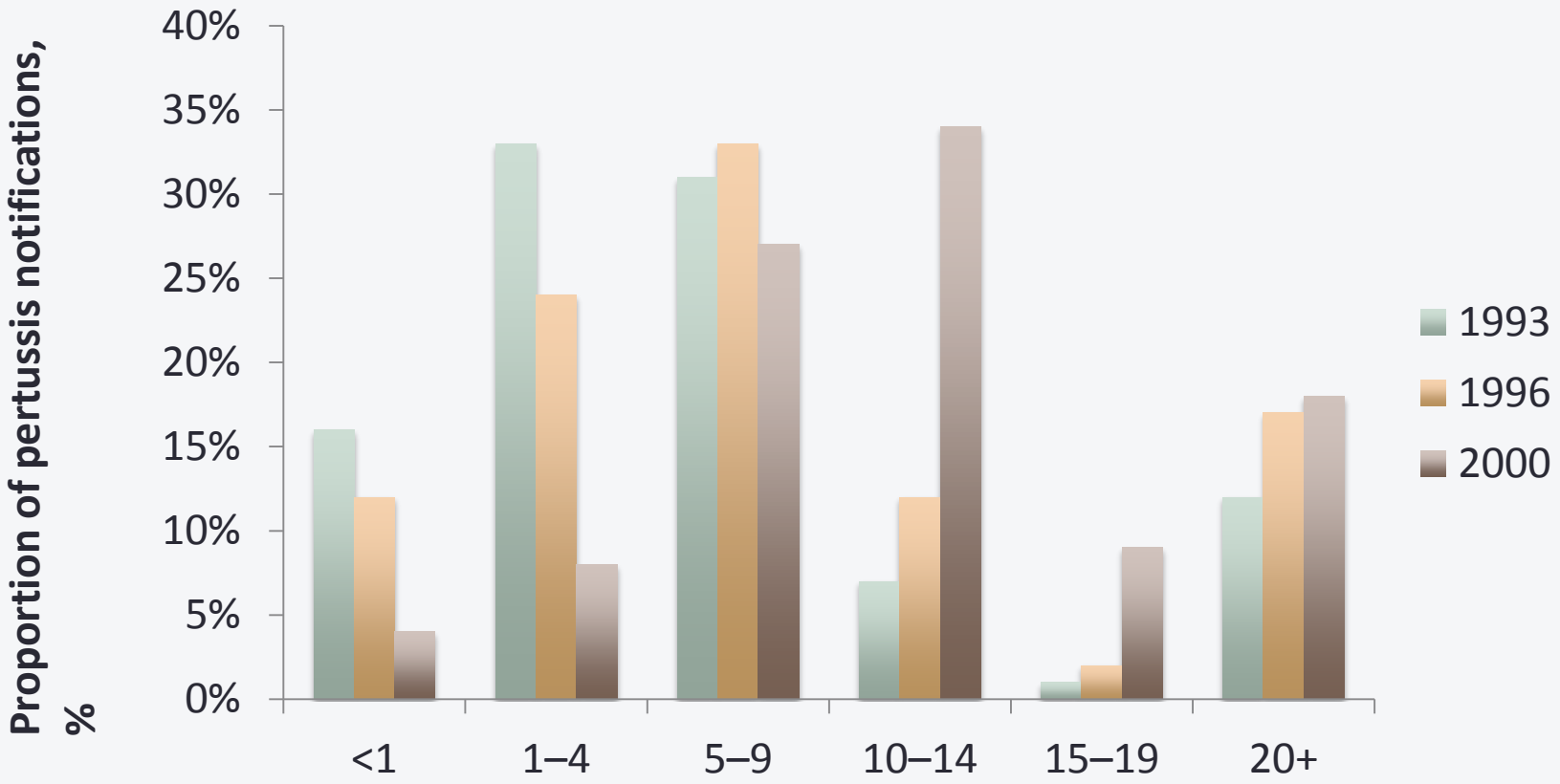


Figure 59: Notification rate for pertussis, Australia, 2012, by year and age group



