Immunisation coverage annual report, 2007

Brynley Hull, Shelley Deeks, Rob Menzies, Peter McIntyre

Executive summary

Currently, the routine reporting of immunisation coverage data from the Australian Childhood Immunisation Register is done for 3 key milestone ages, nationally and by jurisdiction, at quarterly intervals. This reporting is limited in a number of ways as timeliness of receipt of vaccines is not captured, not all vaccines currently in the National Immunisation Program (NIP) are included and coverage is reported only at the jurisdictional level, with information about smaller geographic units not provided. The aim of this 1st annual immunisation coverage report is to highlight important trends and significant issues including overall immunisation coverage by Indigenous status and for individual vaccines in the NIP; timeliness of immunisation; and immunisation coverage mapping in smaller geographic areas.

The data in this report reveals that Immunise Australia Program coverage targets have been reached for children at both 12 and 24 months of age and are being approached for children at 6 years of age. With up to 3% of Australian parents not immunising their children for philosophical or religious reasons, it will be difficult for 'fully immunised' coverage estimates to exceed 95%, especially as the reporting of immunisation encounters is still not totally complete.

Coverage at 24 months of age exceeded that at 12 months of age for the first time at the end of 2003 and has remained higher since that time. This is likely related to the removal of the 18-month booster dose of DTP, as well as the impact of immunisation incentives. Coverage estimates for the 6-year age group also increased noticeably in June 2006. A possible factor in this increase in coverage is the introduction of the multivalent combination vaccine Infanrix-IPV in November 2005.

A number of vaccines in the NIP are not included when determining 'fully immunised' status or eligibility for incentive payments. Despite this, coverage data for the 7vPCV and meningococcal C vaccines is comparable with currently reported vaccines, while coverage for varicella is lower.

Coverage for vaccines recommended for Indigenous children only (i.e. hepatitis A and pneumococcal polysaccharide vaccine) remains sub-optimal. This has been previously reported for other vaccines for both children and adults.

Although coverage data reveal that most children eventually complete the scheduled vaccination series by the 24-month milestone, many do not do so in a timely manner. While there have been significant improvements in coverage in Australia over the past 4–5 years, vaccination delay as measured in this report has increased slightly.

Although Indigenous children in Australia have coverage levels that are similar to non-Indigenous children at 24 months of age, the disparity in delay in receipt of vaccination between Indigenous and non-Indigenous children, which is up to 17% for the 3rd dose of DTP and 7vPCV, remains a challenge.

Rationale for an annual immunisation coverage report

Currently, the routine reporting of immunisation coverage data from the Australian Childhood Immunisation Register (ACIR) is done for 3 key milestone ages, nationally and by jurisdiction, at quarterly intervals and published in the *Communicable Disease Intelligence* (*CDI*) journal.[1,2] The age milestones are 12 months (for vaccines due at 6 months), 24 months (for vaccines due at 12 months), and 6 years (for vaccines due at 4 years). From the beginning of 2008, immunisation coverage for vaccinations due by 4 years of age has been assessed earlier, at 5 years rather than 6 years of age.[3] This reporting is limited in a number of ways. First, timeliness of receipt of recommended vaccines is not captured; second, these coverage calculations do not include all vaccines currently in the National Immunisation Program (NIP); and third, coverage is reported only at jurisdictional level and information about smaller geographic units is not provided.

Timeliness of immunisation

The most widely accepted indicator of national immunisation coverage internationally is the proportion of children who have received all recommended vaccines by 24 months of age, as prescribed by the World Health Organization,[4] but this does not capture late immunisation, which may be substantial by 24 months of age. Late acquisition of immunity due to delay in immunisation is especially important for a number of severe infections of young infants, such as pertussis and invasive disease due to *Haemophilus influenzae* type b (Hib) or *Streptococcus pneumoniae*. Immunisation at the earliest appropriate age (timeliness) is thus an important public health goal, especially for countries such as Australia where high levels of vaccine

coverage at milestone ages have been achieved. However, published reports on timeliness of vaccine administration are limited primarily to the United States of America[5–12] and 1 report from Sweden,[13] and methods of measuring timeliness have varied.

Reporting on all National Immunisation Program vaccines

Table 1 shows the Australian National Immunisation Program Schedule (NIPS) in 2007. Only those vaccines that were on the schedule prior to 1993 were considered when determining whether a child is 'fully immunised' for the calculation of coverage rates and payment of parental and provider incentives. The Australian Government had not made a decision to include vaccines added after this date in the assessment of vaccination status.

