Pertussis epidemiology in Australia over the decade 1995–2005 – trends by region and age group

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Abstract

Important changes have occurred in the National Immunisation Program for pertussis during the decade 1995–2005, including the introduction of acellular pertussis vaccine for all doses, removal from the schedule of the booster dose at 18 months, and the introduction of a booster dose for adolescents. In addition, the coverage of pertussis vaccine at 12 and 24 months has substantially increased as recorded by Australian Bureau of Statistics surveys and the Australian Childhood Immunisation Register. There were 75,458 notifications nationally between 1995 and 2005, with little change in the annual number of notifications at the national level but with periodic epidemics, which varied among states and territories and dramatic changes in the age distribution of notified cases. Pertussis is well controlled in the 1–4 and 5–9 year age groups, and the highest annual notification rates continue to be in infants under 6 months of age. Adolescents aged 10–19 years had high notification rates in all states and territories, over this period, but 63% of notifications are now in the 20–59 year age range. Following the introduction of a fifth dose for adolescents, the current focus should be on protecting infants too young to be vaccinated and further defining the true morbidity of the disease in the elderly population. *Commun Dis Intell* 2007;31:205–215.

Keywords: pertussis, disease surveillance, immunisation

Introduction

Pertussis hospitalisations and deaths decreased dramatically in Australia following the introduction of mass immunisation in the 1950s, reaching record low levels in the 1970s and 1980s. However, particularly since measles control was achieved in 1998, notifications of pertussis have outnumbered those for any other vaccine preventable disease targeted by the National Immunisation Program (NIP).[1]

Important changes have occurred in the NIP for pertussis during the decade 1995–2005. From 1978, the Australian pertussis schedule, using a locally manufactured whole cell pertussis vaccine (DTPw), was 3 primary doses at 2, 4 and 6 months of age. A booster dose of DTPw at 18 months of age, which had previously been included in the schedule and was subsequently removed, was reintroduced in 1985. In 1994, a fifth dose at 4–5 years (school entry) was recommended. In 1997, acellular pertussis vaccines (DTPa) replaced DTPw for booster doses and from 1999 for all doses, although South Australia and the Northern Territory used DTPa for all doses from 1997. In September 2003, the spacing of the 5-dose schedule was changed, with the 18-month booster no longer recommended, based on evidence that 3 doses of acellular pertussis vaccine in the first year of life provide adequate protection until the age of 6 years.[2] From the beginning of 2004, an adolescent/adult formulated booster (dTpa) replaced the use of the adult diphtheria-tetanus vaccine (ADT) at 15–17 years of age. The latter change was prompted by evidence of a shift in pertussis notifications to these age groups following the introduction of the fifth dose of DTPa at 4–5 years.[1,3]

In addition, the coverage of pertussis vaccine at 12 and 24 months has substantially increased during this period. Coverage with three doses of DTP at 12–23 months of age was recorded at 86% during the 1995 Australian Bureau of Statistics survey,[4] rising to 92% for 3 doses of DTPa at 12 months and 95% for 3 doses of DTPa at 24 months, as assessed using the Australian Childhood Immunisation Register in December 2003.[1]

This paper summarises the age-specific trends in pertussis notifications over the 10 years (1995–2005) at the regional and national level in the context of the vaccine schedule and vaccine coverage changes during this period.

Methods

Notifications

In Australia, pertussis cases are notifiable under each state and territory Public Health Act. The criteria for notification can be a combination of clinical, epidemiological or laboratory evidence. Laboratory evidence includes culture of *Bordetella pertussis*, nucleic acid testing, serology or immunofluorescence assay.[5]

Disease notification data from the National Notifiable Diseases Surveillance System (NNDSS), for cases with an onset between 1 January 1995 and 31 December 2005, are included in this report. Notification data are presented and reported by date of onset. From 2000, the laboratory diagnosis method field in NNDSS was completed for more than 60% of notifications. Analysis using this field was performed for cases with an onset between 1 January 2000 and 31 December 2005. Only data from New South Wales, Queensland and the Northern Territory were included, as more than 70% of cases from other states and territories had an unknown diagnosis method recorded.

Population estimates

All rates were calculated using Australian Bureau of Statistics mid-year estimated resident populations, and are presented as annual rates or average annual rates per 100,000 total population, or population in age or geographical subgroups, as appropriate. Average annual rates were calculated by dividing the total number of cases for the period of investigation by the sum of the population for the same period.