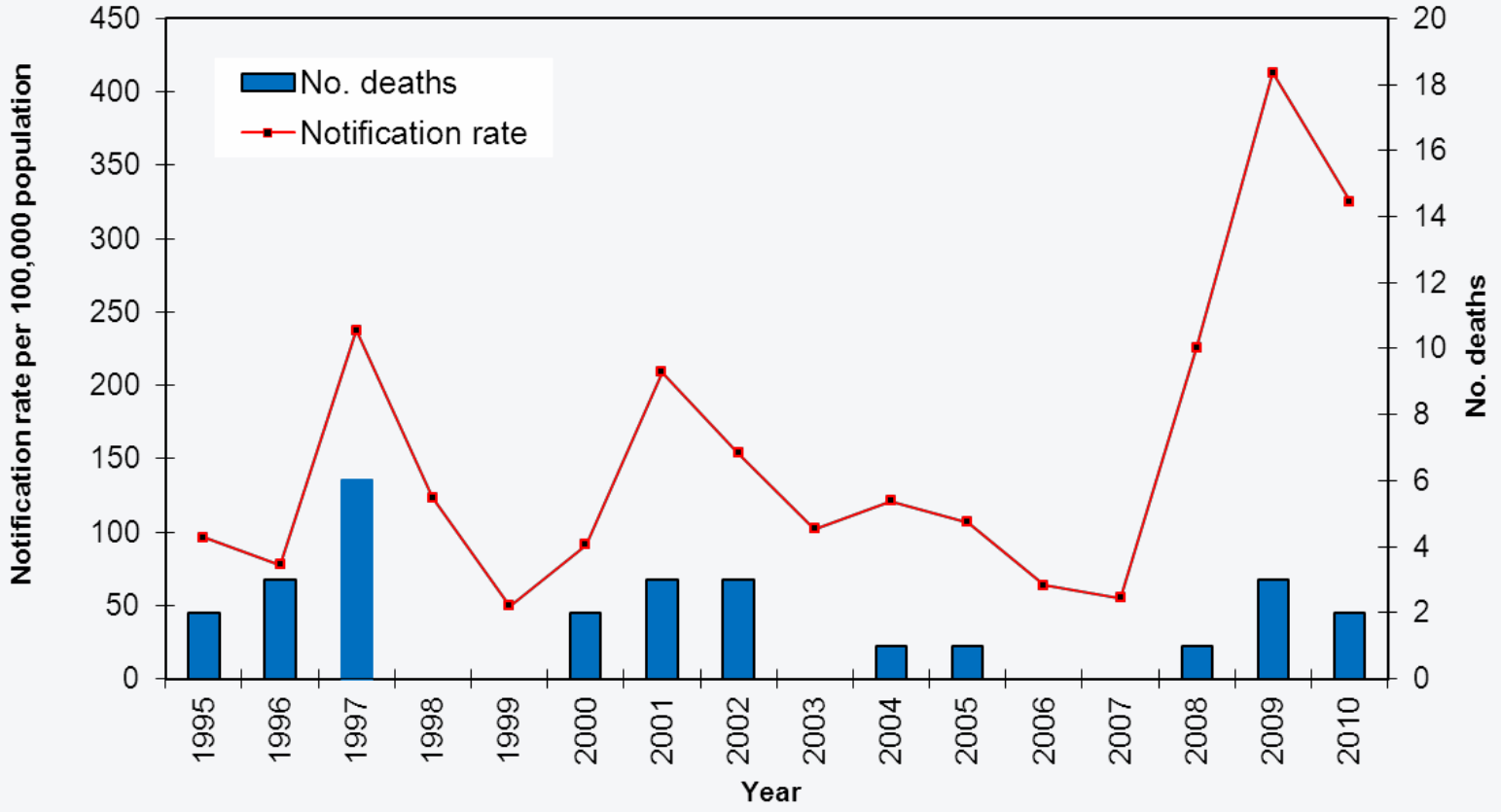
Changing Age Distribution of Pertussis



Year	Incidence per 100,000 individuals					
2000	197	80	185	230	58	10

1. Skowronski DM, et al. *J Infect Dis.* 2002;185:1448–53.

Pertussis notification rates and deaths, 1995-2010 Australia



From: McIntyre P, NCIRS

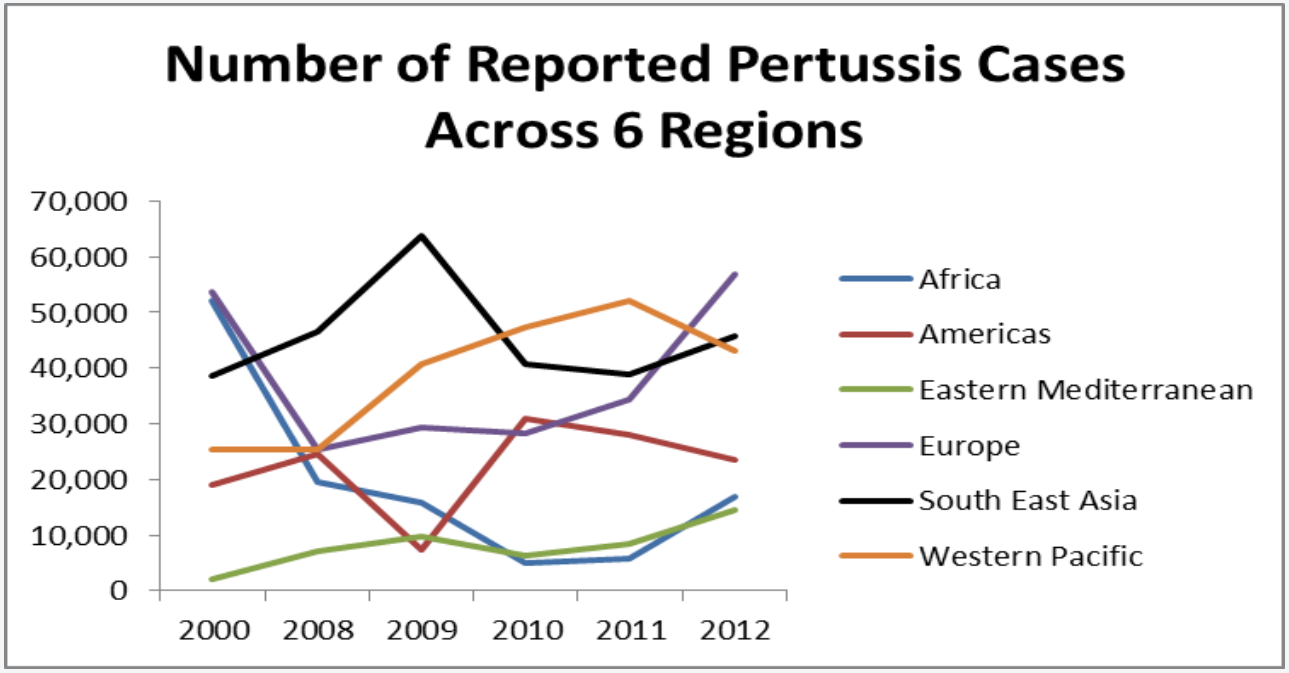
Pertussis: A Resurgent Problem

- Despite routine and widespread vaccination, a resurgence of pertussis cases has been observed in the post-vaccination era.
  - Pertussis resurgence reported in many countries, including Argentina, Australia, Austria, Brazil, Canada, Chile, Czech Republic, Denmark, Finland, Germany, Greece, Ireland, Japan, Netherlands, Nigeria, Norway, Poland, South Korea, Spain, Switzerland, United Kingdom, and the United States.[1–7]
- Hypotheses for this resurgence include:
  - Improved surveillance, diagnostic methods and disease awareness.[8]
  - Incomplete vaccination.[9]
  - Waning vaccine- or natural infection-induced immunity.[10–15]
  - Adaptability of bacterium to immunity conferred by vaccines.[10–15]
  - The acellular vaccine may not fully prevent pertussis transmission.[16]

1. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18. 2. Crowcroft NS, Pebody RG. *Lancet.* 2006;367:1926–36. 3. Sato H, Sato Y. *Clin Infect Dis.* 1999;28(Suppl 2):S124–S130. 4. Hozbor D, et al. *J Infect.* 2009;59:225–31. 5. Hellenbrand W, et al. *BMC Infect Dis.* 2009;9:22. 6. Glismann S, et al. *Euro Surveill.* 2001;6:94–8. 7. Celentano LP, et al. *Pediatr Infect Dis J.* 2005;24:761–5. 8. Fisman DN, et al. *BMC Public Health.* 2011;11:694. 9. Riolo MA, et al. *Vaccine.* 2013;31:5903–8. 10. Brinig MM, et al. *J Bacteriol.* 2006;188:2375–82. 11. Lee GM, et al. *Am J Prev Med.* 2007;32:186–93. 12. Schellekens J, et al. *Pediatr Infect Dis J.* 2005;24:S19-S24. 13. Mooi FR. *Infect Genet Evol.* 2010;10:36–49. 14. Mooi FR, et al. *Epidemiol Infect.* 2013;1–10. 15. Schmidtke AJ, et al. *Emerg Infect Dis.* 2012;18:1248–55. 16. Warfel JM, et al. *Proc Natl Acad Sci USA.* 2014;111:787–92.

Regional Epidemiological Trends

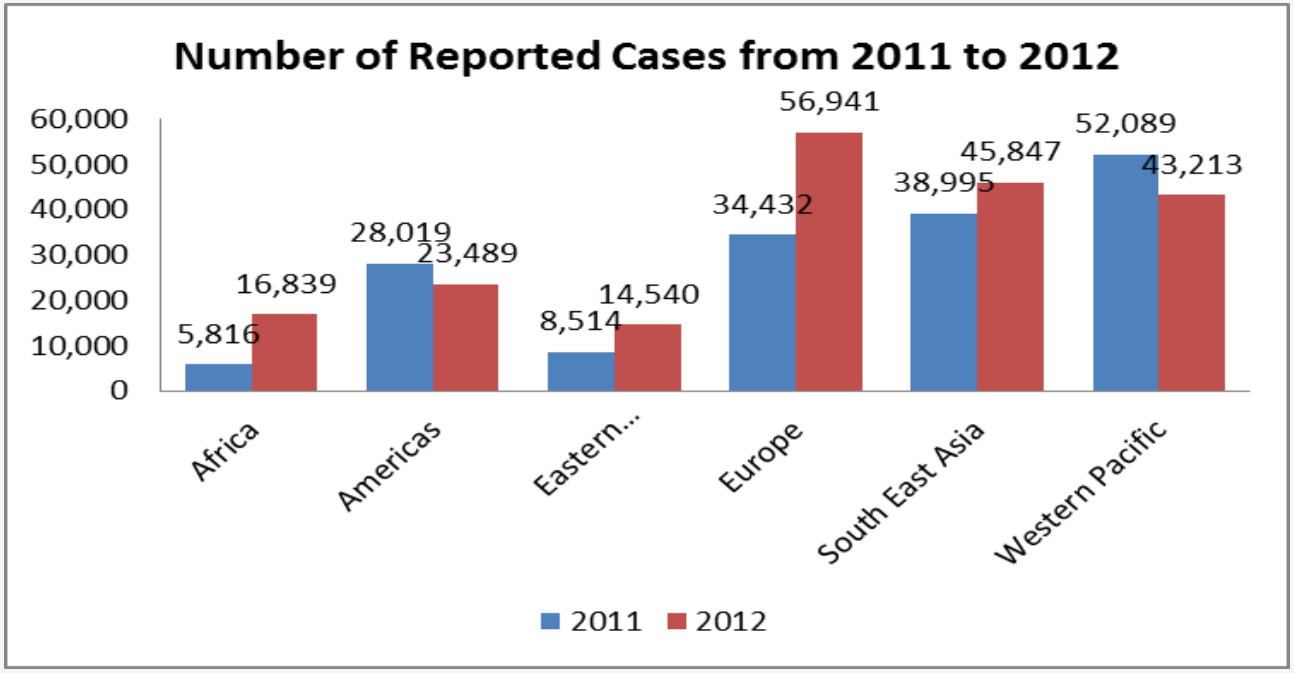
- Despite the stable number of cases reported worldwide between 2000 to 2012, many regions experienced a resurgence in pertussis cases[1–7]



1. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18.
2. World Health Organization (WHO). Available at: http://www.who.int/immunization/monitoring_surveillance/data/gs_afrprofile.pdf.
3. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/AMR/en/index.html.
4. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/EMR/en/index.html.
5. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/EUR/en/index.html.
6. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/SEAR/en/index.html.
7. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/WPR/en/index.html.

Regional Epidemiological Trends (cont.)

- Four of six regions showed an increase in number of reported cases from 2011 to 2012.



1. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18.
2. World Health Organization (WHO). Available at: http://www.who.int/immunization/monitoring_surveillance/data/gs_afrprofile.pdf.
3. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/AMR/en/index.html.
4. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/EMR/en/index.html.
5. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/EUR/en/index.html.
6. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/SEAR/en/index.html.
7. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/WPR/en/index.html.

Table 1
Epidemiology of pertussis in Asia-Pacific.

	Age cohort with the highest pertussis burden
Australia	0-14 year olds
China	<4-year olds
India	<5 year olds, but beginning to be recognized in older children and adults
Indonesia	<1 year olds
Japan	Previously infants, but incidence increasing in older cohorts
New Zealand	School-aged children
Pakistan	<5 years
Philippines	Infants
Singapore	<5 years
South Korea	<1 year olds
Taiwan	<1 year olds
Thailand	<4 year olds
Vietnam	<5 year olds

K Forsyth, Usa Thisyakorn et al, Southeast Asian J Trop Med Public Health 2012; 43: 699-711

Surveillance

Surveillance and Epidemiological Trends in the Western Pacific

- Australia has a national surveillance system that implements active surveillance, and pertussis is a notifiable disease.[1]
  - The notification rate increased from 4.4 per 100,000 in 1991 to 161.6 per 100,000 in 2012.[1]
  - In infants <1 yr, rate was 200–400 (2010), 300–500 (2011) and 200–300 (2012).
- In the Western Pacific region as a whole, the number of reported cases increased from 25,282 in 2000 to 43,213 in 2012.[2]
- In China, pertussis is a reportable disease but surveillance is passive and variable.[1]
- In Japan, pertussis incidence has increased since 2008 corresponding to an outbreak that lasted until 2011.[3,4]
  - Adolescent and adult cases accounted for 40–52% of all cases; however, increased disease burden also observed in primary and junior high school aged children.