The vaccines included in the assessment of vaccination status were: diphtheria, *Haemophilus influenzae* b (Hib), hepatitis B, measles, mumps, pertussis, polio, rubella and tetanus. Vaccines not included are: meningococcal C vaccine (Men C), 7-valent pneumococcal conjugate vaccine (7vPCV), and rotavirus vaccine. Varicella vaccine was not included for coverage assessment but, in 2007, eligible immunisation providers received an information payment (up to $6) and a Service Incentive Payment (SIP) ($18.50) for reporting completion of the NIP 18-month schedule point, at which varicella vaccine was given.[14,15]

Other vaccines that were not included in the assessment of vaccination status for coverage or payment eligibility purposes were NIP vaccines recommended for specific populations, that is hepatitis A and 23-valent pneumococcal polysaccharide (23vPPV) vaccines, and non-NIP vaccines such as Bacillus Calmette-Guérin (BCG).

Geographic units for reporting of immunisation coverage

Data at the local, jurisdictional, and national level is necessary for comprehensive planning and delivery of immunisation programs. Without this information, public health administrators cannot reliably detect low rates of immunisation in specific geographic areas or populations, especially with respect to prevention of disease outbreaks in communities. While national immunisation coverage may be above the targets for 12 and 24 months of age at the national and jurisdictional level, less is known about coverage in smaller regions within jurisdictions. To date, mapping has revealed pockets of low coverage in inner urban and some rural areas, which are likely to be more a result of reporting problems in the former.[16] Immunisation coverage maps based on ACIR data by region are of interest to a range of national stakeholders but are not routinely published.

Two of the important and unique features of the ACIR are the ability to record a conscientious objection to immunisation and the ability to calculate the percentage of children who have no vaccines recorded. A previous unpublished National Centre for Immunisation Research and Surveillance (NCIRS) study found that having no vaccines recorded on the ACIR was a good proxy for conscientious objection to immunisation, although lack of reporting by providers may sometimes be the cause. Examining trends in both the percentage of children with no vaccines recorded and the percentage

Table 1: Australian National Immunisation Program Schedule for children in 2007

Age	Vaccine									
Birth	Hep B									
2 months	Hep B*,†	DTPa*	Hib†,‡	IPV				7vPCV		Rotavirus
4 months	Hep B*,†	DTPa*	Hib†,‡	IPV				7vPCV		Rotavirus
6 months	Hep B*	DTPa*	Hib‡	IPV				7vPCV		Rotavirus¶
12 months	Hep B†		Hib†		MMR		Hep A§		Men C	
18 months						VZV		23vPPV‖		
4 years		DTPa		IPV	MMR					

* Diphtheria-tetanus-acellular pertussis/Hep B vaccine from May 2000 (Pathway 1).

† Hib PRP-OMP/hep B from May 2000 (Pathway 2).

‡ Hib PRP-OMP (Pathway 1) from May 2000.

§ Aboriginal and Torres Strait Islander children in high risk areas.

‖ 23-valent pneumococcal polysaccharide vaccine for Aboriginal and Torres Strait Islander children in high prevalence jurisdictions only from September 2003.

¶ 3rd dose of vaccine is dependent on vaccine brand used in state or territory.

of registered conscientious objectors to immunisation provides a more complete picture of geographic areas particularly affected by under-immunisation.

In recent years, the NCIRS has published a number of reports[4,17–28] examining aspects of immunisation coverage in Australia, including coverage for different vaccines, at different ages and for Indigenous children, as well as timeliness of immunisation and small area mapping. NCIRS has also assessed coverage rates for NIP vaccines not routinely reported in *CDI*; however, these have not been routinely published. The aim of this 1st annual immunisation coverage report is to combine all these data in one document, highlighting important trends and significant issues over the preceding 12 months. These include overall immunisation coverage by Indigenous status and for individual vaccines included on the NIP; timeliness of immunisation; and immunisation coverage mapping in smaller geographic areas.

Methods

The Australian Childhood Immunisation Register

The ACIR was established on 1 January 1996, and includes all children under the age of 7 years enrolled in Medicare.[19] Participation in the ACIR is opt-out so it constitutes a nearly complete population register, as approximately 99% of children are registered with Medicare by 12 months of age.[19] Children not enrolled in Medicare can also be added to the ACIR via a supplementary number. Since 2001, immunisations given overseas may be recorded if a provider endorses their validity. Data are transferred nightly from the Medicare database to the ACIR when a recognised immunisation provider supplies details of an eligible immunisation either through the Internet using the Medicare Australia web site or by submitting paper encounter forms, which are scanned at a central location. The existence of medical contraindications and conscientious objection to immunisation is also recorded on the ACIR. All vaccination records for a child remain on the register indefinitely, but no new immunisation encounter records are added after the 7th birthday.