Incidence rate ratios (IRR) were calculated to compare annual notification rates to state averages. Ninety-nine per cent confidence intervals (CI) and P values were calculated for each IRR using a standard procedure in EpiBasic (University of Aarhus, Denmark). Variables were explored for possible associations using a chi square test for trend, a P value of 0.05 was considered statistically significant.

Results

Secular trends

Pertussis is by far the most common vaccine preventable illness in Australia, with 75,458 notifications nationally between 1995 and 2005 (Table 1). Periodic epidemics of pertussis occur in Australia at intervals of 3–4 years, on a background of endemic circulation. In recent years the epidemic peaks have not been as evident in children aged less than 10 years. A seasonal pattern can be observed, with peak notifications in spring each year (Figure 1).

Regional variations in pertussis notification rates

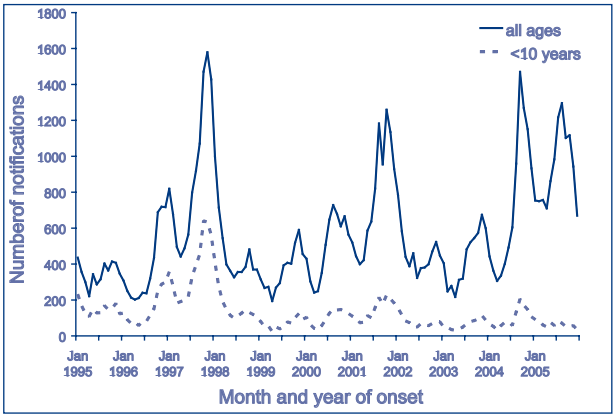
Table 1 shows crude national and jurisdictional notification rates over the decade 1995–2005 ordered by highest average rate from left to right. The national crude notification rate varied from 23.1 cases per 100,000 population in 1999 to 58.1 cases per

Table 1. Pertussis notification rates, Australia, 1995 to 2005, by state and territory

Year		State or territory								
		SA	NSW	ACT	Qld	Tas	WA	NT	Vic	Aus
1995		31.0	22.4	10.8	41.3	23.2	19.6	74.3*	9.0	23.2
1996		62.6	18.6	13.0	23.2	6.5	12.9	7.7	30.1*	24.8
1997		110.6*	67.7*	34.3	56.0*	23.6	67.1*	12.8	32.9*	58.1
1998		36.9	36.4	32.3	40.4	11.7	15.6	12.6	20.7	30.3
1999		15.2	22.0	26.6	27.5	135.3*	5.2	1.0	20.1	23.1
2000		39.1	56.7*	66.3*	15.1	30.3	5.0	4.6	15.1	31.2
2001		133.0*	64.1*	26.9	44.9*	22.0	11.9	75.8*	18.0	47.8
2002		31.1	30.2	17.1	50.0*	7.8	12.1	18.7	18.0	28.3
2003		15.2	42.5	112.6*	18.8	27.8	13.2	2.5	12.8	26.1
2004		65.2	52.8*	38.3	27.2	7.8	107.8*	13.6	17.8	43.9
2005		96.8*	86.2*	96.6*	44.7*	6.8	25.3	42.9*	23.0	55.1
Total	Number	9,587	32,605	1,514	13,919	1,433	5,575	511	10,314	75,458
	Average rate	63.9	45.8	43.6	39.2	30.2	30.0	24.1	21.8	39.6

* Incidence rate ratio significantly higher (P<0.05) than the state average.

Figure 1. Notifications of pertussis, Australia, 1995 to 2005, by month of onset



100,000 population in 1997, with an average annual national notification rate over the analysed period of 39.6 cases per 100,000 population.

Sixty-two per cent of all pertussis notifications occurred in New South Wales (n=32,605) and Queensland (n=13,919) in the 10 year period, although these states account for 53% of the Australian population. The highest average annual notification rate was recorded in South Australia (63.9 cases per 100,000 population; Table 1). All states and territories have had peak incidence rates significantly higher than the average annual national notification rate at various times since 1995.