1 Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18. 2. World Health Organization (WHO). Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/SEAR/en/index.html. 3. National Institute of Infectious Diseases. *Infectious Agents Surveillance Report.* 2012;12:321–2. 4. Miyaji Y, et al. *PLoS One.* 2013;8:e77165

Surveillance and Epidemiological Trends in Southeast Asia

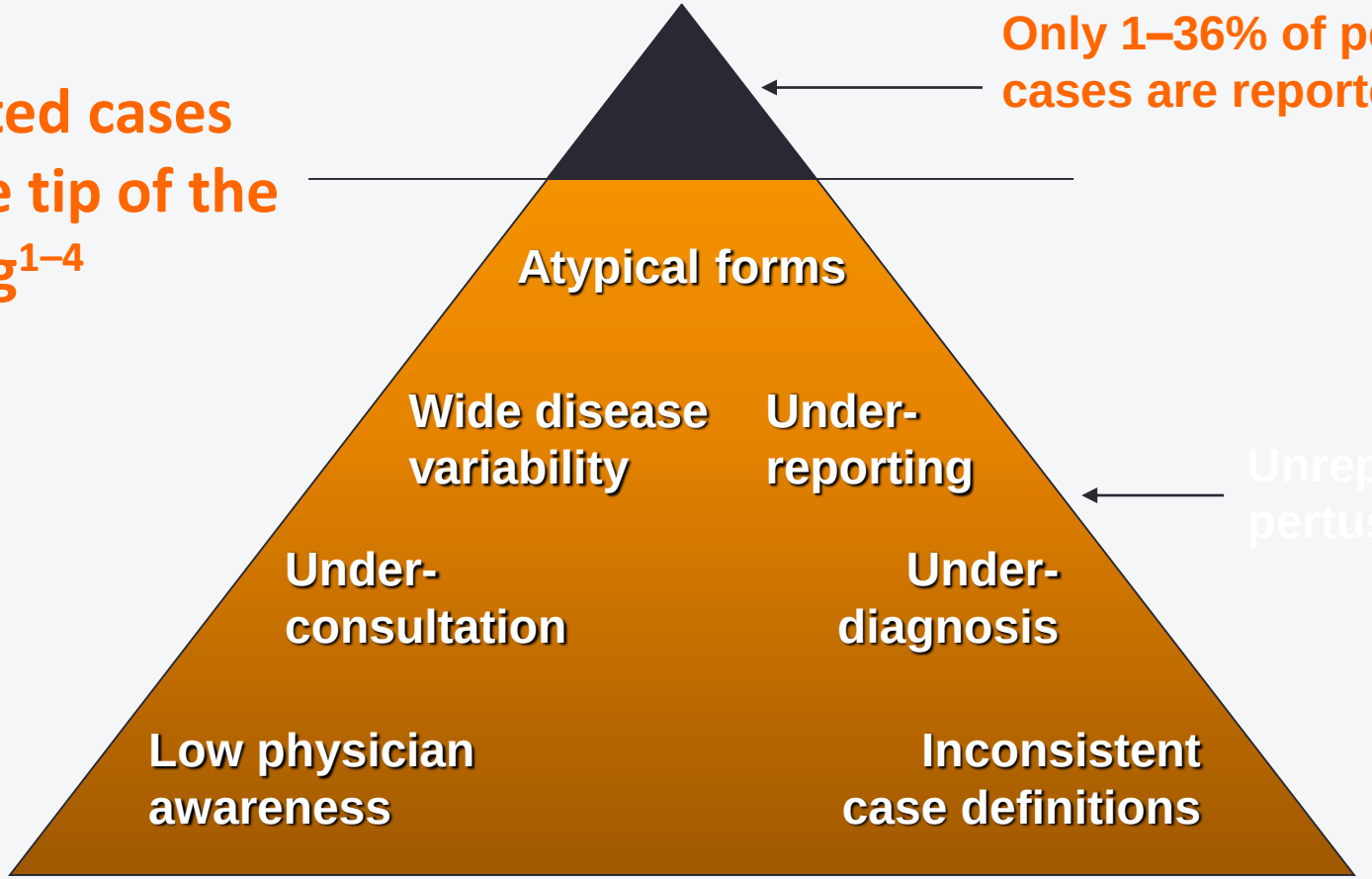
- Surveillance in the region is effected by a lack of diagnostic laboratories and adequate healthcare infrastructure.
- Since 2000, the number of reported cases has remained stable at around 40,000 cases except in 2009 when it increased to 63,798.[1]
  - Child mortality rates from pertussis have fluctuated from 4% of child deaths in 2008 to <1% in 2010.
- South Korea has a national passive surveillance system.[2]
  - Reported pertussis cases have increased since 2000, especially in adolescents ≥15 years old and adults who account for 29% of cases.
  - This shift in incidence to an older age group is attributed to waning vaccine or natural immunity.
- In 2007, an outbreak occurred in India affecting children ≤5 years old; none were vaccinated.[3]

1. World Health Organization (WHO). Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/SEAR/en/index.html. 2. Choe YJ, et al. *Int J Infect Dis.* 2012;16:e850–e854. 3. Takum T, et al. *Indian Pediatr.* 2009;46:1017–20.

Under-Reporting of Pertussis

Reported cases are the tip of the iceberg[1–4]

Only 1–36% of pertussis cases are reported[5-6]



1. Forsyth KD, et al. *Vaccine.* 2007;25:2634–42. 2. Riffelmann M, et al. *J Clin Microbiol.* 2005;43:4925–9. 3. Crowcroft NS, et al. *Lancet.* 2006;367:1926–36. 4. Tan T. *Pediatr Infect Dis J.* 2005;24(5 Suppl):S35–S38. 5. Miller E, et al. *Commun Dis Public Health.* 2000;3:132–4. 6. Strebel P, et al. *J Infect Dis.* 2001;183:1353–9.

Problems with Under-reporting and Surveillance Systems

- Although a mandatory notifiable disease in most countries, pertussis is likely to be significantly under-reported (especially in adolescents and adults).[1,2]
- Passive surveillance statistics underestimate incidence by 10- to 1000-fold, depending on quality of surveillance system.[3–5]
- Under-reporting in some countries may be exacerbated by weak healthcare infrastructure, lack of diagnostic tools, and challenges of poverty.[6,7]
- Although both WHO and CDC have established pertussis case definitions,[8,9] these are difficult to apply.[2,10]

1. Pertussis surveillance–United States, 1984 and 1985. *MMWR Morb Mortal Wkly Rep.* 1987;36:168–71. 2. Gabutti G, Rota MC. *Int J Environ Res Public Health.* 2012;9:4626–38. 3. Cherry JD. *Pediatrics.* 2005;115:1422–7. 4. Celentano LP, et al. *Pediatr Infect Dis J.* 2005;24:761–5. 5. European Centre for Disease Prevention and Control (ECDC). Available at: http://www.ecdc.europa.eu/en/publications/surveillance_reports/Pages/index.aspx. Accessed February 3, 2014. 6. Broutin H, et al. *Proc Biol Sci.* 2010;277:3239–45. 7. Nsubuga P, et al. In: Jamison DT, Breman JG, Measham AR, et al., eds. Disease Control Priorities in Developing Countries. 2nd ed. 2006:997–1015. 8. Centers for Disease Control and Prevention (CDC). Available at: http://www.cdc.gov/pertussis/surv-reporting.html. Accessed December 4, 2013. 9. World Health Organization (WHO). Available at: http://www.who.int/immunization_monitoring/diseases/pertussis_surveillance/en/. Accessed December 4, 2013. 10. Cherry JD, et al. *Clin Infect Dis.* 2012;54:1756–64.

Epidemiology & Surveillance Conclusions

- No clear picture currently of worldwide epidemiology of pertussis.[1]
  - Global epidemiology is complex and differs from country to country.
- Although it is evident that infants bear the greatest disease burden, poor reporting and dubious statistics from many countries confound efforts to discern patterns.[1]
- Key findings:
  - Despite routine and worldwide vaccination, pertussis remains a serious health concern in all age groups.[1]
  - In many regions, there has been an increase in cases in older children, adolescents, and adults.[1,2]
  - Although not surprising to see an increase in regions with lower DTP3 coverage, the findings in Europe and the US where vaccine coverage is high suggests other factors are responsible for the increase in pertussis cases.[1]
    - Waning vaccine immunity?

1. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18. 2. Schellekens J, et al. *Pediatr Infect Dis J.* 2005;24:S19–S24.

Epidemiology & Surveillance Conclusions

- Key findings (cont.)
  - Waning immunity is a problem in countries using acellular vaccines.[1–3]
  - The situation in countries still using whole cell vaccines is less clear.[1,2]
  - It is likely both acellular and whole cell vaccines give impermanent immunity.
- The situation today:
  - Pertussis disease is widespread, even in countries with high vaccine coverage.[1,4]
  - Pertussis vaccines, and especially acellular vaccines, are currently imperfect in that they do not provide prolonged immunity.
  - *B. pertussis* is likely evolving to escape the protection offered by natural immunity and vaccination.