For an immunisation to be recorded on the Register as a valid dose, it must be given in accordance with current National Health and Medical Research Council guidelines published in *The Australian Immunisation Handbook*.[29] Notifications falling outside these guidelines or duplicate notifications prompt an enquiry with the provider and, if their validity cannot be established, they are rejected.

Measuring immunisation coverage using the Australian Childhood Immunisation Register

The cohort method has been used for calculating coverage at the population level (national and state or territory)[30] since the ACIR's inception, with each cohort defined by date of birth in 3-month age groups. Cohort immunisation status is assessed at 12 months of age (for vaccines due at 6 months), 24 months of age (for vaccines due at 12 months), and 6 years of age (for vaccines due at 4–5 years). A minimum 3-month lag period is allowed for late notification of immunisations to the Register, but only immunisations given on or before a child's 1st, 2nd or 6th birthday are considered.[30] If a child's records indicate receipt of the last dose of a vaccine that requires more than 1 dose to complete the series, it is assumed that earlier vaccinations in the sequence have been given. This assumption has been shown to be valid.[21,22]

Full year cohorts are predominantly used in the analyses in this report, also with a minimum 3-month lag for late notifications. These cohorts are children born between 1 January and 31 December 2006 for the 12-month milestone age; children born between 1 January and 31 December 2005 for the 24-month milestone age; and children born between 1 January and 31 December 2001 for the 6-year (72-month) milestone age. Three-month cohorts are also used but for time trend analyses only.

The proportion of children designated as 'fully immunised' is calculated using the number of Medicare-registered children completely immunised with the vaccines of interest by the designated age as the numerator and the total number of Medicare-registered children in the age cohort as the denominator. 'Fully immunised' at 12 months of age is defined as a child having a record on the ACIR of 3 doses of a diphtheria (D), tetanus (T) and pertussis-containing (P) vaccine, 3 doses of polio vaccine, 2 or 3 doses of Hib vaccine, and 2 or 3 doses of hepatitis B vaccine. 'Fully immunised' at 24 months of age is defined as a child having a record on the ACIR of 3 doses of a DTP-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of Hib vaccine, 2 or 3 doses of hepatitis B vaccine, and 1 dose of a measles, mumps and rubella-containing (MMR) vaccine. 'Fully immunised' at 6 years of age is defined as a child having a record on the ACIR of 4 doses of a DTP-containing vaccine, 4 doses of polio vaccine, and 2 doses of an MMR-containing vaccine.

Immunisation coverage estimates were also calculated for individual NIP vaccines, including the 6 NIP vaccines not routinely reported in *CDI*. They were: 3 doses of 7vPCV due by 12 months of age; 1 dose of varicella vaccine and 1 dose of meningococcal C vaccine due by 24 months of

age; 2 doses of hepatitis A vaccine in Indigenous children due by 30 months of age; and 1 dose of 23-valent pneumococcal polysaccharide vaccine in Indigenous children due by 36 months of age. In addition, 1 dose of rotavirus vaccine due by 4 months of age was assessed. Although this is not the complete series for rotavirus vaccine, 1 dose was assessed as the vaccine was only added to the NIP in July 2007, the year under surveillance for this report. The complete rotavirus vaccine series will be assessed in subsequent annual reports.

Timeliness

Age-appropriate immunisation was defined as receipt of a scheduled vaccine dose within 30 days of the recommended age. For example, a child who received the 1st dose of DTP (due at 60 days of age) when he or she was more than 90 days of age was classified as not age-appropriately immunised (i.e. late for the dose). For descriptive purposes, we categorised the outcome measure for each dose as either 'no delay' (age-appropriately immunised), vaccines received 'too early' (greater than 30 days prior to when it was due), vaccine dose 'not recorded', vaccine received 'acceptably early' (within 30 days prior to when it was due), 'delay of between 1 to 6 months', or 'delay greater than 6 months'. However, we have only reported on the latter 2 categories within this report. All children included in the analysis were at least 36 months of age when the data were extracted and, therefore, old enough to potentially experience delays in immunisation greater than 6 months for immunisation due by 24 months of age or earlier. The interval between doses was not evaluated. Timeliness of different vaccines and doses was also compared by plotting the cumulative percentage receiving each vaccine dose by age, with the proportion ever immunised set as 100%.