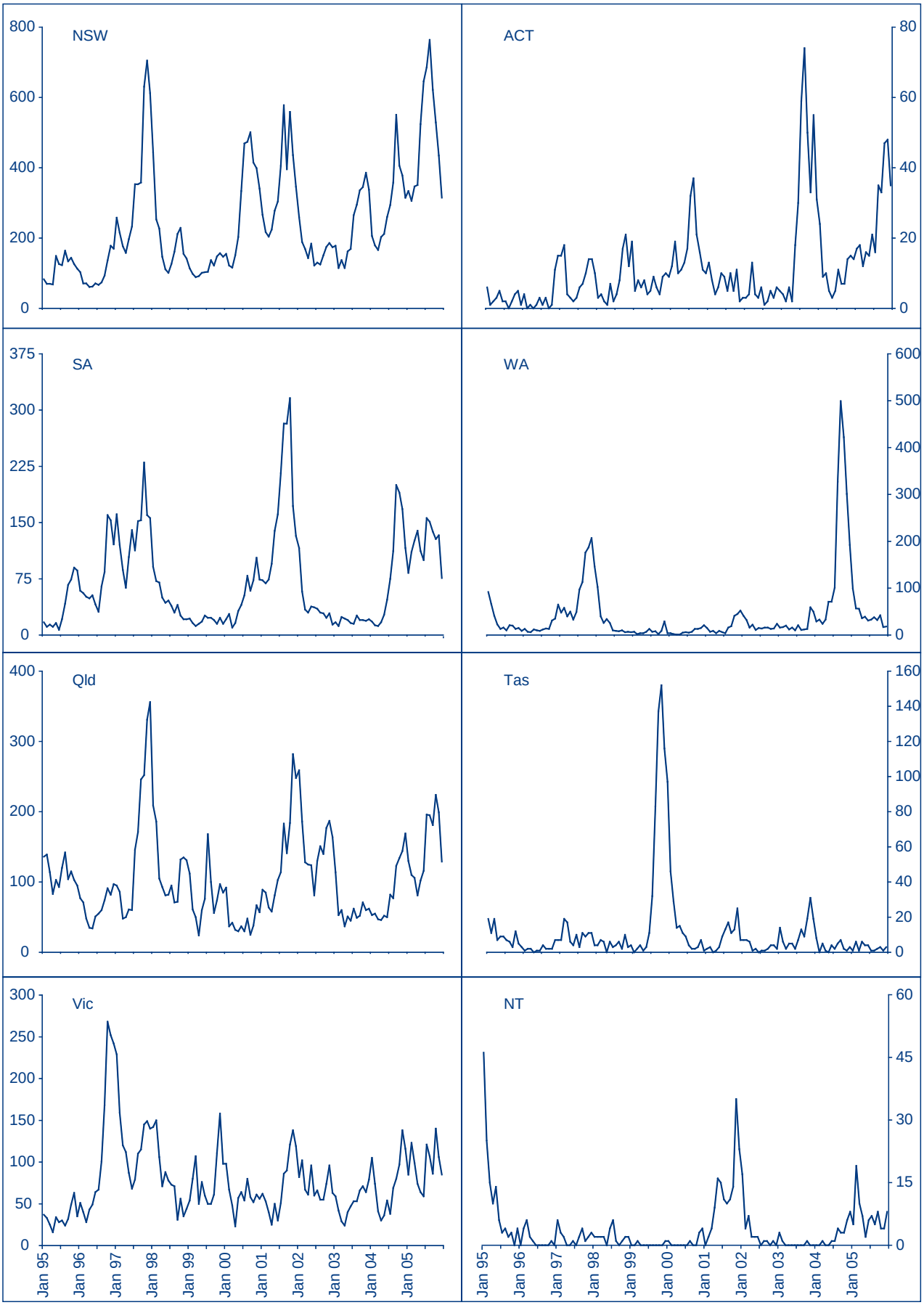
The epidemic cycles in New South Wales, Queensland and South Australia have followed a similar pattern, including double peaks during epidemics, however, the inter-epidemic period has varied. In the less populated and/or geographically isolated states and territories of Western Australia, the Northern Territory and Tasmania, epidemic cycles were spaced further apart (Figure 2).

Age distribution of cases

The age-specific pertussis incidence rates over the analysed period are shown in Figures 3a and 3b. Children less than 6 months of age had the highest annual notification rate in all of the analysed years. High rates were seen among children aged 5–9 years in the first years of the decade, with a peak notification rate in 1997 of 194 cases per 100,000 population. The notification rate in this age group has declined dramatically and remained at less than 50 cases per 100,000 population since 1999. High annual notification rates were recorded for children aged 10–19 years in 1997 and 2001 (114 and 128 cases per 100,000 population, respectively), corresponding to the national epidemic cycle. The notification rates for the 20–39, 40–59 and 60 years and over age groups have recently risen to record highs.

