Original article

Australian vaccine preventable disease epidemiological review series: pertussis, 2006–2012

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Abstract

Despite pertussis vaccine being available since the 1940s and immunisation programs using combined diphtheria-tetanus-pertussis vaccine since the mid-1950s, pertussis has been the most commonly notified vaccine preventable disease in Australia over the past 20 years. Pertussis notification and hospitalisation data have been available nationally since 1993, and provide different perspectives for understanding epidemiological trends. This report follows on from a previous review of Australian pertussis epidemiology from 1995–2005 and summarises routinely collected notification, hospitalisation and mortality data for 2006–2012. During the latter 7-year period, which incorporated epidemics in all jurisdictions, and in which acellular vaccines (as opposed to whole cell vaccines) were used exclusively, the average annual notification rate was more than 2.8 times that of the previous decade. In contrast, hospitalisation and mortality rates remained similar. The pattern of age-specific notification rates changed substantially, with cases aged 15 years or over representing 93% of total cases in 2006, but only 58% by 2012; the steepest increases were seen in children 2–4 and 6–9 years of age. In South Australia, where acellular vaccines were introduced into the primary schedule 2 years earlier than in other jurisdictions except the Northern Territory, a peak in notifications among those aged 5–9 and 10–12 years was observed earlier. Likely contributors to both the overall increase in notifications and changes in age distribution include increased diagnostic testing and more rapid waning of effectiveness following vaccination with acellular compared with whole cell vaccines, exacerbated by cessation of the 18-month dose in the National Immunisation Program from 2003. *Commun Dis Intell* 2014;38(3):E179–E194.

Keywords: pertussis, disease surveillance, immunisation

Introduction

In Australia, universal childhood immunisation with combined diphtheria-tetanus-pertussis (DTP) vaccine began in 1953 and was continued in the national schedule when it commenced in 1975. Since 1982, the primary schedule has recommended infant doses at 2, 4 and 6 months, but both the number and timing of booster doses and vaccines in use have changed substantially since then. Recent modifications have included the switch for all scheduled doses from the diphtheria-tetanus-whole cell pertussis vaccine (DTPw) to the diphtheria-tetanus-acellular pertussis vaccine (DTPa) in 1999; the change in recommendation for the 5th dose to be administered at 4 years rather than 4 to 5 years of age in 2000; the removal of the 18-month booster in 2003; and the addition in 2004 of the adolescent booster reduced antigen content diphtheria-tetanus-acellular pertussis vaccine dose (dTpa) recommended with varying ages of administration by jurisdiction.[1]

The pertussis immunisation program is well established in Australia and vaccination coverage is high, at 92.2% for 3 DTPa doses in those aged 12 months and 91.7% for 4 DTPa doses in those aged 5 years.[2] Nevertheless, pertussis continues to be the most commonly notified vaccine preventable disease in Australia,[3] with increases in national notification rates over the past 20 years, in different age groups and epidemic cycles. Similar trends have occurred in other developed countries, though typically later than in Australia.[4–7]

Several changes in diagnostic testing are likely to have contributed to the observed increase in pertussis notifications. Firstly, the availability and use of serologic testing in adolescents and adults increased from the early 1990s. Secondly, from 2000, polymerase chain reaction (PCR) became available as a diagnostic test, initially in hospitals and then, with changes in reimbursement arrangements, also in primary care from 2007.[8] Thirdly, the use of PCR in primary care was facilitated by laboratories accepting specimens collected by throat swab, as well as nasopharyngeal aspirate, which particularly facilitated testing of young children. Laboratories are legally mandated to report positive tests for pertussis under state and territory public health legislation. In the case of notifications based on PCR, which are accepted as confirmed cases without supplementary clinical criteria being required, diagnostic testing changes directly contributed to the rise in notifications.

Beyond the influence of changes in diagnostic practice, recent evidence has shown that protection from the acellular vaccine, universally adopted in Australia in 1999 and in South Australia and the Northern Territory from 1997, is not as long-lasting as that from the whole cell vaccine.[9–11] In turn, the shorter duration of immunity from the acellular vaccines has the potential to magnify the impact of changes to the vaccination schedule with subsequent epidemic cycles. This is likely to have occurred among children aged 1–3 years following the removal of the 18-month booster.[12]

This analysis provides a detailed overview of Australian pertussis trends nationally, regionally and by age group from 2006–2012, following a similar review for the period 1995–2005. Trends are considered both in historical context and in the context of recent changes to the National Immunisation Program (NIP).

Methods

Data sources

Notifications

In Australia, pertussis is notifiable in each state and territory; both confirmed and probable pertussis cases are required to be notified. For the period under review, under the Communicable Diseases Network Australia national case definition, a confirmed case required either laboratory confirmation or a combination of laboratory suggestive and clinical evidence.[13] A confirmed case could also consist of clinical and epidemiological evidence. A probable case required clinical evidence only. Laboratory confirmation included isolation of *Bordetella pertussis* or detection by PCR. Laboratory suggestive evidence included serology (single point high titre or seroconversion) or an immunofluorescence assay.[13]

For this report, notification data were obtained from the NNDSS. All state and territory pertussis notifications with a diagnosis date between 1 January 2006 and 31 December 2012 were included. The diagnosis date field is derived from the date of onset, or where not supplied, the earliest recorded date entered for either date of specimen, date of notification, or date when the notification was received. Laboratory diagnostic data were available for all states and territories except Tasmania; limited data were available for South Australia. For all other jurisdictions, data completeness ranged from 86.3% (Victoria) to 99.3% (Australian Capital Territory). For the purpose of this review, where multiple diagnostic methods were recorded in the dataset, the case was classified as having been diagnosed by the most sensitive method.[14] Typically, this was PCR.

As part of this review, an ecological analysis of vaccine cohorts based on individual jurisdiction of birth was conducted. This analysis involved South Australia and New South Wales as representing the 2 differing time periods when DTPa was adopted by states and territories. South Australia and the Northern Territory introduced the acellular vaccine in 1997; the other states and territories did so in 1999. For each of these 2 jurisdictions, further sub-grouping was performed based on birth cohort and subsequent eligibility for different vaccine types: whole cell vaccine for all doses; whole cell vaccine for the primary series; or acellular vaccine for all doses. Rates over time for children aged 5–9 and 10–12 years were then calculated for these groups.

This report forms an extension of a previous analysis that reviewed pertussis trends from 1995–2005. Data from the previous analysis have been referred to and incorporated into several graphs in order to provide broader context.[3]

Hospitalisation and mortality data

Hospitalisation data were obtained from the Australian Institute of Health and Welfare National Hospital Morbidity Database, which compiles administrative, demographic and clinical information about patients admitted to public and private hospitals. For this report, all hospital admissions between 1 January 2006 and 31 December 2010 were included. Eligible hospital admissions were extracted based on the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM), code A37 (whooping cough), or a subcode, listed as the principal or other diagnosis.