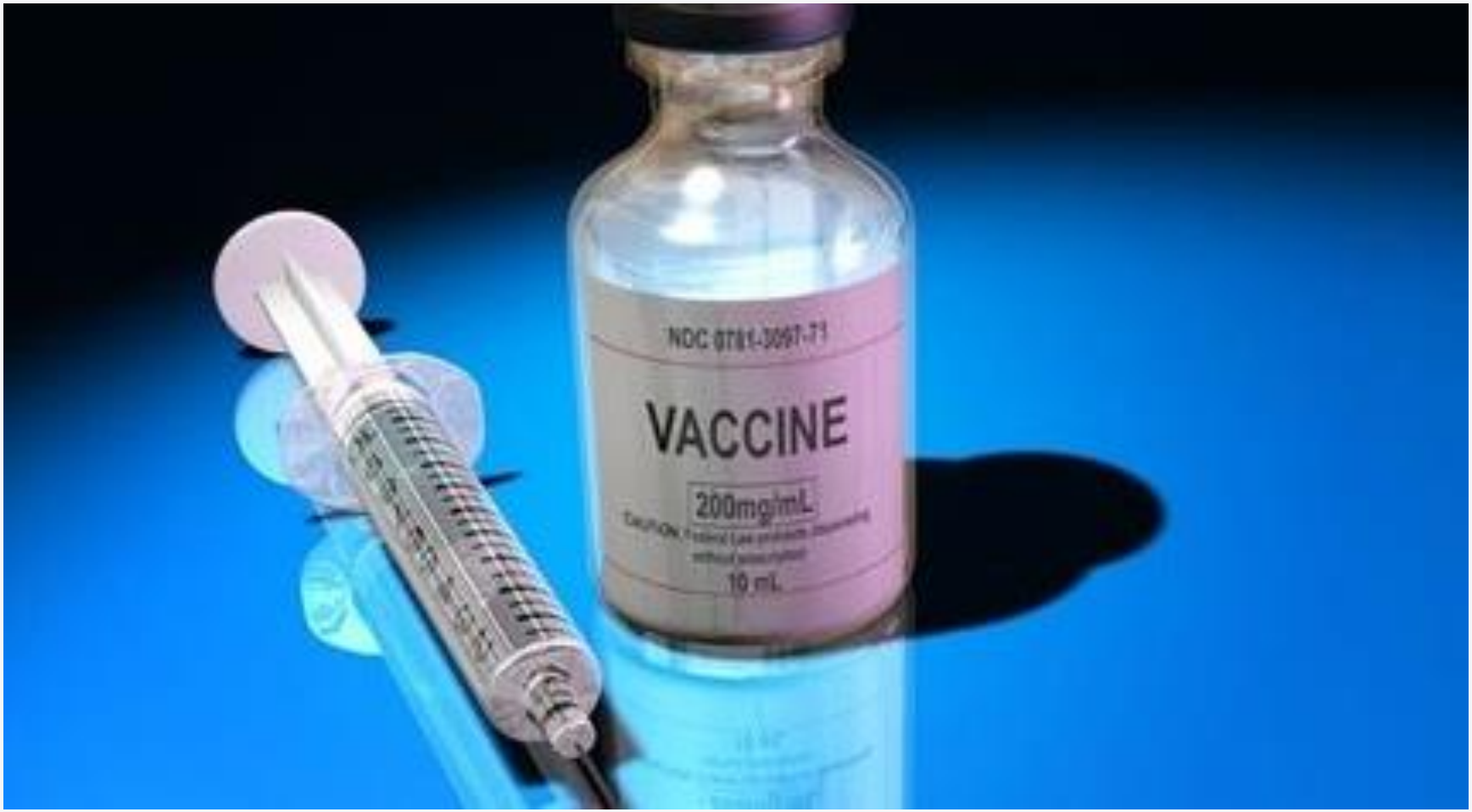
1Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18 2. Simondon F, et al. *Vaccine.* 1997;15:1606–12. 3. Witt MA, et al. *Clin Infect Dis.* 2013;56:1248–54. 4. World Health Organization (WHO). Available at: http://www.who.int/immunization/monitoring_surveillance/data/gs_gloprofile.pdf.

Epidemiology & Surveillance Conclusions

- What needs to be done:[1,2]
  - Improvement in infant primary- and booster-vaccine coverage rates are needed in many countries.
  - Strategies to decrease the reservoir for disease transmission to infants are needed, such as booster vaccination of adolescents and adults, immunizing healthcare workers and maternal immunization.
  - Additional studies are needed to evaluate:
    - The duration of immunity of current vaccines in order to optimize vaccination schedules.
    - The impact that antigenic and genotypic changes in circulating *B. pertussis* organisms are having on pertussis epidemiology.
  - More systematic and standardized epidemiological evaluation of pertussis is needed throughout the world to better elucidate the problem, compare between countries, and to find possible solutions.
  - Improvement and implementation of surveillance systems, particularly in Africa and Asia, are needed to provide accurate epidemiological data.

1 Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18. 2. Presented at Global Pertussis Initiative meeting, Dublin, 2014.

Vaccines

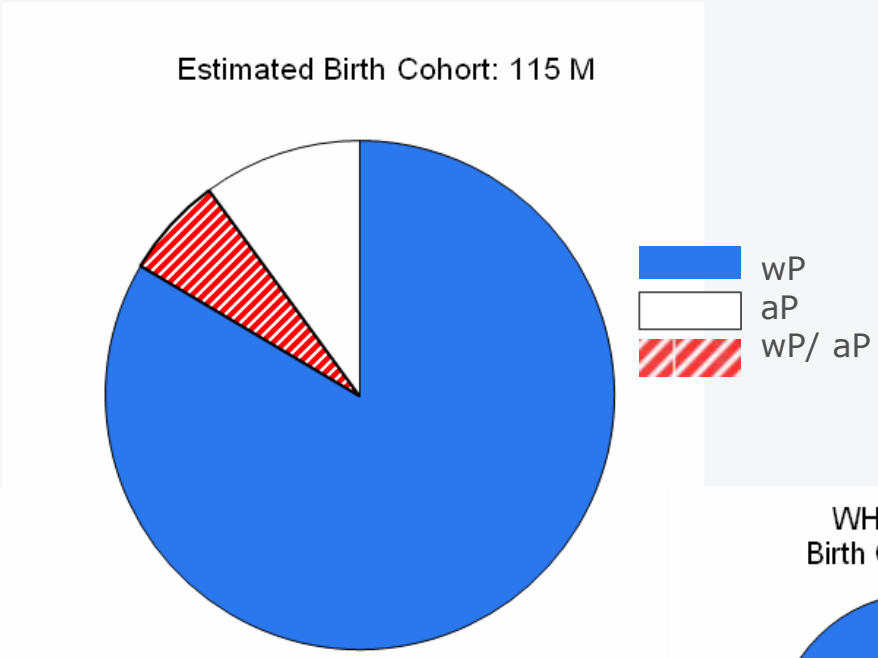


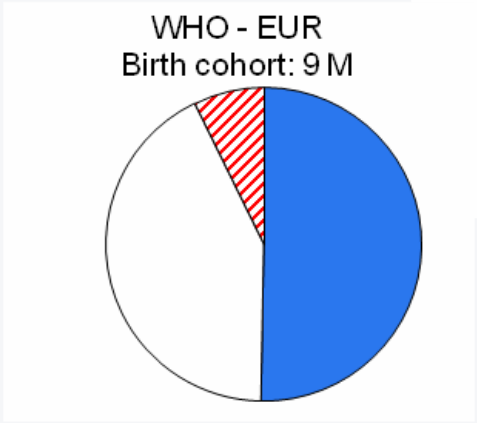
Pertussis vaccination schedules in Asia-Pacific.

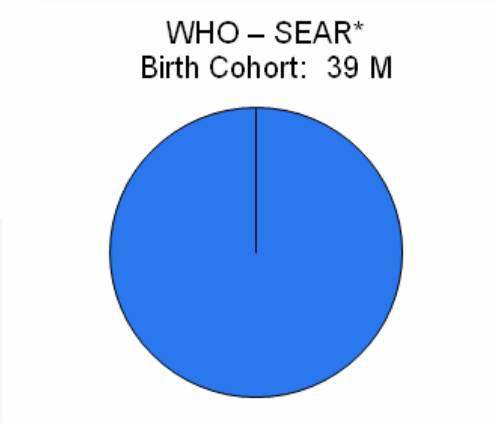
	Primary series	Booster dose		Adolescent/ adult immunization
		2nd Year of life	Pre-school	
Australia[1]	2, 4 and 6 months	-	4 years	15-17 years
China[2]	3, 4 and 5 months	18 months	-	-
India[3]	Public: 6, 10 and 14 weeks Private: 6, 10 and 14 weeks	Public: 16-24 months Private: 18 months	Private: 5 years	Private: 10 years
Indonesia[4]	2, 4 and 6 months	18-24 months	5 years	-
Japan[5]	3, 4-5 and 6-7 months[a]	18 months	-	-
New Zealand[6]	6 weeks, 3 and 5 months	-	4 years	11 years
Pakistan[7]	Public: 6, 10 and 14 weeks Private: 6, 10 and 14 weeks	Private: 18 months	Private: 4-5 years	Private: 10 years
Philippines[2]	Public: 6, 10 and 14 weeks Private: 6, 10 and 14 weeks or 2, 4 and 6 months	Private: 15 months	Private: 4-6 years	Private: 10 years
Singapore[8]	3, 4 and 5 months	18 months	-	10-11 years[b]
South Korea[2]	2, 4 and 6 months	15-18 months	4-6 years	Private: Available
Taiwan[9]	2, 4 and 6 months	18 months	6 years	-
Thailand[2]	2, 4 and 6 months	18-24 months	4-5 years	Private: Available
Vietnam[2]	2, 3 and 4 months	18 months (as of June 2011)	-	-