The majority of cases from year to year are now in the adult population (Figure 4). The proportion of adult cases has steadily increased, with 83% of pertussis notifications in persons aged over 20 years in 2005. Between 1995 and 2005 there was a significant downward trend in the proportion of cases occurring in the less than 1 year, 1–4 and 5–9 years age groups (P<0.001). During the same period there was a significant increasing trend in the proportion of cases occurring in the 10–19, 20–59 and 60 years and over age groups (P<0.001).

Figure 2. Pertussis notification patterns, Australia, 1995 to 2005, by state or territory



Note: Scales vary between jurisdictions.

Figure 3a. Age-specific incidence of pertussis for the age groups <6 month, 6–<12 months, 1–4, 5–9 and 10–19 years, Australia, 1995 to 2005, by age group

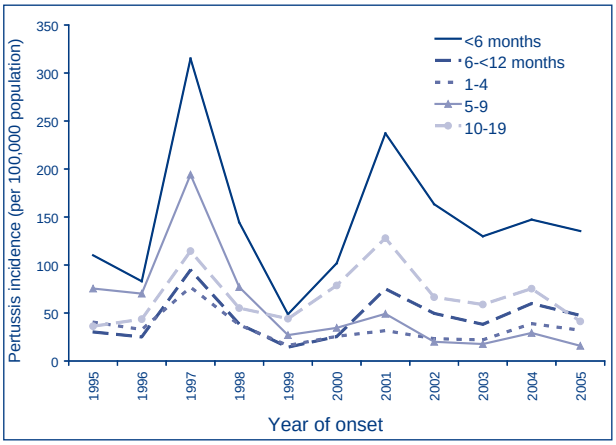
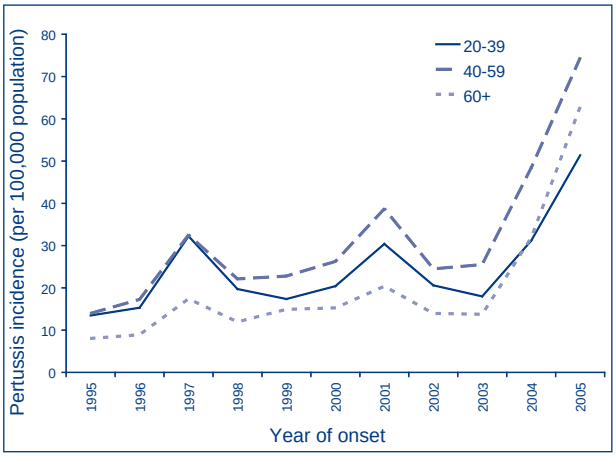
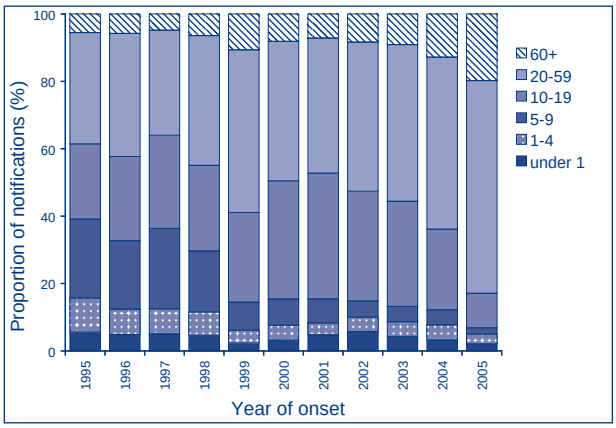


Figure 3b. Age-specific incidence of pertussis for the age groups 20–39, 40–59 and 60+ years, Australia, 1995 to 2005, by age group



As with the epidemic cycles of disease, the age distribution of cases varies among states and territories over time (Appendix 1 and Figure 5). In historical terms and with respect to other age groups, pertussis is relatively well controlled in the 1–4 and 5–9 year age groups; the exception to this being in Western Australia, where notification rates in these age groups were high in the 2004 epidemic year. High

Figure 4. Distribution of pertussis notifications, Australia, 1995 to 2005, by age group



annual notification rates in children under 1 year of age occur in all states and territories, and adolescents aged 10–19 years have also experienced high pertussis rates in all states and territories, relative to other age groups. In New South Wales and Western Australia, where whole of high school dTpa programs were conducted in 2004, the incidence in these age groups fell in 2005. During the period 1999–2003, combined pertussis incidence in New South Wales and Western Australia was 85.7 cases per 100,000 population. In 2005, this had decreased to 37.2 cases per 100,000 population. The increasing notification rate in the over 60 years age group observed nationally, is seen to varying degrees in all jurisdictions except the Northern Territory.