Remoteness status

The area of residence of children was defined as accessible or remote using the Accessibility/Remoteness Index of Australia (ARIA), which was developed by the then Department of Health and Aged Care, and proposed as the national standard measure of remoteness for inclusion in the Australian Bureau of Statistics (ABS) 2001 census.[31] We define the 2 ARIA categories with most restricted access to services as 'remote' (approximately 2.6% of the Australian population) and all other areas as 'accessible'.

Indigenous status

Indigenous status on the ACIR is recorded as 'Indigenous', 'non-Indigenous' or 'unknown', as reported by the child's carer to Medicare, or by the immunisation provider to the ACIR. For this report we considered 2 categories of children: 'Indigenous' and 'non-Indigenous', combining children with unknown Indigenous status and those recorded as 'non-Indigenous' for the latter category. Coverage estimate time trends are presented from 2004 only, due to poor rates of reporting Indigenous status prior to then.[32]

Small area coverage

Coverage was calculated for ABS-defined Statistical Subdivisions (SSD).[33] We chose ABS-defined SSD as areas to be mapped because each is small enough to show differences within jurisdictions but not too small to render maps unreadable. The total number of children included in each cohort was approximately 275,000. Coverage was calculated using the cohort method described in *CDI*, March 1998.[30]

Maps were created using version 7 of the MapInfo mapping software[34] and the ABS Census Boundary Information. As postcode is the only geographical indicator on the ACIR, the ABS Postal Area to SLA Concordance 2006 was used to match ACIR postcodes to SSDs, in order to create a SSD field for each child in the relevant study cohorts.[35]

Conscientious objection/no vaccine recorded

A child must be registered with Medicare before its parent(s) can lodge a conscientious objection to immunisation. Parents can also object to immunisation but refuse to lodge any official objection to the ACIR. We used the percentage of children with no vaccines recorded on the ACIR as a proxy measure of the number of these children. Proportions of conscientious objectors and children with no vaccines recorded by region were calculated from the cohort of children registered with Medicare, and born between 1 January 2001 and 31 December 2006. At the time of data extraction on 31 March 2008, they were between 12 and 72 months of age. We chose this cohort when calculating proportions so that children under the age of 12 months were not included.

Results

Coverage estimates

Overall

The 2007 coverage estimates, calculated for full-year birth cohorts, for the 3 milestone ages of 12 months, 24 months and 6 years are provided in Tables 2, 3 and 4. Nationally, 'fully immunised' coverage and coverage for all individual vaccines for the 12-month and 24-month age groups are greater than the Immunise Australia Program's target of

Table 2: Percentage of children in 2007 immunised at 12 months of age, by vaccine and state or territory*

Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,636	93,305	3,633	57,759	18,511	6,237	68,181	28,612	280,874
Diphtheria, tetanus, pertussis (%)	94.1	92.0	91.0	92.0	91.7	92.6	92.9	89.7	92.0
Poliomyelitis (%)	94.2	91.9	91.1	91.9	91.7	92.5	92.8	89.7	91.9
Haemophilus influenzae type b (%)	96.1	94.9	95.0	93.9	94.4	95.5	94.9	93.4	94.5
Hepatitis B (%)	96.1	94.8	95.5	93.8	94.4	95.4	94.8	93.3	94.4
Fully immunised (%)	93.9	91.6	90.6	91.1	90.9	92.3	91.9	89.1	91.3

* For the birth cohort born in 2006, assessment date 31 March 2008.

Table 3: Percentage of children in 2007 immunised at 24 months of age, by vaccine and state or territory*

Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,378	90,908	3,602	57,278	17,942	6,029	65,428	27,393	272,958
Diphtheria, tetanus, pertussis (%)	95.4	95.1	96.1	94.6	95.2	96.6	95.8	94.2	95.1
Poliomyelitis (%)	95.4	95.0	96.0	94.6	95.1	96.5	95.8	94.1	95.1
Haemophilus influenzae type b (%)	95.2	94.9	94.5	93.7	93.9	96.4	94.7	93.7	94.4
Hepatitis B (%)	96.0	95.8	97.1	95.5	95.8	96.7	96.4	95.1	95.9
Measles, mumps, rubella (%)	94.4	93.9	95.5	93.7	94.1	95.6	94.9	93.0	94.1
Fully immunised (%)	93.4	92.5	93.6	92.2	92.8	95.0	93.8	91.0	92.7

* For the birth cohort born in 2005, assessment date 31 March 2008.