[a]The primary series can be started as late as 8 months of age in Japan.
[b]In Singapore, the booster dose administered to children 10 to 11 years of age can be either Td or Tdap.
[1]http://www.health.gov.au/internet/immunise/publishing.nsf/Content/E875BA5436C6DF9BCA2575BD001C80BF/$File/nip-schedule-card-july07.pdf
[2]http://apps.who.int/immunization_monitoring/en/globalsummary/ScheduleSelect.cfm
[3]http://whoindia.org/en/Section6/Section284/Section286_508.htm
[4]http://www.idai.or.id/
[5]http://idsc.nih.go.jp/vaccine/dschedule/Imm11EN.pdf
[6]http://www.moh.govt.nz/moh.nsf/pagesmh/7890/$File/natl-immunisation-sched-21mar-11.pdf
[7]http://www.pildat.org/publications/publication/publichealth/Immunizationinpakistan.pdf
[8]http://www.hpb.gov.sg/studenthealth/article.aspx?id=630
[9]http://www.cdc.gov.tw/public/Data/031517593171.pdf

Current worldwide use of wP and aP vaccines







DTwPHBV-Hib vaccines are the cornerstone of Global Immunization programs

Source: WHO/UNICEF Joint Reporting Form (2010); 2008 population/birth rates NationMaster.com; WHO/UNICEF coverage estimates 2014 revision, July 2015, * South East Asian Region. Adapted from Jan Poolman

Pertussis vaccine availability and coverage in Asia-Pacific.

Country	Pertussis vaccines available	Vaccine trade name [number of pertussis components], manufacturer	DTP3 coverage
Australia[a]	DTaP, DTaP+IPV, DTaP+HepB+IPV, DTaP+HepB+Hib+IPV, Tdap, Tdap+IPV	ADACEL [5], Sanofi Pasteur; ADACEL-Polio [5], Sanofi Pasteur; BOOSTRIX [3], GSK; BOOSTRIX-IPV [3], GSK; INFANRIX hexa [3], GSK; INFANRIX-IPV [3], GSK; INFANRIX penta [3], GSK	92%
China[a]	DTwP, DTaP, DTaP+Hib+IPV	BOOSTRIX [3], GSK; INFANRIX [3], GSK; INFANRIX-HiB [3], GSK; PENTAXIM [2], Sanofi Pasteur **Local production** China National Biotec Group DTaP [2]; Wuhan Institute of Biological Products DTaP [2]; Chengdu Institute of Biological Products (wP); Shanghai Institute of Biological Products (wP); Wuhan Institute of Biological Products, (wP)	97%
India[a]	DTwP, DTwP+HepB, DTwP+Hib, DTwP+Hib+HepB, DTaP (private sector), DTaP+Hib+IPV (private sector)	ADACEL [5], Sanofi Pasteur; BOOSTRIX [3], GSK; EASY FOUR (wP), Chiron Panacea; EASY FIVE (wP), Chiron Panacea; INFANRIX [3] GSK; PENTAXIM [2], Sanofi Pasteur; TetrACT-Hib (wP), Sanofi Pasteur; TRIPACEL [5], Sanofi Pasteur **Local production** Bharat Biotech: COMVAC4-HB (wP), COMVAC5 (wP) Serum Institute of India: Q-VAC (wP), PENTAVAC (wP), QUADROVAX (wP), TRIPLE (wP)	66%
Indonesia[a]	DTwP+HepB, DTwP, DTaP (private sector), DTaP+Hib (private sector), DTaP+Hib+IPV (private sector), DTwP+Hib (private sector)	INFANRIX [3], GSK; INFANRIX-HiB [3], GSK; PEDIACEL [5], Sanofi Pasteur; TetrACT-Hib (wP), Sanofi Pasteur; TRIPACEL [5], Sanofi Pasteur **Local production** Bio Farma (wP)	82%

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Japan[a]	DTaP	**Local production** Biken [2], Denka [4], Kaketsuken [2], Kitasato [4], Takeda [4]	98%
New Zealand[a]	DTaP+HepB+Hib+IPV, Tdap	BOOSTRIX [3], GSK; INFANRIX hexa [3], GSK	92%
Pakistan[a]	DTwP+HepB+Hib, DTaP+Hib+IPV (private sector), DTaP+HepB+Hib+IPV (private sector)	INFANRIX hexa [3], GSK; PENTAXIM [2], Sanofi Pasteur; QUINVAXIM (wP), Novartis	85%
Philippines[a]	DTwP, DTaP (private sector), Tdap (private sector)	ADACEL [5], Sanofi-Pasteur; BOOSTRIX [3], GSK; INFANRIX hexa [3], GSK; INFANRIX penta [3], GSK; PENTAct-Hib [2], Sanofi Pasteur; PENTAXIM [2], Sanofi Pasteur; QUINVAXEM (wP), Novartis; TETRAXIM [2], Sanofi Pasteur	87%
Singapore[a]	DTaP, DTaP+IPV, DTaP+HepB+Hib+IPV, DTaP+Hib, DTaP+IPV+Hib, Tdap	ADACEL [5], Sanofi Pasteur; BOOSTRIX [3], GSK; BOOSTRIX-IPV [3], GSK; INFANRIX [3], GSK; INFANRIX hexa [3], GSK; INFANRIX-Hib [3], GSK; INFANRIX-IPV-Hib [3], GSK; PEDIACEL [5], Sanofi Pasteur; PENTAXIM [2], Sanofi Pasteur	97%

K Forsyth, Usa Thisyakorn et al, Southeast Asian J Trop Med Public Health 2012; 43: 699-711

Country	Pertussis vaccines available	Vaccine trade name (number of pertussis components), Manufacturer	DTP3 coverage
South Korea[a]	DTaP, Tdap (private sector), Tdap+IPV (private sector)	ADACEL [5], Sanofi Pasteur; BOOSTRIX [3], GSK; INFANRIX [3], GSK; KINRIX [3], GSK; TETRAXIM [2], Sanofi Pasteur **Local production** Biken DTaP [2], Boryeong; Kaketsuken DTaP [2], LG Life Sciences	94%
Taiwan[b]	DTaP+IPV+Hib, Tdap	ADACEL [5], Sanofi Pasteur; BOOSTRIX [3], GSK; PEDIACEL [5], Sanofi Pasteur	96%
Thailand[a]	DTwP, DTaP (private sector), DTaP+IPV+Hib (private sector), DTaP+IPV+Hib+HepB (private sector)	ADACEL [5], Sanofi Pasteur; ADACEL-Polio [5], Sanofi Pasteur; BOOSTRIX [3], GSK; BOOSTRIX-IPV [3], GSK; D.T.COQ/DTP (wP), Sanofi Pasteur; INFANRIX hexa [3], GSK; INFANRIX-IPV [3], GSK; INFANRIX [3]-IPV+Hib, GSK; PEDIACEL [5], Sanofi Pasteur; PENTAXIM [2], Sanofi Pasteur; TETRAXIM [2], Sanofi Pasteur; TRIPACEL [5], Sanofi Pasteur; TRITANRIX HepB (wP), GSK **Regional production** Biofarma Indonesia (wP)	99%
Vietnam[a]	DPwT, DPwT+Hib+HepB, DTaP (private sector), Tdap	ADACEL [5], Sanofi Pasteur; INFANRIX hexa [3], GSK; PENTAXIM [2], Sanofi Pasteur; TETRAXIM [2], Sanofi Pasteur **Regional production** QUINVAXIM (wP), Berna Biotech (Korea) **Local production** IVAC Nha Trang (wP)	96%