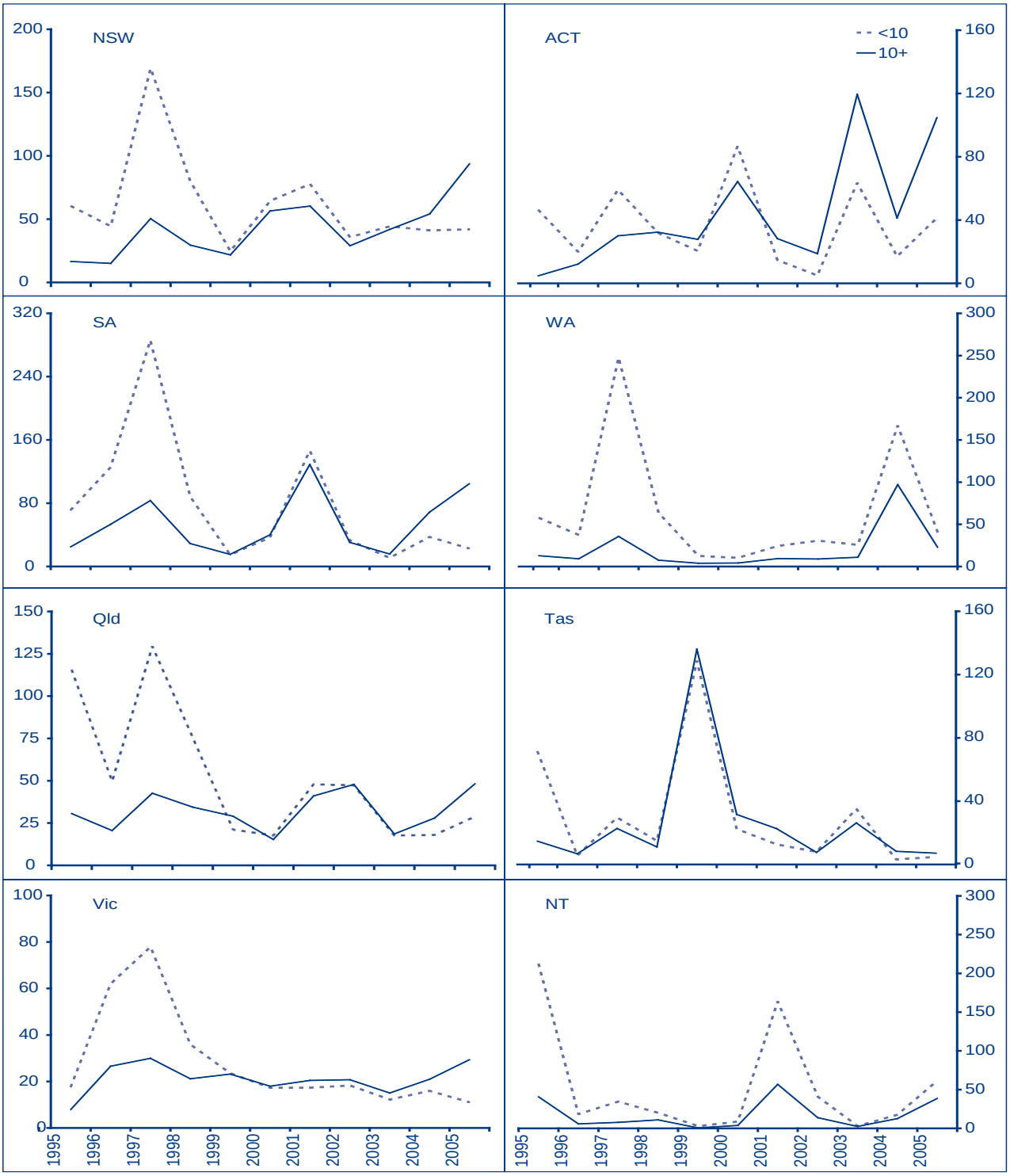
Method of diagnosis

Overall, serology was the predominant laboratory method for diagnosis of pertussis (74%), followed by nucleic acid testing (NAT; 12%). Diagnosis by serology increased from 41% of cases in 2000, to 65% of cases in 2005. NAT has been increasingly used as a method of diagnosis over time, and is the most common method for diagnosis in infants. The proportion of notifications diagnosed by NAT declines with increasing age, with serology the most prevalent diagnostic method over the age of 5 years. Culture is now used rarely, principally for diagnosis in infants less than 1 year of age (Table 2).