Table 4: Percentage of children in 2007 immunised at 6 years of age, by vaccine and state or territory*

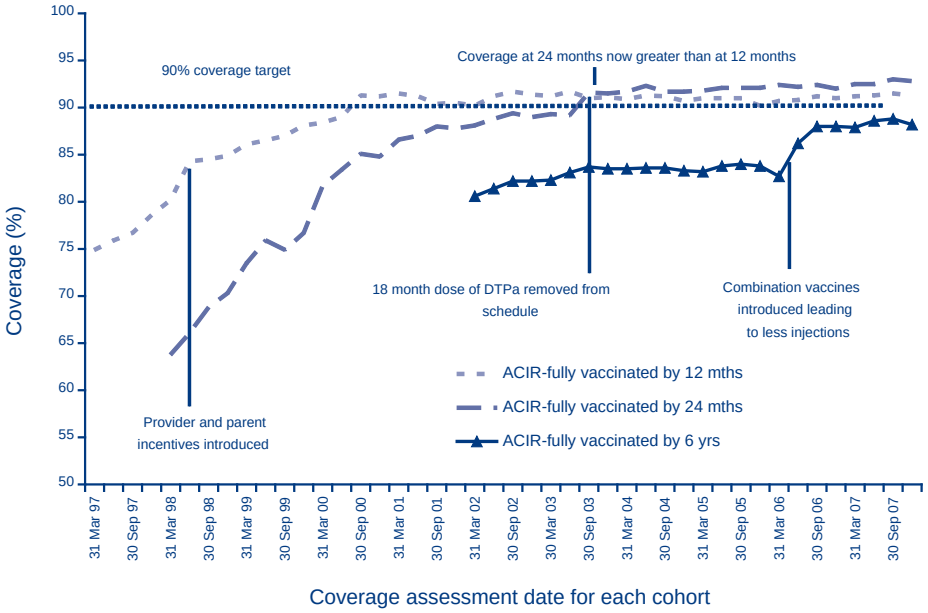
Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,153	88,221	3,615	55,185	18,139	6,012	63,806	26,753	265,884
Diphtheria, tetanus, pertussis (%)	90.4	89.1	87.9	88.8	87.3	89.4	91.4	85.4	89.1
Poliomyelitis (%)	90.5	89.0	87.8	88.9	87.3	89.3	91.5	85.5	89.1
Measles, mumps, rubella (%)	90.1	89.1	88.0	88.8	87.2	89.5	91.4	85.5	89.1
Fully immunised (%)	89.5	88.3	87.2	88.1	86.7	88.7	90.9	84.5	88.4

* For the birth cohort born in 2001, assessment date 31 March 2008.

90%. Recorded coverage for the 6-year age group is approaching, but still below, the target. The trends in 'fully immunised' childhood vaccination coverage in Australia at 12 months, 24 months, and at 6 years of age are shown in Figure 1. Coverage was calculated for 42 consecutive 3-month cohorts born from 1 January 1996 to 31 December 2006. For all vaccines due by 1 year of age, coverage estimates increased steadily from 75% for the 1st cohort to 91% by the 42nd cohort, assessed on 31 December 2007. For all vaccines due by 24 months of age, coverage estimates also increased steadily from 64% for the 1st cohort to 92.8% by December 2007. Coverage estimates for all vaccines due by 6 years of age were first reported in *CDI* in 2002, and have also increased steadily from 80.6% in early 2002 to 87.3% in late 2007.

Coverage estimates for the 24-month age group increased substantially and suddenly in

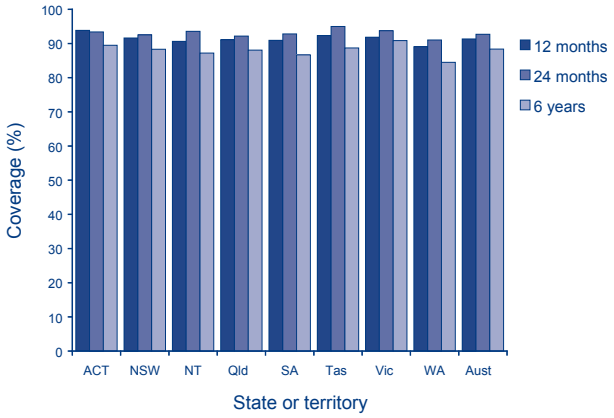
Figure 1: Trends in 'fully immunised' vaccination coverage, Australia, 1997 to 2007, by age cohort



September 2003 to 91.6% following the removal from the immunisation schedule of the 4th dose of DTPa (due at 18 months of age) from this quarter onwards. Coverage estimates for the 12-month age group have, however, remained steady over the past 5 years, fluctuating around the 91% level.