Mortality data were obtained from the NNDSS data field, which recorded whether the notified case had died from pertussis. This data field has been reliable since 2000.[15]

Population estimates

National, jurisdictional and age-specific mid-year estimated resident population data were obtained from the Australian Bureau of Statistics (ABS).[16]

Data analysis

Annual notification numbers and diagnostic test data were reviewed nationally, regionally, and by age group for the time period 2006–2012. National, regional and age group-specific rates were calculated using ABS population data. Similarly, hospitalisations were reviewed for 2006–2010 with national, regional and age group-specific rates calculated. Medians were used to summarise length of stay data for hospitalised cases. Mortality data were reviewed nationally by age group for the period of 2006–2012.

Analysis was conducted using Stata 12 and Excel 2010.

Ethical approval was not required for this review as de-identified population based data were collected and summarised for routine public health surveillance only.

Results

Secular trends

From 2006 to 2012, 156,200 notifications of pertussis were recorded by the NNDSS (Table 1). The average annual national rate for this 7-year period was 103.1 per 100,000 population, varying from a low of 23.1 in 2007 to a high of 173.3 per 100,000 in 2011. Though national notification rates initially fell during the period 2006–2007 from those in 2005, rates steadily increased from 2008 through 2011. This pattern of decreasing notifications followed by a consistently upward trend with varying peak years was largely repeated across all jurisdictions but in different time frames. In 2006 and 2007, notification rates for those less than 15 years of age were lower than those aged 15 years or over, but this pattern reversed in 2008–2012 such that notification rates in those less than 15 years of age became more than double those in persons aged 15 years or over (Figure 1).

Figure 1: Incidence rates and incidence rate ratios for pertussis comparing children aged less than 15 years with the remainder of the population, Australia, 1995–2012, by year of onset

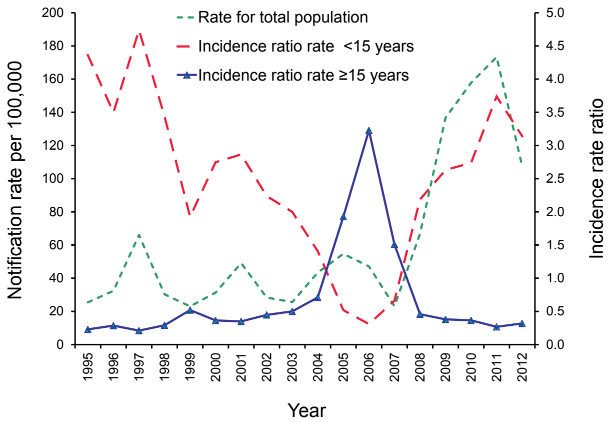


Table 1: Notification and hospitalisation rates per 100,000 population for pertussis, Australia, 2006 to 2012,* by state or territory

Year	Data source	State or territory								
		ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aus.
2006	Notifications	77.2	54.0	46.1	53.1	139.0	8.4	20.8	12.9	47.2
	Hospitalisations	0.3	3.2	4.3	2.6	4.9	0.4	1.0	0.8	2.3
2007	Notifications	28.4	23.5	12.6	36.7	23.9	5.1	20.2	6.3	23.1
	Hospitalisations	0.6	1.5	1.4	2.1	1.4	0.2	1.2	0.3	1.3
2008	Notifications	41.7	108.0	216.4†	53.0	92.5	39.9	32.7	21.3	66.8
	Hospitalisations	2.0	5.6	14.0	2.7	3.9	2.2	2.0	1.9	3.6
2009	Notifications	99.2	176.1	94.8	142.4	332.6	122.8	70.3	34.7	136.8
	Hospitalisations	4.0	9.4	7.9	6.9	14.2	5.8	3.8	2.4	7.0
2010	Notifications	197.6	130.4	142.8	185.8	453.6†	55.3	29.5	63.2	157.7
	Hospitalisations	3.0	4.6	10.4	6.8	17.4	2.8	6.0	3.3	6.2
2011	Notifications	225.4†	182.3†	163.4	200.9†	143.4	68.9	156.3†	169.6†	173.3†
2012	Notifications	117.7	80.7	128.0	168.3	54.4	246.5†	79.8	142.8	107.6
Total number notifications		2,826	53,573	1,820	36,926	20,039	2,777	27,795	10,444	156,200
Total number hospitalisations		35	1,700	85	911	676	57	750	194	4,408
Average rate notifications		114.3	108.6	116.2	122.0	177.8	79.0	74.0	67.0	103.1
Average rate hospitalisations		2.0	4.9	7.7	4.3	8.5	2.3	2.8	1.8	4.1

* Hospitalisation data available through 2010.

† Peak incidence rates for each state or territory for the period 2006–2012.

For the period 2006–2010, 4,408 hospitalisations were coded as pertussis equating to 4.7% of the number of notifications over this period and skewed significantly towards the lowest end of the age spectrum. Nevertheless, secular trends in hospitalisation rates generally reflected those of notification rates (Table 1). Over this period, 73.8% (n = 3,255) of total ICD-10-AM coded pertussis hospitalisations had a whooping cough code as the principal diagnosis, decreasing with age from 89.2% for those aged less than 6 months, to 50.0% for those aged 65 years or over. During 2006–2010, there was little difference between the average percentage of all age primary diagnoses coded as *B. pertussis* (49.0%) compared with those coded as whooping cough unspecified. However, for those aged less than 6 months, the percentage of diagnoses coded as *B. pertussis* (57.6%) increased, in 2010 becoming higher than the proportion coded as whooping cough unspecified for the first time in the 5-year period since 2006.

State and territory variations

Together, New South Wales (n = 53,573) and Queensland (n = 36,926) contributed 57.9% of all national notifications during the 7-year period 2006–2012. South Australia had the highest annual notification rate at 453.6 per 100,000 (2010) as well as the highest average jurisdictional rate for the 7-year period at 177.8 per 100,000 (Table 1). All states and territories, however, reported peak average annual notification rates, which ranged from 1.8 to 4.6 times higher than those for the same jurisdictions during the previous decade.[3] With respect to timing, the Northern Territory and Tasmania had earlier epidemic peaks occurring in 2008–2009; most other states and territories peaked later between 2010–2011, with Western Australia the last to reach epidemic levels in 2011–2012 (Table 1, Figure 2, Figure 3). By 2012, notification rates had decreased in most jurisdictions, with the notable exception of Tasmania where rates had climbed. Jurisdictional hospitalisation rates from 2006–2010 demonstrated that hospitalisation patterns closely followed notification patterns, but on a reduced scale (Figure 3).

Age distribution

During the 7-year period, the average notification rate for those aged less than 15 years was 205.6 per 100,000 (range: 16.4–434.3) compared with 79.0 per 100,000 (range: 24.8–118.5) for those aged 15 years or over (Figure 1). For infants and children aged less than 15 years, notification rates increased steeply from 2007, while rates for those aged 15 years or over were lower, with a less dramatic increase through 2010. By 2012, rates for both of these broad age groups were decreasing. The proportion of total notified cases aged 15 years or over was 93.0% in 2006, decreasing to 57.8% by 2012.