Table 2. Age-specific pertussis diagnostic methods for New South Wales, Queensland and the Northern Territory, 2000 to 2005, by age group

Diagnostic method	% by age group					
	<1	1–4	5–9	10–19	20–59	60+
Culture	9.6	3.1	1.9	1.3	0.9	0.9
Nucleic acid testing	59.7	39.1	21.3	11.1	7.1	4..3
Serology	8.7	26.4	52.5	73.8	81.3	88.0

Figure 5. Pertussis incidence for under 10-year-olds compared with over 10-year-olds, Australia, 1995 to 2005, by state or territory



Note: Scales vary between jurisdictions.

Discussion

This review highlights several aspects of the pattern of pertussis, as reflected in notification data, in Australia over the past decade; a time of significant changes in both diagnostic test availability and notification practice on the one hand and vaccination practice and vaccination coverage on the other.

Pertussis remains the most common vaccine preventable disease in Australia, with an average annual incidence rate of 39.6 cases per 100,000 population

and periodic epidemics. This review highlights for the first time the regional differences in epidemic patterns by magnitude and inter-epidemic period. South Australia (which only accounts for 8% of Australia's population), had a much higher average notification rate than any other state, 1.6 times the national average. The high notification rate in South Australia may in part be a result of greater case reporting, as the South Australian health department receives notifications from general practitioners as well as laboratories. In contrast, general practitioners in New South Wales are reluctant to notify pertussis without a laboratory confirmed diagnosis.[6] Differences among other states and territories with regard to use and availability of diagnostic tests, may have contributed to the variation in case ascertainment and notification rates. Unfortunately, there is insufficient detail on laboratory diagnosis methods in NNDSS to examine this in more detail but it is clear that serologic diagnosis is the primary method except in infants. While the national epidemiology of pertussis between 1995 and 2005 is similar to that of New South Wales, large outbreaks in other states or territories have influenced national trends at times, such as the 2004 peak in national notifications, which reflected an epidemic in Western Australia that year. Less populated and/or geographically isolated states and territories appear to be characterised by longer inter-epidemic periods and more intense epidemics than in other states. These notification patterns are synchronous with pertussis hospitalisations.[1,7]

The age-specific patterns of notification have reflected changes in vaccination practice, however the total number of notifications has not changed, with upward trends in older age groups not targeted for vaccination. Since 1999, notifications rates fell significantly among the 5–9 years age group reflecting the impact of the fifth dose of pertussis vaccine which was introduced nationally since 1994–1995.[8] High rates continue to occur in children aged less than 6 months who have received less than 3 vaccine doses, although there is a trend for less pronounced peaks to be seen over time, despite the increased availability of NAT as a diagnostic method for this age group. Both of these age distribution trends are consistent in all states and territories.

In 2005, there was a decrease in the national notification rate for the 10–19 year age group, which includes a highly susceptible cohort of adolescents in New South Wales, previously described,[9] and nationally.[8] New South Wales experienced a 43% decrease in the notification rate for the 10–19 year age group in 2005, following the implementation of a 'whole of high school' dTpa vaccination program in 2004.[10] As Australian school-based dTpa programs mature and successive cohorts are vaccinated in future years, pertussis in adolescents should be better controlled, as occurred in the 5–9 year age group following the introduction of the preschool booster.

The increasing adult burden of pertussis may be in part due to increasing awareness among clinicians, as well as waning vaccine induced immunity. The rise in adult cases raises several new issues and challenges both for diagnosis and for potential immunisation strategies. With respect to diagnosis, the majority of adult cases are diagnosed by serology, as older individuals often only present to a doctor after several weeks of coughing illness, when the probability of isolating *B. pertussis* is greatly reduced.[11] In Australia, serological diagnosis based on the detection of IgA antibodies to whole cell *B. pertussis* antigens has been available in some jurisdictions since the 1980s and nationally since 1993. Although insensitive, previous work suggested a specificity of 93%–98% in the presence of appropriate clinical symptoms.[12] However, specificity is likely to be considerably reduced by a change in diagnostic practice with a wider population of adults being tested, or by immunisation. The adult acellular pertussis vaccine trial (APERT) in the United States of America showed that IgA antibody responses to pertussis toxin (PT) after immunisation were predicted to remain above the threshold of detection for a minimum of 3.6 years.[13] This is in contrast to young children who do not produce an IgA antibody response after immunisation.[14] Within one year of vaccination, differentiating between antibody response due to immunisation and infection is particularly difficult and requires the use of a range of serologic criteria usually not available in a routine public health diagnostic setting.[15] It is unclear whether the response following adult immunisation with acellular pertussis vaccine observed with IgA-PT antibody assays, would be similar when using the current Australian IgA whole cell diagnostic assay. This requires urgent investigation, given the increasing reliance on serology for diagnosis of pertussis in Australia. It also stresses the need for serologically positive results to be notified only if the case has appropriate clinical symptoms, which can be challenging in the public health setting as it requires the active follow-up of all positive pertussis serology results.