There is a clear trend of increasing vaccination coverage over time for children of all age groups assessed, with the 2 youngest age cohorts having the highest coverage. Coverage at 24 months of age exceeded that at 12 months of age for the first time at the end of 2003 and has remained higher since that time. Coverage estimates for the 6-year age group also had a noticeable increase in June 2006, corresponding with the introduction of combination vaccines.

Figure 2: 'Fully immunised' vaccination coverage estimates, 2007, by state or territory



Estimates of the proportion of children classified as 'fully immunised' by state and territory for all 3 milestones are shown in Figure 2. There are variations in 'fully immunised' coverage for all 3 milestones. Almost all jurisdictions, except for Western Australia, reached the Immunise Australia Program target of 90% coverage for the 1st and 2nd milestone vaccines. However, only 1 jurisdiction, Victoria, attained the 90% coverage target for the 3rd milestone at 6 years of age.

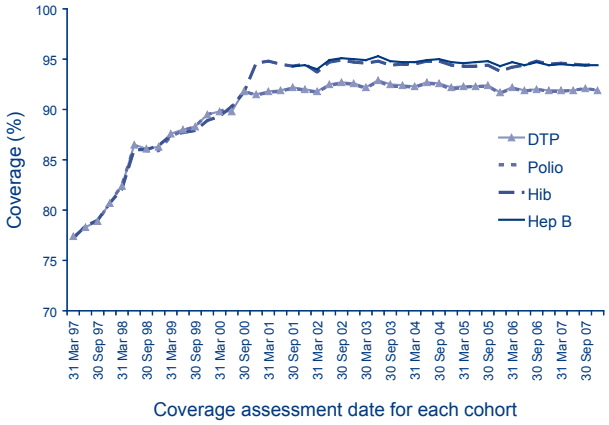
Individual vaccines

The trends in childhood vaccination coverage in Australia for individual vaccines due at 12 months of age (DTP, polio, Hib and hepatitis B) are shown in Figure 3, calculated for consecutive 3-month cohorts born from 1 January 1996 to 31 December 2006. Coverage estimates for all vaccines remained relatively stable throughout the latter part of 2001 to 2007. Coverage for the Hib and hepatitis B vaccines is greater than DTP and polio coverage. This is likely to be largely due to the change in the immunisation schedule in mid-2000, altering the algorithm used to calculate coverage at 12 months of age such that a record of 2 doses of Hib and hepatitis B on the ACIR renders a child 'fully immunised' for these vaccines.

The trends in childhood vaccination coverage in Australia for individual vaccines due at 24 months of age (DTP, polio, Hib, hepatitis B and MMR) are shown in Figure 4, calculated for consecutive 3-month cohorts born from 1 January 1996 to 31 December

2005. The significant increase in coverage for DTP during 2003 has been previously mentioned. For most of the study period, hepatitis B coverage was higher than for all other vaccines, just below 96%, due to the coverage algorithm changes described above, while coverage was lowest for the MMR and Hib vaccines.

Figure 3: Trends in vaccination coverage estimates for individual vaccines at 12 months of age (DTP, polio, hepatitis B and Hib)*

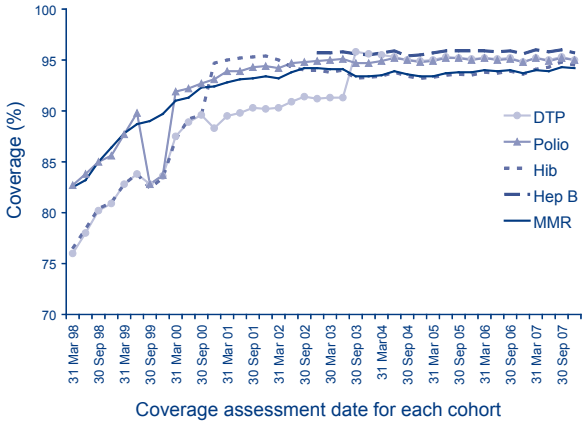


* 3rd dose of DTP and polio, 2nd or 3rd dose of Hib and Hep B

By 3-month birth cohorts born between 1 January 1996 and 31 December 2006. Coverage assessment date was 12 months after the last birth date of each cohort.