During the 2008–2011 epidemic period, the highest notification rates were seen in infants aged 0–5 months of age. Among children aged 6 months to 4 years, the highest notification rates were seen in the 3rd year, peaking at 411.0 per 100,000 in 2011 (Figure 4). However, the highest rates among all age groups were in children aged 5–9 years which reached 426.5 per 100,000 in 2010 and 556.2 in 2011. From 2008, rates among children in the 5–9 year age group increased progressively for each single year age group, peaking at 627.9 and 651.0 per 100,000 for those aged 7 and 8 years respectively. Children aged 10–14 years also had relatively high average notification rates, peaking in 2011 at 397.0 per 100,000. Within this age group, during 2006–2012, rates were more than 1.8 times higher for those aged 10–12 years compared with those aged 13–14 years, peaking at 659.5 per 100,000 in 2011 for those aged 10 years. Among older age groups, rates were considerably lower, averaging 62.1 and 47.2 per 100,000 for those aged 15–19 and 20–29 years respectively. For those aged 30–64 years, rates were highest for those aged 40–44 years, averaging 99.8 per 100,000. For those aged 65 years or over, the average rate was 86.0 per 100,000.

Age trends varied across states and territories, with the lowest notification rates among those 15 years of age or over (Appendix). In the Australian Capital Territory and New South Wales, the highest notification rates were in children aged 5–9 years during 2010–2011. In the Northern Territory, Queensland, South Australia, Tasmania, Victoria and Western Australia the highest notification rates were seen among infants less than 6 months of age in varying individual years between 2008 and 2012. The highest age-specific jurisdictional notification rates were in South Australia, where rates of 1,119.3 per 100,000 were recorded for infants aged less than 6 months and 1,117.4 per 100,000 among children aged 5–9 years in 2010. Tasmania experienced similarly high rates for infants less than 6 months of age in 2012, at 1,328.3 per 100,000. In South Australia, high rates were also experienced by those aged 10–12 years, with a peak of 1,158.9 per 100,000 in 2010. Figure 5 displays rates for those aged 5–9 and 10–12 years for South Australia compared with the same age groups in New South Wales, by birth cohort. Rates peaked for those aged 5–9 and 10–12 years in South Australia a year earlier than in New South Wales.

Figure 2: Notification rates for pertussis, Australia, 2006 to 2012, by year and state or territory

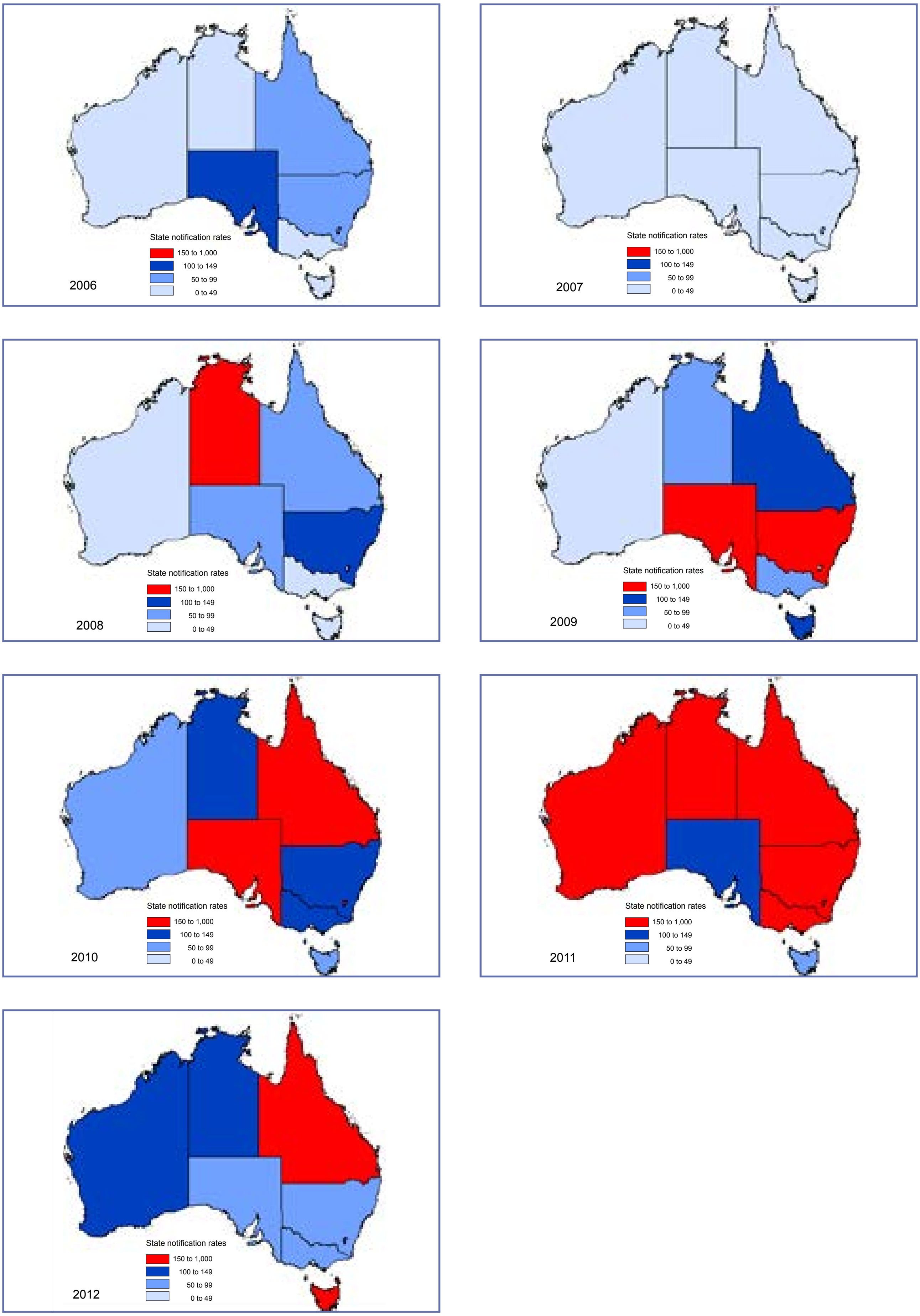
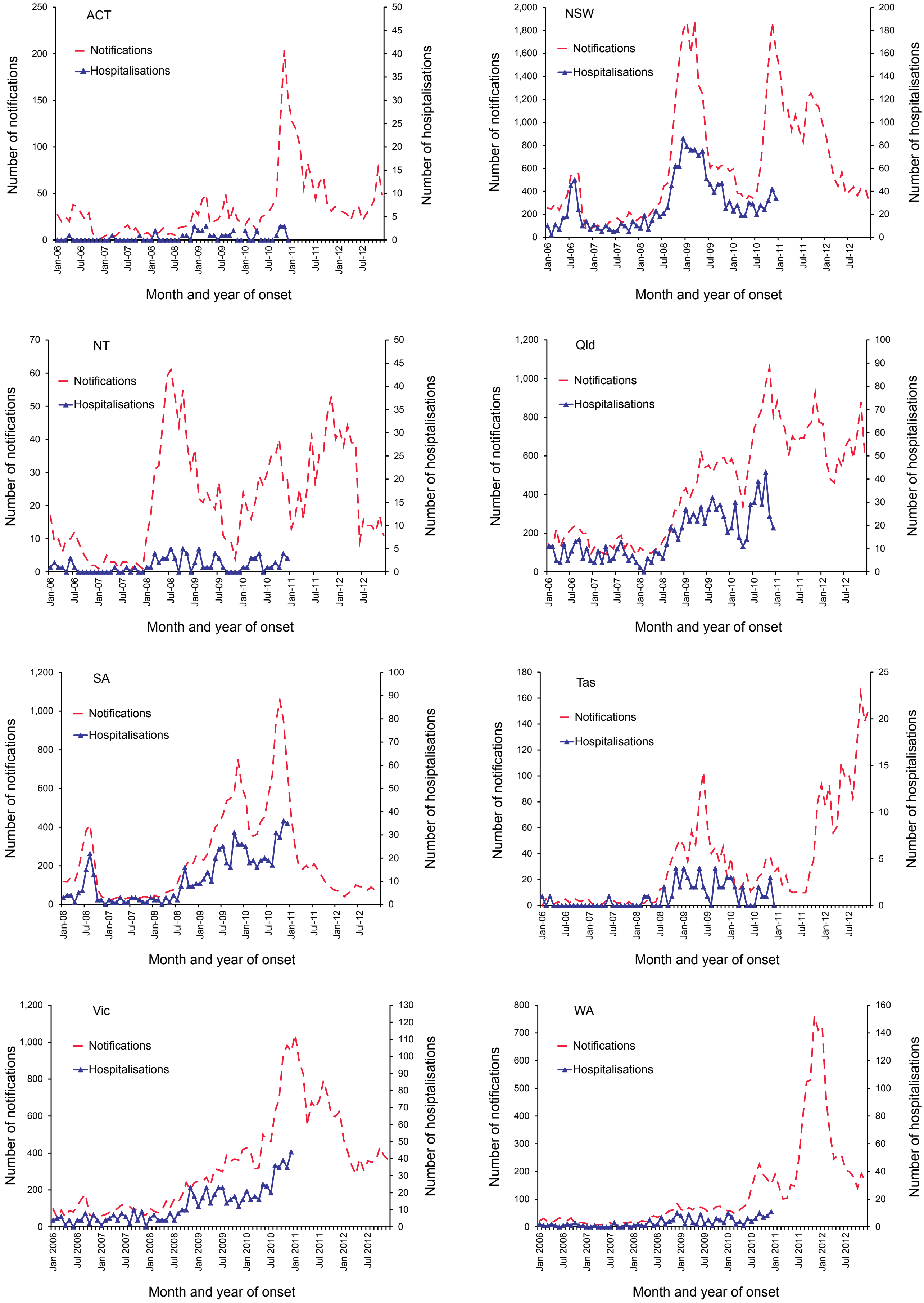