The recent increase in the pertussis notification rate in the elderly warrants further investigation. Although less important than parents, grandparents can be a significant source of pertussis transmission to infants.[16] The level of morbidity from pertussis among the elderly is poorly defined and vaccines are currently not approved for use in persons aged over 65 years. However, 2 of 8 recorded pertussis deaths in the past 5 years have been in people aged 60 years or more.[1,17]

Although severe morbidity and mortality are less likely in adults, substantial morbidity still occurs[18,19,20] and increased circulation of pertussis can facilitate transmission to susceptible infants who are too young to be vaccinated.[16,21,22] Current adult pertussis immunisation recommendations in Australia aim at 'cocooning' infants by recommending immunisation in adults who are most likely to come into contact with them.[23] A universal adult immunisation strategy would be difficult to implement, as it is challenging to reach adults for immunisation.[24,25] The only current universal adult immunisation recommendations in Australia are a diphtheria-tetanus booster at 50 years of age and influenza (annually) and pneumococcal (5-yearly) vaccines from 65 years of age.[23]

The control of pertussis in all Australian states and territories remains a challenge despite a long history of immunisation and repeated modifications to the schedule. Immunisation has led to a change in the age distribution of cases, bringing about new issues with regard to diagnostic practices and future recommendations for immunisation. With the burden of disease now largely in adults, the current focus needs to be in protecting infants too young to be vaccinated and further defining the true morbidity of the disease in the elderly population.

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Appendix

Appendix 1. Age-specific pertussis notification rates, Australia 1995 to 2005, by state or territory

State or territory	Age group					
	<1	1–4	5–9	10–19	20–59	60+
ACT						
1995	135.0	16.4	53.1	2.1	5.6	3.5
1996	44.8	16.4	17.7	30.8	7.3	10.6
1997	70.8	46.2	66.8	47.3	28.0	17.7
1998	24.3	23.1	40.1	68.8	24.8	23.6
1999	71.5	5.8	22.3	49.5	22.6	26.6
2000	72.6	57.8	111.4	174.2	44.2	23.6
2001	74.3	12.5	4.8	58.9	24.2	14.0
2002	25.2	0.0	4.8	37.1	18.0	2.3
2003	124.6	62.4	52.4	421.2	70.1	21.0
2004	71.4	12.5	9.5	34.9	42.8	41.9
2005	23.8	37.4	47.7	69.8	105.1	139.8
Average	67.4	26.4	39.6	89.6	36.3	31.7
NSW						
1995	91.6	34.8	74.8	34.2	14.3	8.5
1996	80.6	29.1	49.5	25.3	14.4	8.4
1997	234.1	90.2	218.6	126.6	41.3	19.6
1998	139.9	43.4	96.7	59.7	26.3	15.6
1999	53.6	17.9	24.3	29.4	20.8	18.1
2000	134.3	46.2	65.2	144.3	43.0	26.1
2001	216.6	47.1	73.8	175.4	44.4	22.9
2002	115.3	30.9	24.4	67.4	24.8	12.8
2003	111.8	40.6	34.2	96.4	35.7	20.1
2004	99.6	46.2	25.8	72.9	53.2	42.6
2005	129.7	44.5	22.9	41.8	105.3	97.2
Average	128.1	42.8	64.8	79.0	39.2	27.5

Appendix 1. Age-specific pertussis notification rates, Australia 1995 to 2005, by state or territory, *continued*