Source: Australian Childhood Immunisation Register.

Figure 4: Trends in vaccination coverage estimates for individual vaccines at 24 months of age (DTP, polio, hepatitis B, Hib and MMR)*



* 3rd dose of DTP and polio, 2nd or 3rd dose of Hib and Hep B, 1 dose MMR.

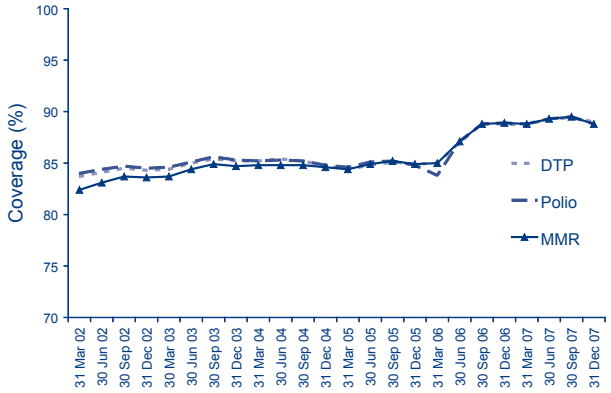
By 3-month birth cohorts born between 1 January 1996 and 31 December 2005. Coverage assessment date was 24 months after the last birth date of each cohort.

Source: Australian Childhood Immunisation Register.

However, coverage for all vaccines currently assessed at this age has been consistent for each of them, as evidenced by the very flat curves over this time.

The trends in childhood vaccination coverage in Australia for individual vaccines due by 6 years of age (DTP, polio and MMR) are shown in Figure 5, calculated for consecutive 3-month cohorts born from 1 January 1996 to 31 December 2001. Coverage for all 3 vaccines was almost identical and remained steady across the whole period, at approximately 85%, until mid-2006 when a sharp increase of almost 5% was recorded. This increase may be related to either or both of the campaigns to promote parental awareness of the 4-year milestone, and school entry provisions in many jurisdictions becoming simpler to administer due to uniform ACIR certificates.

Figure 5: Trends in vaccination coverage estimates for individual vaccines at 6 years of age (DTP, polio, and MMR)*



* 4th dose of DTP and polio, 2nd dose of MMR.

By 3-month birth cohorts born between 1 January 1996 and 31 December 2001. Coverage assessment date was 72 months after the last birth date of each cohort.

Source: Australian Childhood Immunisation Register.

Coverage estimates for Indigenous children

Vaccination coverage estimates in 2007 for the 3 milestone ages for individual vaccines by Indigenous status are shown in Table 5. These show that coverage is lower for Indigenous children than non-Indigenous at all 3 age milestones, with the difference being greatest at 12 months of age. The difference in coverage at 12 months of age has been relatively consistent for the past 6 years. However, the coverage differential between Indigenous and non-Indigenous children for individual vaccines varies, with coverage at

Table 5: Vaccination coverage estimates, 2007, by age, vaccine and Indigenous status

Vaccine	Milestone age	Indigenous	Non-Indigenous
DTP	12 months*	84.8	92.2
	24 months†	94.0	94.8
	6 years‡	87.7	88.9
Polio	12 months*	84.8	92.2
	24 months†	93.9	94.8
	6 years‡	87.9	89.1
Hib	12 months*	92.2	94.5
	24 months†	91.8	93.6
	6 years‡	N/A§	N/A§
Hep B	12 months*	92.6	94.3
	24 months†	97.0	95.5
	6 years‡	N/A§	N/A§
MMR	12 months*	N/A§	N/A§
	24 months†	93.6	93.9
	6 years‡	88.2	89.0

* Birth cohort born 1 January 2006 – 31 December 2006, data as at 31 March 2008.

† Birth cohort born 1 January 2005 – 31 December 2005, data as at 31 March 2008.

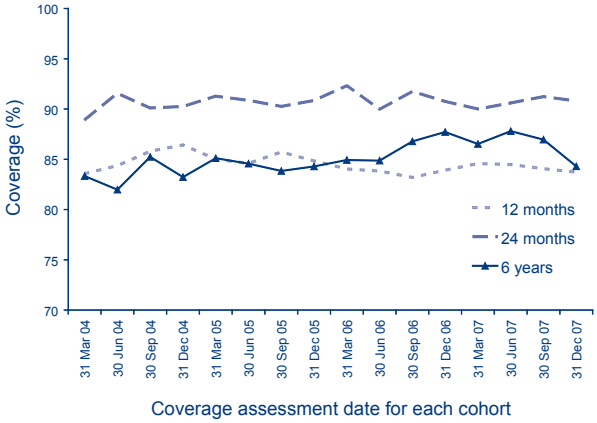
‡ Birth cohort born 1 January 2001 – 31 December 2001, data as at 31 March 2008.