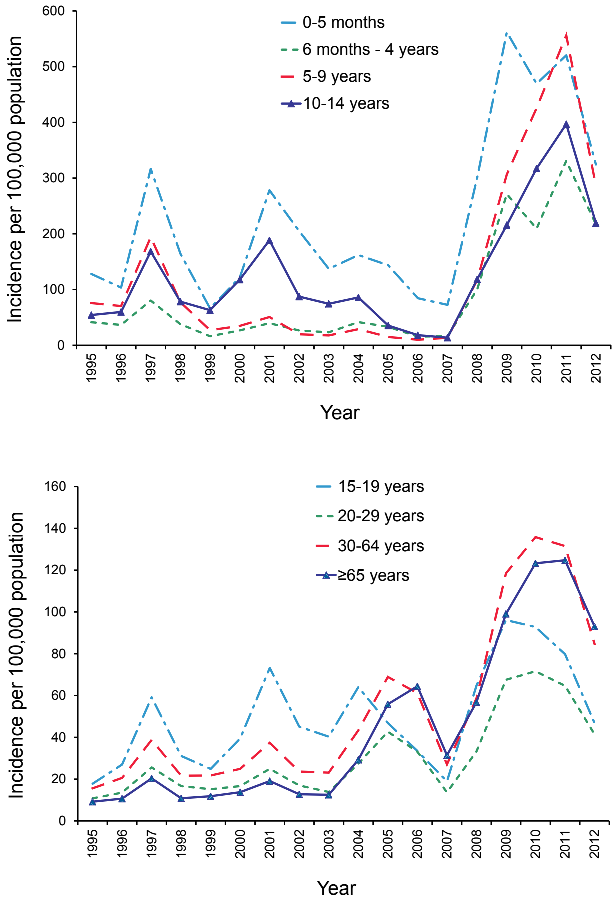
Figure 3: Notification and hospitalisation patterns of pertussis, Australia, 2006 to 2012,* by year and month of onset or admission and state or territory†



* Hospitalisation data available through 2010.

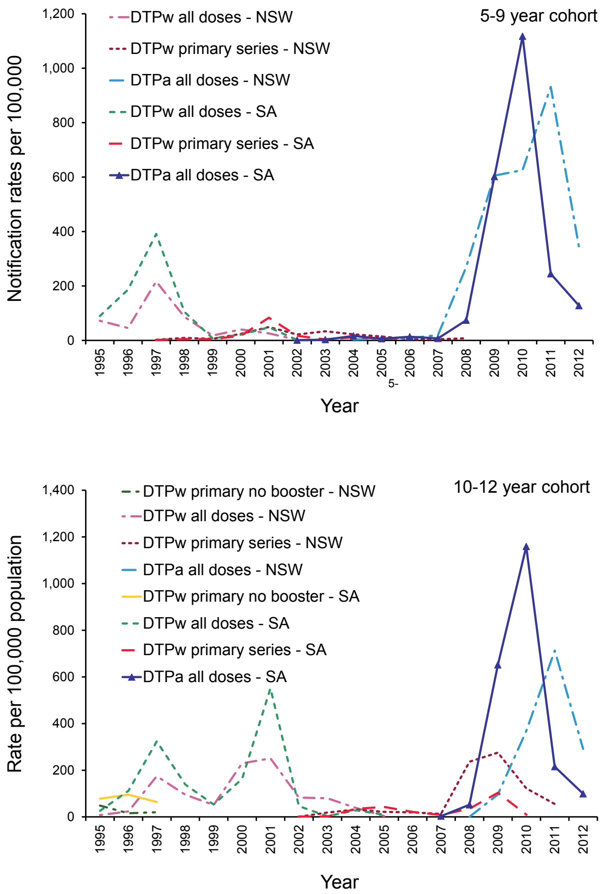
† Scales vary between states and territories.