State or territory	Age group					
	<1	1–4	5–9	10–19	20–59	60+
NT						
1995	384.2	161.9	215.4	46.7	42.2	0.0
1996	54.1	7.4	19.0	10.8	4.9	0.0
1997	56.5	35.2	29.3	16.7	5.2	9.7
1998	83.6	0.0	23.4	6.7	13.1	0.0
1999	28.3	0.0	0.0	3.3	0.0	0.0
2000	28.0	7.0	5.9	6.7	3.5	0.0
2001	762.9	71.9	108.2	171.2	33.4	6.7
2002	137.1	28.7	30.0	35.5	8.4	13.3
2003	26.9	0.0	0.0	0.0	3.3	0.0
2004	27.1	14.4	18.0	32.3	8.4	6.7
2005	0.0	8.2	3.1	2.9	6.2	12.9
Average	167.5	35.2	41.5	33.9	14.3	9.8
Qld						
1995	56.7	76.3	158.9	65.8	24.9	15.6
1996	25.0	25.4	74.1	47.9	16.5	7.6
1997	109.5	49.8	195.1	142.8	25.4	10.5
1998	67.8	42.2	102.9	88.2	26.2	13.4
1999	35.9	11.7	25.7	47.1	26.3	22.2
2000	31.3	10.7	20.6	35.1	11.3	10.9
2001	133.7	28.8	46.3	123.1	27.8	15.0
2002	186.5	33.8	32.5	128.9	34.5	22.8
2003	71.6	14.4	10.5	39.7	15.7	10.1
2004	63.3	14.4	12.3	48.6	24.8	20.6
2005	57.3	26.6	13.5	68.0	112.7	106.5
Average	81.4	30.1	61.2	76.3	25.4	18.8
SA						
1995	118.4	37.7	88.4	69.3	18.1	10.8
1996	109.8	55.3	182.7	140.0	42.4	19.7
1997	414.0	117.7	392.2	247.2	60.9	30.5
1998	152.7	45.3	110.0	84.6	20.4	14.5
1999	21.8	15.5	13.0	25.0	13.6	13.8
2000	66.7	28.4	37.0	101.1	31.8	20.0
2001	481.8	77.1	136.2	353.7	100.9	55.4
2002	159.6	18.2	20.8	51.4	28.9	21.1
2003	52.1	5.6	7.3	10.3	16.8	16.5
2004	97.5	35.0	28.1	83.2	66.8	63.6
2005	162.9	42.2	16.5	21.3	23.7	20.9
Average	157.6	42.4	94.6	112.2	47.0	34.9

Appendix 1. Age-specific pertussis notification rates, Australia 1995 to 2005, by state or territory, *continued*

State or territory	Age group					
	<1	1–4	5–9	10–19	20–59	60+
Tas						
1995	87.8	60.0	77.2	26.9	12.7	10.4
1996	15.0	0.0	8.3	9.9	5.6	7.8
1997	96.0	22.6	23.1	42.0	20.1	14.7
1998	17.1	3.8	23.1	7.2	12.6	9.8
1999	46.8	48.9	205.2	380.7	96.8	51.3
2000	50.8	18.8	20.2	57.9	29.9	14.7
2001	64.7	4.1	9.2	46.6	19.4	14.0
2002	68.5	0.0	3.1	10.2	6.6	8.6
2003	225.3	12.3	18.5	46.6	24.1	17.2
2004	34.5	0.0	0.0	4.4	7.0	15.0
2005	243.8	64.7	18.0	38.8	36.8	53.3
Average	63.9	16.8	36.4	57.7	21.9	15.9
Vic						
1995	69.4	8.9	19.1	13.5	5.6	4.2
1996	142.2	28.7	91.7	50.6	18.5	9.9
1997	117.6	49.5	92.5	60.0	20.2	14.2
1998	44.7	28.5	40.0	38.8	15.7	8.3
1999	35.2	17.8	25.8	47.1	16.5	7.6
2000	51.3	13.5	14.0	39.6	11.2	8.9
2001	70.0	7.8	14.7	39.7	14.1	10.4
2002	103.0	9.0	9.4	41.9	14.4	9.2
2003	68.1	6.6	5.9	27.5	10.6	8.1
2004	67.5	15.6	6.2	31.9	15.7	13.5
2005	112.4	26.8	14.9	67.2	42.6	50.7
Average	71.1	18.6	29.5	37.3	15.3	11.2
WA						
1995	135.2	48.1	50.0	27.0	11.5	3.0
1996	98.9	20.6	38.5	23.0	6.6	4.8
1997	513.1	145.9	276.5	93.8	26.0	15.0
1998	210.6	41.8	53.8	13.5	7.3	1.9
1999	23.8	9.7	12.7	8.6	3.2	1.9
2000	47.9	7.8	5.2	12.0	2.9	1.5
2001	112.9	21.1	10.5	28.3	6.4	3.5
2002	146.7	27.1	12.7	22.7	7.2	2.8
2003	113.8	24.1	11.2	30.1	8.1	4.4
2004	401.2	140.5	142.2	259.1	72.0	39.2
2005	12.9	16.8	6.2	21.4	25.2	26.3
Average	178.8	48.1	57.4	50.0	16.3	9.6