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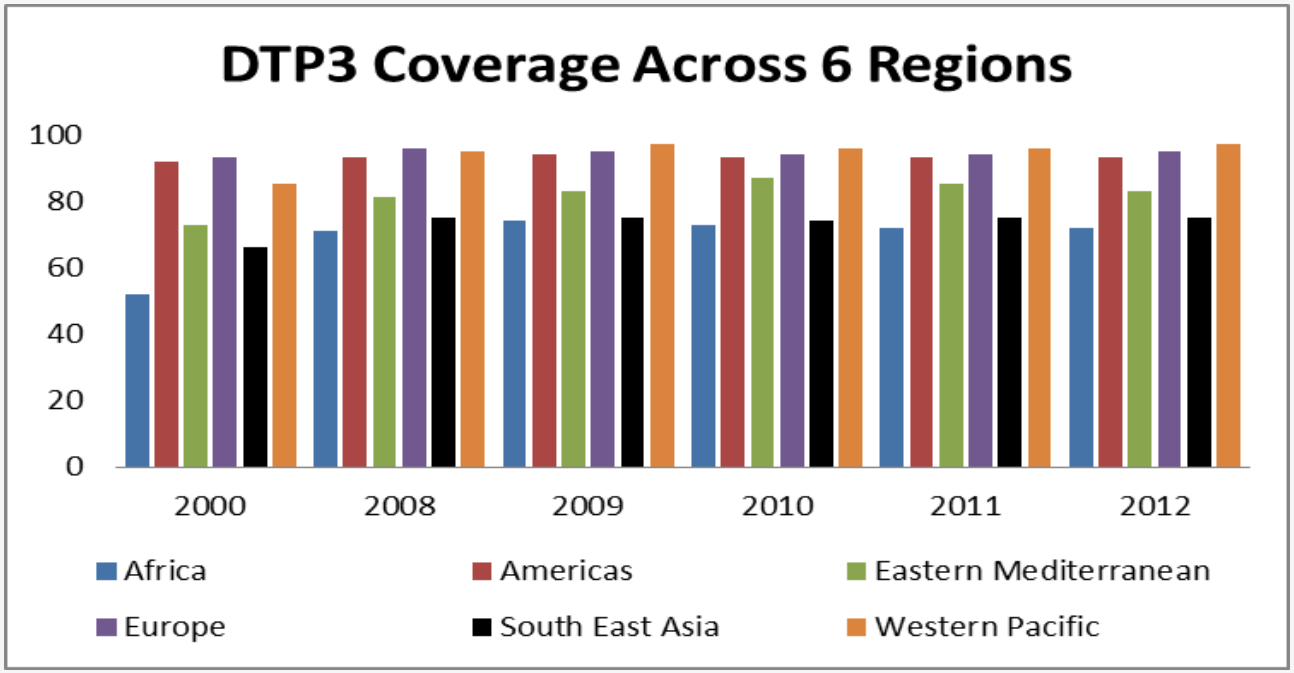
Regional Pertussis Vaccine Coverage

- DTP3 coverage in infants differs according to region



1. Tan T, et al. *Pediatr Infect Dis J.* 2005;24:S10–S18.
2. World Health Organization (WHO). Available at: http://www.who.int/immunization/monitoring_surveillance/data/gs_afrprofile.pdf.
3. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/AMR/en/index.html.
4. WHO. Available at: http://www.who.int/immunization/monitoring_surveillance/data/EMR/en/index.html.
5. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/EUR/en/index.html.
6. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/SEAR/en/index.html.
7. WHO. Available at: http://www.who.int/entity/immunization/monitoring_surveillance/data/WPR/en/index.html.

Are Current Vaccines and Vaccination Strategies the Future of Pertussis Control?

- Although it is accepted that currently-used pertussis vaccines (acP and wcP) are effective in preventing disease, some data suggest duration of protection is shorter with acP.[1,2]
  - caution needs to be applied in interpreting these data due to little or no information regarding efficacy of current wcP vaccines.
- The reasons for this are unclear, but may include a different quality of immune response to acP versus wcP.
  - Priming with acP induces a Th2 cellular response.[3]
  - Optimum protection against *B. pertussis* requires induction of Th1/Th17 cells.[4]
  - T-cell memory is more robust following wcP versus acP vaccination.[5]

acP, acellular pertussis vaccine. wcP, whole cell pertussis vaccine.

1. Simondon F, et al. *Vaccine.* 1997;15:1606–12.
2. Witt MA, et al. *Clin Infect Dis.* 2013;56:1248–54.
3. Ryan M, et al. *Immunology.* 1998;93:1–10.
4. Ross PJ, et al. *PLoS Pathog.* 2013;9:e1003264.
5. Smits K, et al. *Vaccine.* 2013;32:111–18.

Pertussis Diagnosis

Method(s) used to diagnose pertussis in Asia-Pacific.

	Method(s) used to diagnose pertussis
Australia	Clinical and laboratory (culture, RT-PCR, serology)
China	Clinical and laboratory (culture, serology)
India	Clinical only
Indonesia	Clinical only (majority of cases)
Japan	Clinical and laboratory [culture, serology (whole cell bacterial agglutination, not ELISA); RT-PCR available, but not widely used]
New Zealand	Clinical and laboratory (culture; RT-PCR; serology, but ELISA has low specificity)
Pakistan	Clinical only
Philippines	Clinical only
Singapore	Clinical and laboratory (culture, immunofluorescence, RT-PCR)
South Korea	Clinical and laboratory (culture; serology; RT-PCR, but not routinely used)
Taiwan	Clinical and laboratory (culture, RT-PCR, serology)
Thailand	Clinical only (majority of cases)
Vietnam	Clinical only

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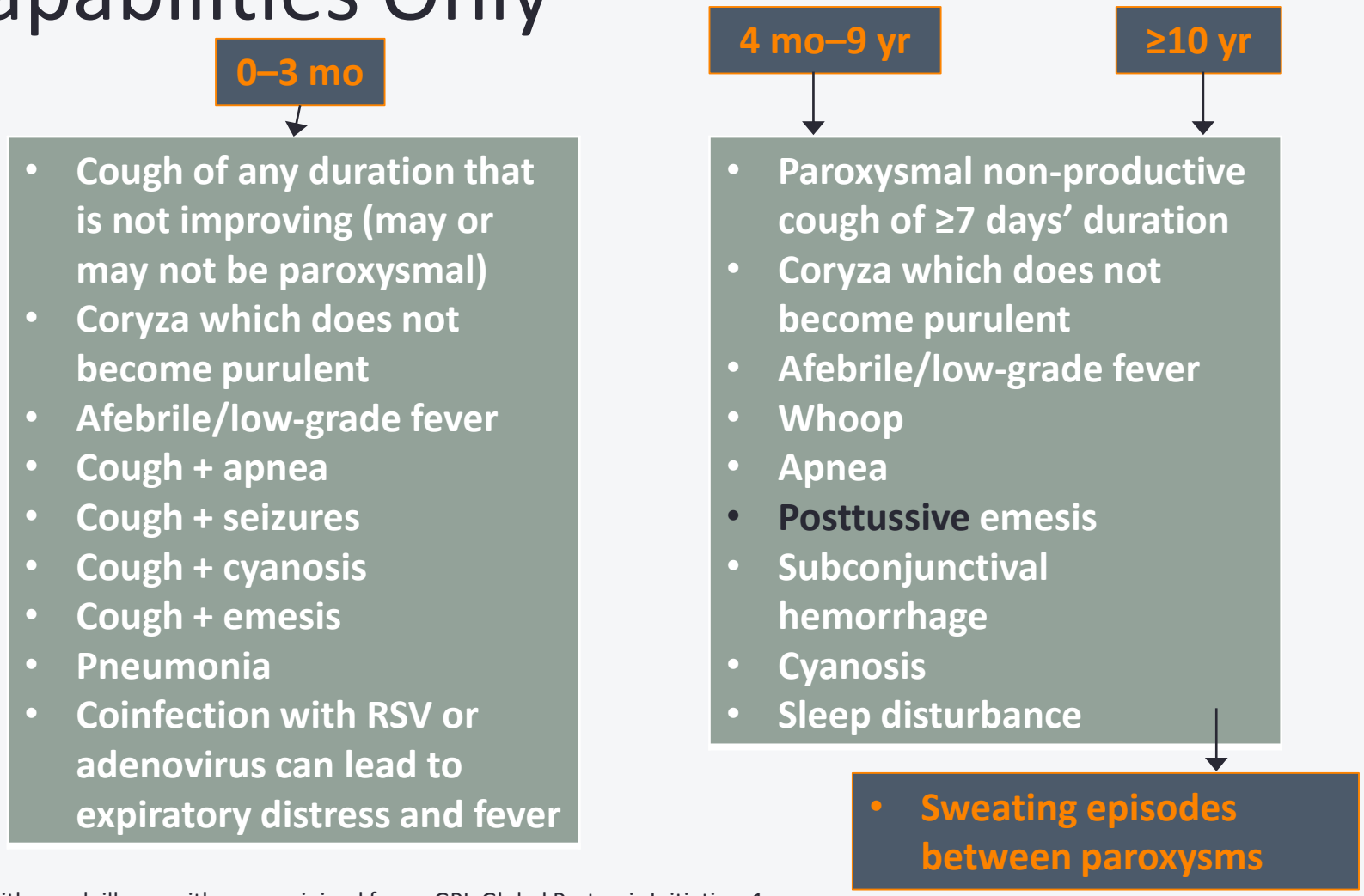
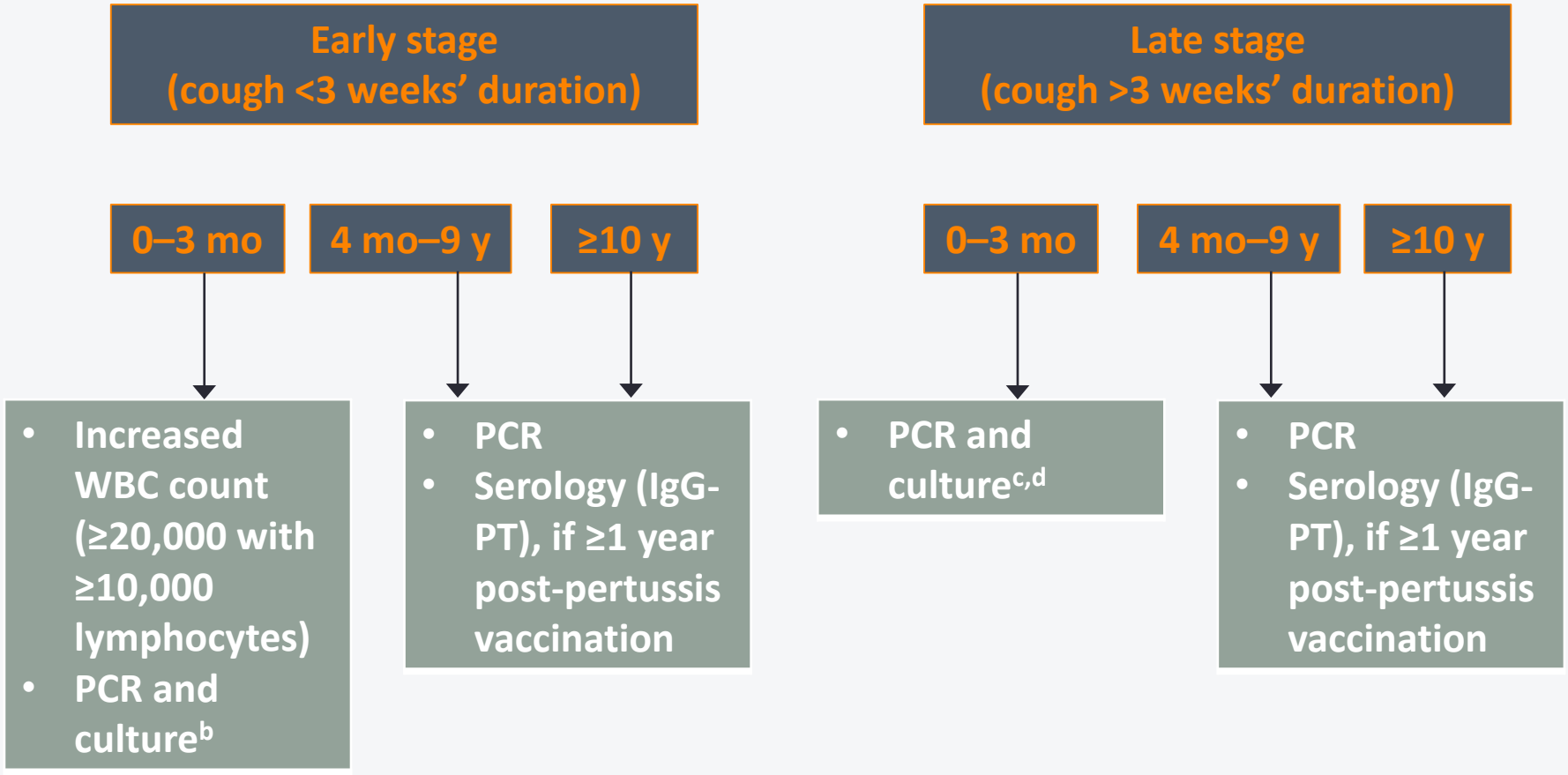
GPI Algorithm for Diagnosis of Pertussis Infection[a]: Clinical Capabilities Only