Figure 4: Age-specific incidence of pertussis for groups aged <15 years and ≥15 years,* Australia, 1995 to 2012, by age group and year



* Scales differ between figures.

Figure 5: Incidence of pertussis for children aged 5–9 and 10–12 years,* New South Wales and South Australia, 1995 to 2012, by birth cohort and year of onset



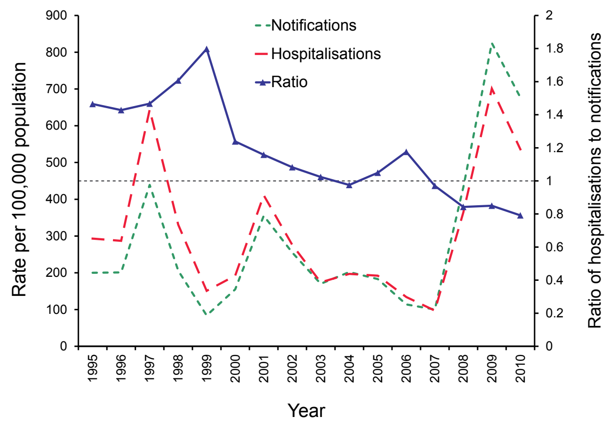
* Scales differ between figures.

Historically, among infants less than 6 months of age, rates of ICD coded hospitalisations have been higher than notification rates. From 2007, however, notification rates for this age group have been consistently higher than hospitalisation rates (Figure 6). The highest hospitalisation rates occurred among those aged 3 months or less, increasing steeply between 2007 and 2009. Though rates were comparatively lower for infants and children aged 6 months to 4 years, this age group also experienced a sharp increase in hospitalisations from 2007–2009. Of all persons aged over 4 years, adults aged 65 years or over had the highest hospitalisation rates (Figure 7).

Diagnostic method

Compared with the previous decade, the completeness of NNDSS diagnostic testing data has improved. For the period of 1995–2005, the method of diagnosis was recorded for 50.1% of notifications, increasing to 85.8% of notifications for the period 2006–2012. Over the 7-year period,

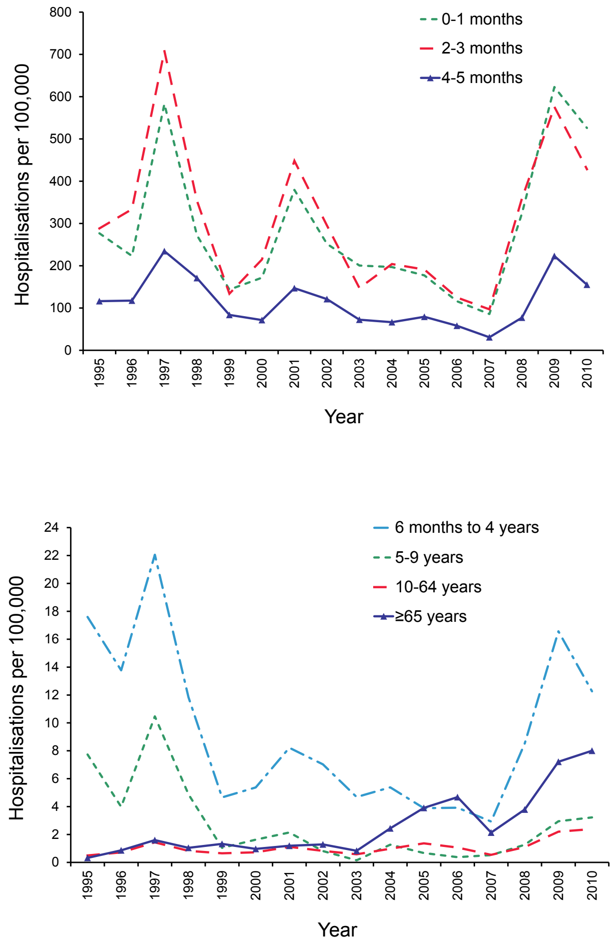
Figure 6: Ratio of national pertussis hospitalisation to notification rates for infants less than 6 months of age, Australia, 1995 to 2010*



* Hospitalisation data available through 2010.

an increasing proportion of notifications had PCR recorded as the method of diagnosis, increasing from 6.9% in 2006 to 58.7% in 2012. The increase in the percentage of diagnoses by PCR testing was most rapid in young children, with a more gradual increase among adults. The proportion of PCR confirmed diagnoses decreased and the proportion of serologic diagnoses increased with age (Figure 8). During the 7-year period, for those aged less than 1 year, culture alone was recorded as the diagnostic method for 67 (1.5%) notifications (range: 0%–6.0%). For the same age group, both culture and PCR together were recorded for 1.8% of notifications (range: 0%–4.3%).

Figure 7: Age-specific hospitalisation rates of pertussis for groups aged <6 months and ≥6 months, Australia, 1995 to 2010*,†



* Scales differ between figures.

† Hospitalisation data available through 2010.

Severe morbidity and mortality

During the period of investigation, 11 notified cases were reported to have died from pertussis. Of these, 10 deaths were in unvaccinated infants less than 2 months of age and one was an adult aged 70 years. There were twice as many infants less than 6 months of age hospitalised for pertussis than adults aged 65 years or over, but the median length of stay per hospital admission was longer for the older adult age group (median: 7 days) than for the infant group (median: 4 days; Table 2).

Discussion

For the period 2006–2012, the average annual pertussis notification rate was 2.8 times that for 1995–2005.[3] Unlike the previous review period, the expected 3–4 year epidemic cycles of approximately 12 months duration[17] were replaced by sustained epidemics, which peaked in 2009 or 2011 in different jurisdictions. This national picture is similar to previously published jurisdictional reviews of notifications for the same time period.[18,19]

Although cases are still believed to be under-reported,[20,21] improved surveillance and laboratory diagnostics as well as heightened awareness among clinicians have led to increased testing and notification of disease.[22–24] In particular, the general availability of commercial PCR kits[25] as well as the

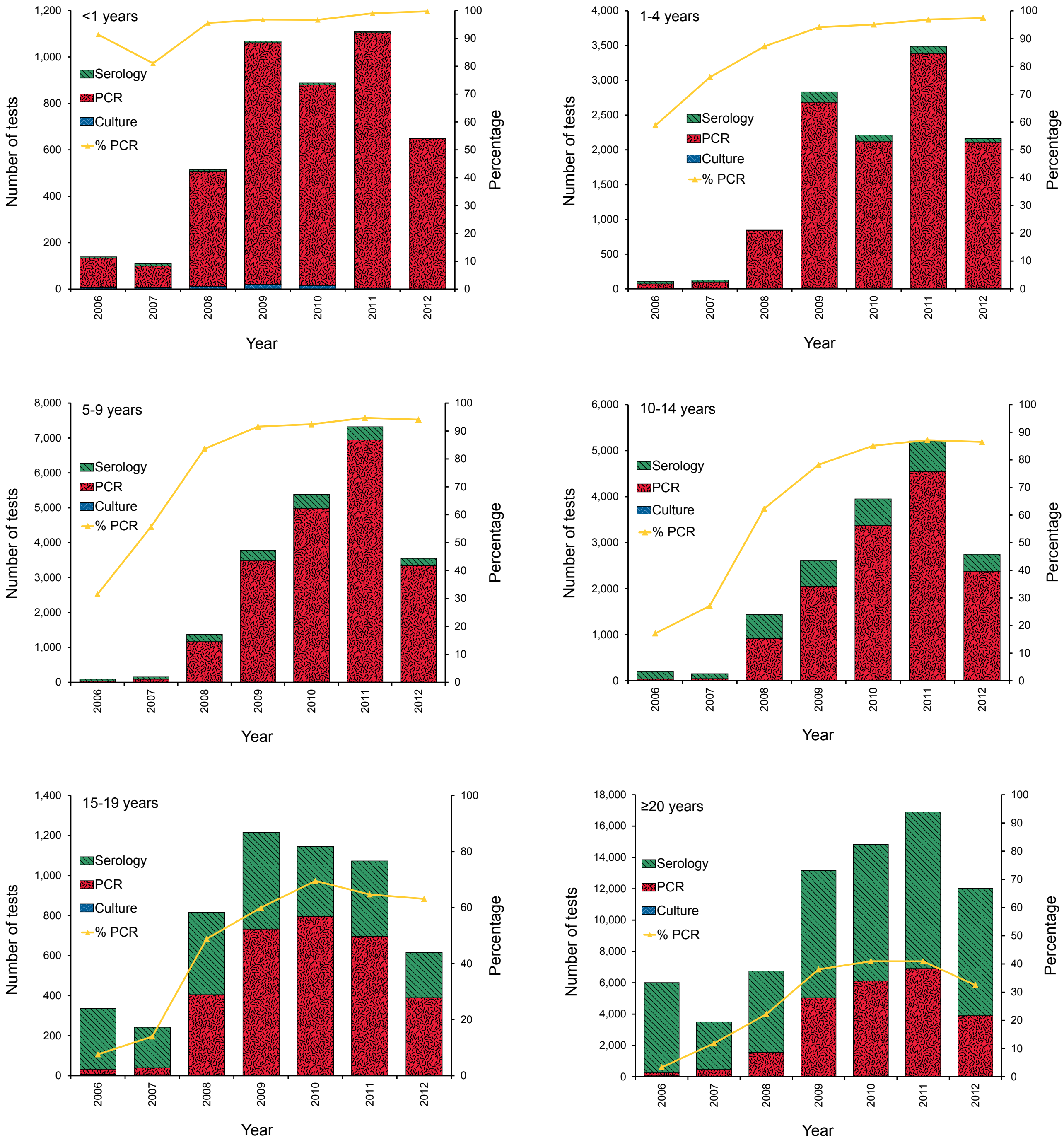
Table 2: Number of pertussis coded hospitalisations, median length of hospital stay and number of pertussis deaths, Australia, 2006 to 2012,*,† by age group

Age group	Hospital admissions		Length of stay (days)†		Deaths*
	n	(Rate per 100,000 population)	Median	Range	n
<6 months	1,832	257.9	4	(1–292)	10
6 months–4 years	557	9.0	2	(1–313)	0
5–9 years	113	1.7	2	(1–477)	0
10–64 years	1,166	1.4	3	(1–139)	0
≥65 years	740	4.9	7	(1–364)	1
All ages	4,408	4.1	3	(1–477)	11

* Deaths are for the period 2006 to 2011.

† Length of stay is for the period 2006 to 2010

Figure 8: Diagnostic methods for pertussis, Australia, 2006 to 2012, by age group*



* Scales differ between age groups.

PCR Polymerase chain reaction.

high sensitivity of PCR testing, as has been noted elsewhere,[26] have encouraged clinicians to test more, thus contributing to the rise in notifications.

It is unlikely, however, that the increase in pertussis notifications documented here is solely attributable to increased testing and diagnosis.[8,12,26] The hospitalisation rates presented in this report, which rose similarly to notification rates but not to the same absolute magnitude, support this claim, as hospitalisation data are likely to be less influenced by diagnostic practices. Because PCR testing has been widely employed by hospitals since about 2000, any changes in hospital coding are likely to have been less dramatic than the more recent adoption of PCR testing in primary care.[8] It is notable that hospitalisation rates in the 2009 epidemic were similar to those recorded in 1997, despite the increased availability of PCR testing from 2000.[27] If anything, this would suggest that hospitalisation for pertussis was less common in the most recent acellular vaccine era. Similarly, the number of deaths for this 7-year review period remained comparable to the number of deaths notified in the previous decade.

During the period 1995–2005, notification rates for Australian adults were much higher than in comparable countries internationally.[28–30] In contrast, in 2006–2012 the highest rates occurred among younger age groups, specifically in infants aged less than 6 months and children aged 5–9 years. Recent outbreaks in the United States of America (US), the Unitied Kingdom (UK), Canada and New Zealand have also been characterised by high rates in infants too young to be vaccinated.[4,31–34] High rates in infants have been common for several decades. When notifications were largely reliant upon clinical diagnoses, higher rates were often detected in hospitalisation data because infant cases admitted to hospital were not notified. Since the increased use of PCR testing in Australia, however, this differential between notification and hospitalisation data for infants has diminished.[35]

Recent trials have investigated the delivery of pertussis vaccine at birth.[36–39] The cocooning strategy (vaccinating close contacts of infants to reduce the likelihood of exposure) and maternal vaccination have been recommended for preventing infection in very young infants and have been given equal preference in the most recent *Australian Immunisation Handbook*.[40] Maternal vaccination has also been recommended by the US, UK, Canada and New Zealand.[31,32,41,42] Systematic evaluation of the various strategies to protect newborn infants is vital to prevent deaths and severe disease from pertussis in this vulnerable group.

The efficacy of DTPa vaccines that contain three or more antigens has been estimated at 71%–78% for the prevention of milder pertussis and 84% for typical disease.[43,44] While data demonstrate that receipt of the 1st dose of the primary DTPa series can reduce incidence of severe illness in infants,[45,46] DTPa vaccine does not appear to confer immunity for as long as the DTPw vaccine.[10,47–52] Consequently, high rates of pertussis in children may have resulted in part from the NIP switch to the DTPa vaccine. Specific estimates of the duration of immunity afforded by the whole-cell vaccine range from 4–14 years, though studies suggest that immunity conferred by the acellular vaccine may only last 5 years or less.[9,53] Average notification rates from 2006–2012 for children aged 7 and 8 years were more than four times as high as those experienced by the same age group from 1995–2005. This suggests that immunity waned in the period following receipt of the 4 year old dose, for which coverage was estimated to be high,[54–56] before the adolescent booster could be administered.[57] Similarly, high rates among US children aged 8–12 years were documented from 2005 and correspond to the first cohort of children to have received a schedule containing all acellular vaccines.[53,58] In Australia, at the state and territory level, the DTPa vaccine was adopted for the primary series in South Australia and the Northern Territory in 1997 before being adopted Australia-wide for all childhood doses in 1999. This is likely to have contributed to notification rates for those aged 5–9 and 10–12 years in South Australia peaking earlier than in New South Wales, despite these states sharing similar overall epidemic patterns.