[a]In a person with cough illness with no or minimal fever. GPI, Global Pertussis Initiative; 1. Cherry JD, et al. *Clin Infect Dis.* 2012;54:1756–64.

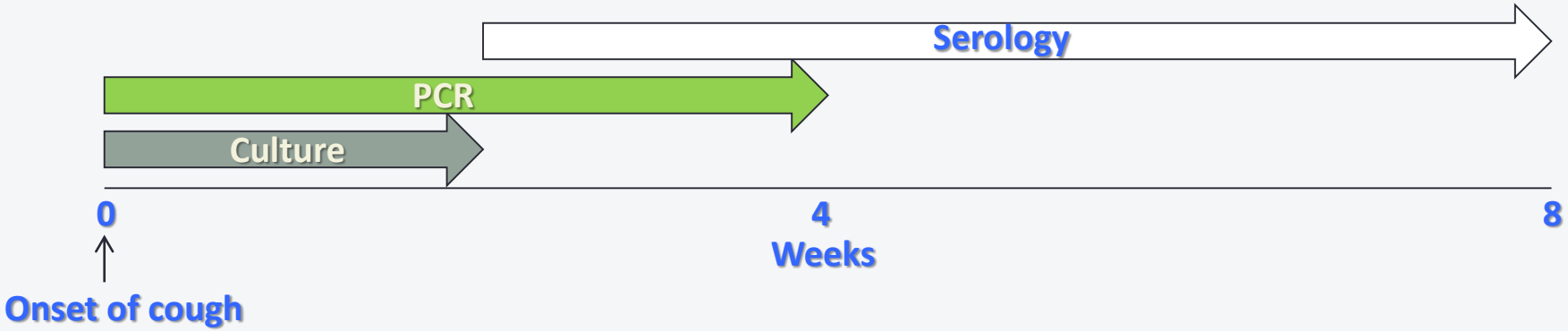
GPI Algorithm for Diagnosis of Pertussis Infection[a]: Access to Laboratory Facilities[1]



[a]In a person with cough illness with no or minimal fever; [b]In resource-limited areas where PCR is not available, samples may be sent to a reference laboratory for culture confirmation; [c]False-negatives possible; [d]Serology not useful in this age cohort.
IgG, immunoglobulin G; PCR, polymerase chain reaction; PT, pertussis toxin; RSV, respiratory syncytial virus; WBC, white blood cell.
1. Cherry JD, et al. *Clin Infect Dis.* 2012;54:1756–64.

Current Pertussis Case Definitions: Summary

- Laboratory confirmation tests include:[1,2]
  - Culture (considered the "gold standard")
  - PCR
  - Serology (generally more useful for diagnosis later in disease)
- The optimal timing for laboratory confirmation tests differs[2]



- However, not all definitions require serology:[1]
  - CDC definition does not include serology
  - WHO definition allows paired serology
  - EU definition allows *B. pertussis*-specific antibody response

CDC, Centers for Disease Control and Prevention; EU, European Union; PCR, polymerase chain reaction; WHO, World Health Organization.

1. Cherry JD, et al. *Clin Infect Dis.* 2012;54:1756–64. 2. CDC Pertussis (Whooping Cough) Diagnosis Confirmation. Available at: http://www.cdc.gov/pertussis/clinical/diagnostic-testing/diagnosis-confirmation.html. Accessed August 21, 2014.

General Comments on Laboratory Diagnosis of Pertussis

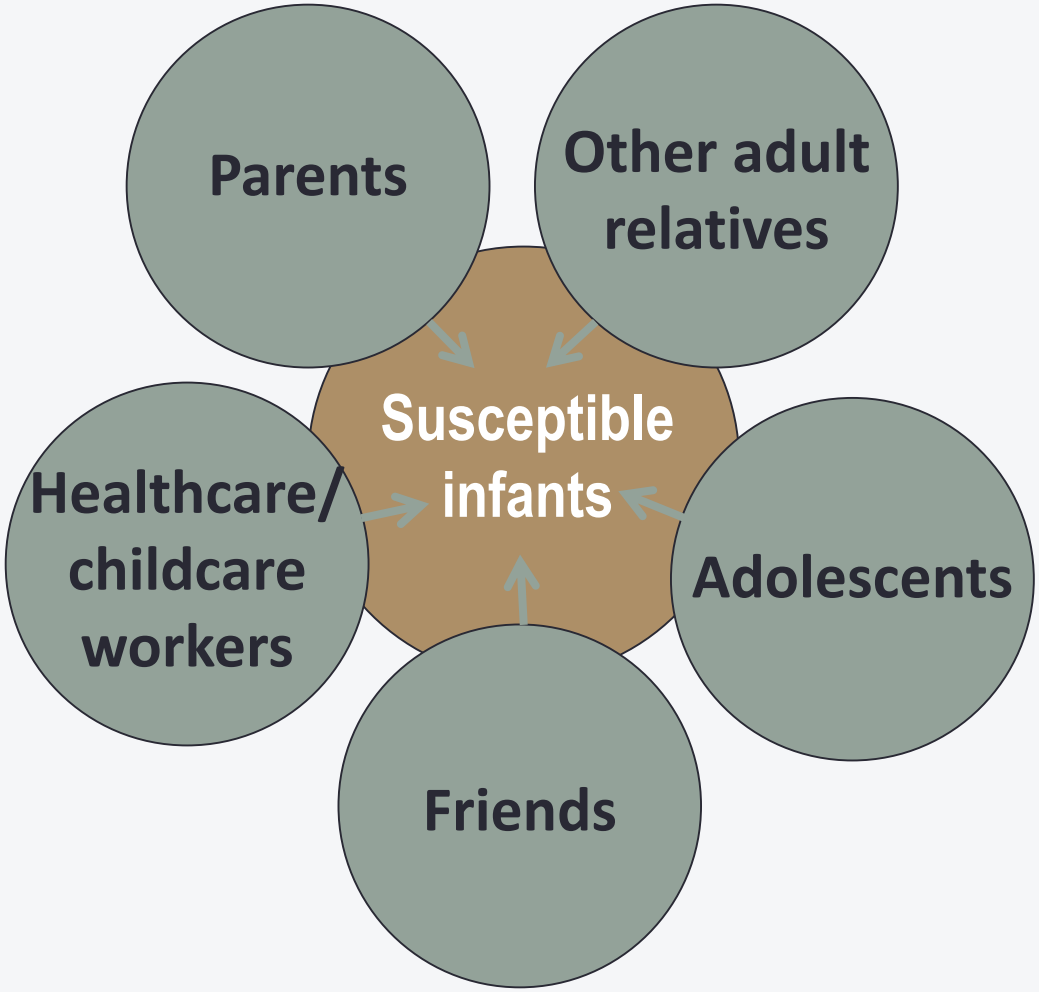
- PCR and culture have the greatest utility in the first 3–4 weeks after onset of illness[1,2]
  - Serology is useful later in the disease[2]
- Serology is inappropriate for diagnosing pertussis in patients <1 year after immunization with an acellular or whole-cell vaccine[1]
- Anti-PT IgG ELISA is preferred to IgA because the IgA response following infection is less common[1]
  - A negative anti-PT IgA test is unreliable for diagnosing pertussis infection.