NIP schedule changes, specifically the 2003 removal of the 18-month booster dose, also likely influenced notification rates among younger age groups by exacerbating the impact of the decreased efficacy and longevity of the acellular vaccine. The removal of the 18-month booster expanded the time interval between doses from 6 months to 4 years of age leaving those aged 1–3 years vulnerable to waning immunity and resulting in record high notification rates for those aged 1–4 years from 2008.[12] Australian serosurvey results from 2007 support this claim, reporting that among children 1–4 years of age, prevalence of undetectable immunoglobulin G (IgG) levels had increased from 25% in 1997–1998 to 62% in 2007.[12]

Based on evidence of waning immunity, as well as evidence that toddlers serve as an important source of infection for infants too young to be vaccinated,[59–61] the current immunisation handbook advises that an additional dose of DTPa in the 2nd year of life will minimise the likelihood of a child developing pertussis prior to their scheduled booster dose at 3.5 to 4 years of age.[40] This is in line with the World Health Organization's 2010 recommendation that a booster be given in the 2nd year of life unless country-specific epidemiological evidence supports delaying this until preschool.[62]

The decreased notification rates among older adolescents and young adults demonstrated in this analysis were likely partially influenced by the 2003 NIP addition of the adolescent booster recommended for those aged 15–17 years. Despite variation in coverage and timing of programs across state and territories,[63,64] the dTpa employed for the adolescent dose has been demonstrated as moderately effective, both in a clinical trial[65] and a field setting.[64,66,67] Though duration of immunity associated with a single booster dose is thought to be limited,[68] both the US and Canada have reported temporally similar decreases in disease among adolescents following the addition of adolescent boosters.[69,70] In response to concern about waning immunity, the Australian Technical Advisory Group on Immunisation has recommended shifting the 5th dose to 11–13 years to decrease the time between the primary childhood series and adolescent booster.[71]

Though notification rates appeared to decrease somewhat in 2012, average rates for the period of investigation were dramatically higher than those experienced in the previous decade. Because of the increase in community PCR testing, baseline pertussis rates may well remain higher than they were prior to this change in diagnostic practice. Nevertheless, in light of the fact that this review demonstrates that pertussis notification rates are once again highest among the young, strategies targeted at reducing disease among infants must continue to be pursued. Due to the dynamic nature of pertussis immunity, it is imperative to continue exploring a broad range of both scientific and policy solutions.

Acknowledgements

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Appendix: Age-specific notification and hospitalisation rates per 100,000 population for pertussis, Australia, 2006 to 2012,* by state or territory

State or territory	Data source	Age group <6 months	6 months–4 years	5–9 years	10–14 years	15–19 years	20–64 years	>65 years
ACT								
2006	Notifications	0.0	32.4	29.2	9.3	36.7	94.4	100.4
	Hospitalisations	0.0	0.0	0.0	0.0	0.0	0.5	0.0
2007	Notifications	43.9	15.5	4.9	0.0	27.9	32.8	39.2
	Hospitalisations	86.8	0.0	0.0	0.0	0.0	0.0	0.0
2008	Notifications	87.1	25.1	58.6	47.1	23.5	41.6	46.7
	Hospitalisations	86.9	0.0	0.0	0.0	0.0	1.8	2.9
2009	Notifications	247.8	78.3	82.4	51.9	46.9	104.4	143.5
	Hospitalisations	371.7	4.9	0.0	0.0	0.0	0.9	5.6
2010	Notifications	159.1	99.3	503.5	377.1	74.4	172.7	221.5
	Hospitalisations	156.0	9.3	0.0	0.0	0.0	1.3	5.4
2011	Notifications	320.6	171.4	363.7	343.2	104.0	201.6	333.5
2012	Notifications	78.0	62.4	130.7	247.9	66.3	106.5	153.2
Average rate notifications		137.0	71.2	169.2	152.4	54.2	109.1	153.4
Average rate hospitalisations		144.0	3.0	0.0	0.0	0.0	0.9	2.9
NSW								
2006	Notifications	161.4	27.4	13.4	18.7	35.2	64.1	60.5
	Hospitalisations	176.9	7.4	0.7	1.1	0.2	1.2	5.0
2007	Notifications	137.7	28.1	24.2	18.3	17.9	23.1	22.3
	Hospitalisations	109.1	5.1	0.5	0.0	0.0	0.3	2.0
2008	Notifications	571.7	233.3	278.9	270.1	135.7	65.9	50.4
	Hospitalisations	456.8	16.3	3.0	0.7	1.3	1.4	3.6
2009	Notifications	911.2	579.4	605.0	342.0	141.1	97.2	63.1
	Hospitalisations	728.3	28.0	3.4	3.8	1.7	2.0	8.3
2010	Notifications	418.2	284.1	626.2	365.0	88.3	62.9	44.9
	Hospitalisations	285.8	12.1	3.2	0.9	0.6	1.9	4.1
2011	Notifications	648.9	492.4	931.1	526.2	77.2	77.0	55.3
2012	Notifications	337.2	239.2	343.6	205.2	33.3	38.3	32.4
Average rate notifications		459.8	273.2	403.3	248.1	75.8	61.3	46.8
Average rate hospitalisations		355.0	13.9	2.1	1.3	0.8	1.4	4.6
NT								
2006	Notifications	109.2	6.3	0.0	0.0	64.4	59.0	51.3
	Hospitalisations	163.8	6.3	0.0	0.0	0.0	3.0	10.3
2007	Notifications	53.9	12.5	5.8	0.0	0.0	13.1	48.2
	Hospitalisations	54.0	6.2	0.0	0.0	0.0	0.7	0.0
2008	Notifications	880.6	277.5	368.1	317.9	121.9	176.0	275.7
	Hospitalisations	827.1	49.6	5.7	0.0	12.1	2.1	9.2
2009	Notifications	465.8	126.3	137.5	119.7	42.0	87.7	61.0
	Hospitalisations	619.5	12.1	5.7	0.0	5.9	1.4	0.0
2010	Notifications	317.5	172.4	315.0	194.0	90.4	116.2	164.8
	Hospitalisations	690.8	6.0	5.7	0.0	5.9	4.7	8.2
2011	Notifications	597.8	197.9	535.0	448.5	61.9	86.7	210.7
2012	Notifications	452.0	196.4	377.2	300.8	36.9	80.4	71.7
Average rate notifications		414.5	142.6	249.5	196.7	59.9	89.1	127.8
Average rate hospitalisations		476.9	16.0	3.4	0.0	4.9	2.4	5.5

Appendix *continued*: Age-specific notification and hospitalisation rates per 100,000 population for pertussis, Australia, 2006 to 2012,* by state or territory

State or territory	Data source	Age group <6 months	6 months–4 years	5–9 years	10–14 years	15–19 years	20–64 years	>65 years
Qld								
2006	Notifications	61.6	13.7	8.3	36.9	47.6	55.8	95.7
	Hospitalisations	50.8	2.9	0.4	0.3	0.0	1.9	7.1
2007	Notifications	52.9	7.3	6.8	11.7	31.7	37.7	79.0
	Hospitalisations	52.7	1.2	0.7	1.0	0.3	1.5	4.5
2008	Notifications	147.6	28.0	26.4	39.3	38.3	51.7	96.7
	Hospitalisations	120.0	2.7	0.4	0.3	0.7	1.2	7.5
2009	Notifications	404.7	136.8	181.2	162.0	101.3	132.4	170.7
	Hospitalisations	353.8	14.0	2.8	2.4	1.0	3.1	9.1
2010	Notifications	471.7	179.6	334.4	262.1	102.9	163.1	210.7
	Hospitalisations	353.1	12.2	2.8	2.0	1.0	2.9	11.3
2011	Notifications	488.2	263.2	471.8	404.6	105.4	152.9	191.6
2012	Notifications	344.6	233.6	397.6	339.6	74.6	119.4	176.9
Average rate notifications		287.6	127.9	207.9	180.0	72.3	103.2	148.6
Average rate hospitalisations		193.0	6.9	1.4	1.2	0.6	2.1	8.0
SA								
2006	Notifications	11.1	7.4	19.9	26.5	83.0	174.4	169.9
	Hospitalisations	44.4	4.9	1.0	1.0	2.9	4.0	11.0
2007	Notifications	0.0	14.7	7.4	9.9	16.0	28.5	26.2
	Hospitalisations	10.6	2.4	2.1	0.0	0.0	1.2	2.5
2008	Notifications	163.3	51.4	74.3	74.7	57.0	97.6	113.8
	Hospitalisations	192.3	3.6	1.1	1.0	1.0	2.4	6.1
2009	Notifications	847.8	338.6	602.2	582.7	181.8	313.7	247.9
	Hospitalisations	673.1	26.7	12.7	6.0	2.0	7.6	18.5
2010	Notifications	1,119.3	493.1	1117.4	872.4	238.1	392.6	334.6
	Hospitalisations	794.4	39.5	9.6	14.0	6.0	7.9	25.1
2011	Notifications	277.2	212.2	244.9	191.1	58.5	132.2	137.8
2012	Notifications	108.1	50.5	127.9	93.6	21.9	46.4	52.1
Average rate notifications		366.0	169.9	310.7	263.5	94.1	169.8	154.4
Average rate hospitalisations		352.5	15.9	5.3	4.4	2.4	4.7	12.8
Tas.								
2006	Notifications	62.8	3.7	0.0	11.7	0.0	8.7	12.6
	Hospitalisations	31.4	0.0	0.0	0.0	0.0	0.0	1.4
2007	Notifications	30.2	7.3	3.2	2.9	2.9	4.5	8.2
	Hospitalisations	0.0	3.6	0.0	0.0	0.0	0.0	0.0
2008	Notifications	303.9	70.8	60.7	83.2	58.4	28.0	26.7
	Hospitalisations	180.1	10.4	0.0	0.0	0.0	0.3	1.3
2009	Notifications	722.1	224.3	162.1	211.3	134.5	107.4	57.0
	Hospitalisations	295.7	23.5	0.0	0.0	2.9	2.7	3.9
2010	Notifications	258.5	82.5	62.0	54.2	67.3	51.9	39.0
	Hospitalisations	320.4	6.6	0.0	0.0	2.9	0.0	1.3
2011	Notifications	256.2	114.9	156.1	197.8	26.5	51.7	41.4
2012	Notifications	1,328.3	677.7	786.9	691.2	130.0	141.7	111.0
Average rate notifications		422.4	171.1	173.9	175.3	60.0	56.7	43.9
Average rate hospitalisations		164.7	9.1	0.0	0.0	1.2	0.6	1.6

Appendix *continued*: Age-specific notification and hospitalisation rates per 100,000 population for pertussis, Australia, 2006 to 2012,* by state or territory

State or territory	Data source	<6 months	6 months–4 years	5–9 years	10–14 years	15–19 years	20–64 years	>65 years
Vic.								
2006	Notifications	30.7	2.8	3.7	6.2	15.5	23.7	32.8
	Hospitalisations	67.6	0.0	0.0	0.0	0.0	0.3	2.5
2007	Notifications	58.8	14.5	13.1	17.6	17.8	21.3	21.2
	Hospitalisations	81.6	2.1	0.3	0.0	0.0	0.5	1.3
2008	Notifications	141.3	25.5	25.9	41.6	20.7	34.0	28.6
	Hospitalisations	134.6	4.7	0.3	0.3	0.6	0.8	1.8
2009	Notifications	302.3	74.8	72.4	81.1	43.5	68.7	72.0
	Hospitalisations	328.8	4.8	0.9	1.2	0.3	1.2	3.5
2010	Notifications	470.3	133.7	207.6	256.3	75.6	113.1	119.5
	Hospitalisations	437.5	8.2	3.0	0.9	1.1	2.3	7.7
2011	Notifications	434.8	189.7	282.3	263.3	75.4	134.0	164.1
2012	Notifications	232.9	98.9	106.6	95.6	31.2	70.0	101.7
Average rate notifications		241.8	79.5	102.5	108.2	40.1	67.5	79.3
Average rate hospitalisations		212.4	4.1	0.9	0.5	0.4	1.1	3.4
WA								
2006	Notifications	66.9	17.1	10.3	5.6	12.3	13.1	13.2
	Hospitalisations	74.3	4.3	0.0	0.0	0.0	0.1	0.0
2007	Notifications	7.0	4.9	2.2	2.8	5.3	7.2	7.2
	Hospitalisations	13.8	1.6	0.0	0.0	0.0	0.0	0.8
2008	Notifications	198.2	30.6	20.9	10.3	10.5	20.2	24.9
	Hospitalisations	184.1	3.9	0.0	0.0	0.0	0.4	0.8
2009	Notifications	240.7	53.1	58.4	31.2	17.4	31.2	30.8
	Hospitalisations	201.1	8.2	0.7	0.7	0.0	0.7	0.4
2010	Notifications	313.0	89.3	122.4	118.5	40.1	49.7	59.3
	Hospitalisations	239.2	7.2	1.4	1.3	0.0	1.2	2.9
2011	Notifications	610.9	285.9	520.3	474.1	71.7	108.4	116.8
2012	Notifications	375.7	284.0	247.9	263.1	63.7	104.5	144.5
Average rate notifications		267.2	116.4	145.1	131.2	31.9	49.9	60.0
Average rate hospitalisations		145.9	5.2	0.4	0.4	0.0	0.5	1.0

* Hospitalisation data available through 2010.