DFA, direct fluorescent antibody; ELISA, enzyme-linked immunosorbent assay; IgA, immunoglobulin A; IgG, immunoglobulin G; PCR, polymerase chain reaction; PT, pertussis toxin.

1. Cherry JD, et al. *Clin Infect Dis.* 2012;54:1756–64.
2. CDC Pertussis (Whooping Cough) Diagnosis Confirmation. Available at: http://www.cdc.gov/pertussis/clinical/diagnostic-testing/diagnosis-confirmation.html. Accessed August 21, 2014.

Maternal Immunization

Adolescents and Adults: a Major Source of *B. pertussis* Infection for Infants



1. Wendelboe AM, et al. *Pediatr Infect Dis J.* 2007;26:293–9. 2. Forsyth KD, et al. *Clin Infect Dis.* 2004;39:1802–9. 3. Rothstein E, Edwards K. *Pediatr Infect Dis J.* 2005;24:S44–S47. 4. Bisgard KM, et al. *Pediatr Infect Dis J.* 2004;23:985–9. 5. Heininger U, Cherry JD. *Expert Opin Biol Ther.* 2006;6:685–97. 6. Zivna I, et al. *Infect Control Hosp Epidemiol.* 2007;28:708–12.

Young Infants Bear the Greatest Disease Burden

- Infants have the highest risk for pertussis-related complications and death,[1] and the highest rates of disease and hospitalization.[2–4]

Age, months	Incidence/month / 100,000	Hospitalization with respiratory illness	Hospitalization with neurologic illness	Deaths/1000
<1	**12.4**	**0.66**	0.01	**22.36**
1	**18.9**	**0.61**	0.01	**9.54**
2	**15.3**	**0.50**	0.01	**4.49**
3	8.9	0.37	0.01	0.41
4	5.7	0.30	0.01	0.63
5	3.2	0.23	0.01	1.14
6	2.4	0.17	0.01	1.53
7	1.6	0.18	0.01	0.00
8	1.5	0.13	0.01	0.00
9	1.4	0.13	0.01	0.00
10	1.1	0.12	0.01	0.00
11	1.4	0.11	0.01	0.00

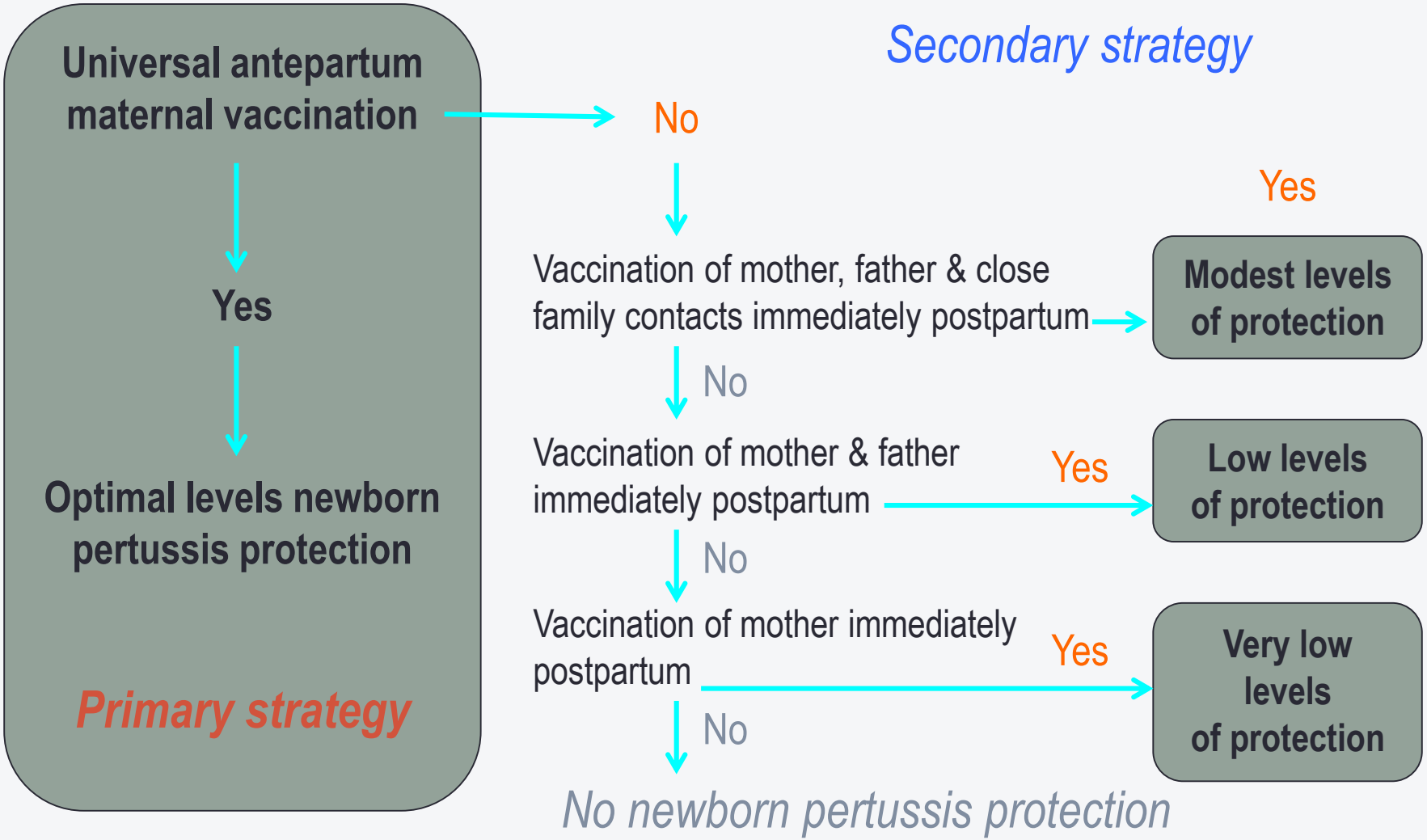
1. Forsyth K et al, Pediatrics. 2015 Jun;135(6):e1475-82 2. Heininger U, et al. *Pediatr Infect Dis J.* 2014;33:147–51. 3. Winter K, et al. *J Pediatr.* 2012;161:1091–6. 4. Terranella A, et al. *Pediatrics.* 2013;131:e1748-e1756.

Maternal Immunization: Rationale

- Maternal immunization during pregnancy has the potential to directly protect infants against pertussis through the passive transfer of maternal antibodies.[1]
- This approach offers an important benefit in that it can protect the very young from birth.
  - Protection provided until the beginning of primary diphtheria, tetanus, and pertussis (DTaP) series.
- Several studies have demonstrated maternal transfer of anti-pertussis antibodies to the fetus following maternal vaccination or natural infection.[2–6]

1. Forsyth K et al, Pediatrics. 2015 Jun;135(6):e1475-82 2. Gall SA, et al. *Am J Obstet Gynecol.* 2011;204:334–5. 3. Leuridan E, et al. *Pediatr Infect Dis J.* 2011;30:608–10. 4. Van Savage J, et al. *J Infect Dis.*1990;161:487–92. 5. Healy CM, et al. *Clin Infect Dis.* 2006;42:1439–42. 6. Munoz FM, et al. *JAMA.* 2014;311:1760–9.

GPI Algorithm to Avoid Newborn and Infant Pertussis Deaths and Severe Disease[1]



1. Forsyth K et al, Pediatrics. 2015 Jun;135(6):e1475-82

Whooping cough vaccination in the third trimester of pregnancy is the first step you can take to provide early protection for your baby against whooping cough.

The second step is to make sure you have your baby vaccinated on time at 6 weeks, 4 months and 6 months of age.

VACCINATE FROM 28

Immunisation Section, SA Health PO Box 6, Rundle Mall SA 5000 Telephone 1300 232 272
sahealth.sa.gov.au/immunisation

References: The Australian Immunisation Handbook 10th Edition Update 2015.
http://immunise.health.gov.au/

If you require this information in an alternative language or format, please contact SA Health via the details provided

Conclusions

- When pertussis is looked for, it is found
- To better inform vaccination approaches at the country level, surveillance is necessary
- Current vaccines are imperfect, but a vast improvement on the pre-vaccine era
- Maternal immunization is an important new development in protection of infants from pertussis
- Adherence to vaccine schedules is a critical public health intervention