§ Not included in coverage estimates for that group.

24 months of age for most vaccines being very similar for both groups and greater among Indigenous children for hepatitis B vaccine.

The trends in 'fully immunised' childhood vaccination coverage in Australia at 12 months, 24 months, and 6 years of age for Indigenous children since 2004 are shown in Figure 6. Coverage was calculated for consecutive 3-month cohorts assessed from 1 March 2004 to 31 December 2007. Coverage for all vaccines due by 24 months of age has consistently remained higher than at 12 months

Figure 6: Trends in 'fully immunised' vaccination coverage for Indigenous children in Australia, 2004 to 2007, by age cohorts



and 6 years of age. Since the beginning of 2006, coverage for Indigenous children at 6 years of age eclipsed coverage at 12 months of age.

Table 6 shows 'fully immunised' vaccination coverage estimates in 2007 for Indigenous children at the 3 milestone ages by state or territory. At age 12 months, the proportion of Indigenous children fully vaccinated was 84.2%, compared with 91.3% for all Australian children (i.e. includes both Indigenous and non-Indigenous children) and was lower among Indigenous children in all jurisdictions. The extent of the difference varied among jurisdictions, reaching more than 10 percentage points in some. However, by age 24 months, coverage disparities between Indigenous and all Australian children had almost disappeared nationally and in most jurisdictions, with the proportion fully vaccinated at 90.7% for Indigenous and 92.7% for all Australian children nationally (Table 6).

At 6 years of age, the proportion recorded as being 'fully vaccinated' was generally lower than that at earlier age milestones. There was little difference between Indigenous and all Australian children at the national level (86.4% and 88.4%, respectively)

Table 6: Percentage of Indigenous children fully immunised at 12 months, 24 months and 6 years of age, 2007, by state or territory *

Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
12 months – fully immunised (%)	87.2	84.9	87.6	85.6	78.1	91.5	86.8	76.9	84.2
24 months – fully immunised (%)	91.8	91.4	93.7	91.5	88.6	93.6	91.3	85.1	90.7
6 years— fully immunised (%)	80.2	84.7	92.1	91.1	73.8	85.9	87.4	79.4	86.4

* Assessment date 31 March 2008

while, for individual jurisdictions, coverage in Indigenous children ranged from 13% lower (in South Australia) to 5% higher (in the Northern Territory) than in all Australian children (Table 6).

Timeliness of the 3rd dose of DTP and the 1st dose of MMR vaccine by Indigenous status and remoteness is shown in Table 7. For both vaccines, the proportion with long delays (i.e. greater than 6 months) was 2–4 times higher in Indigenous children than in non-Indigenous children, with greater differentials in accessible than in remote areas. A similar pattern was seen for delays of 1–6 months. When we examined the degree of vaccination delay among Indigenous children only by remoteness, we found that, for the 3rd dose of DTP vaccine, the proportion with short delays was greater among Indigenous children residing in remote areas than in accessible areas (36% versus 31%).

Coverage for National Immunisation Program vaccines not routinely reported

7vPCV

7vPCV was first added to the NIP in January 2005. Figure 7 shows that since coverage was first calculated for this vaccine in early 2006, it has remained at high levels, with a slight increase from 89% to 91%. Coverage of 7vPCV is similar in all jurisdictions at greater than or approaching 90% (Table 8).

Rotavirus

Rotavirus vaccine was added to the NIP in July 2007 so there is only a small series of trend data available. Assessment is limited to receipt of the 1st dose by 4 months of age and is currently lower than that for 7vPCV. Reported coverage for 1 dose of rotavirus at 4 months of age does vary by jurisdiction, from 80.3% in Tasmania to 87.2% and 91% in the Northern Territory and Australian Capital Territory, respectively (Table 8).

Meningococcal C

Meningococcal C vaccine was added to the NIP in January 2003. Figure 8 shows that since coverage was first calculated for this vaccine in early 2006, it has remained at high levels, with an increase over 2 years from 88% to a high of 93%. There is little variation by jurisdiction with all jurisdictions greater than 92% (Table 8).

Figure 7: Trends in coverage for 7vPCV and rotavirus vaccines

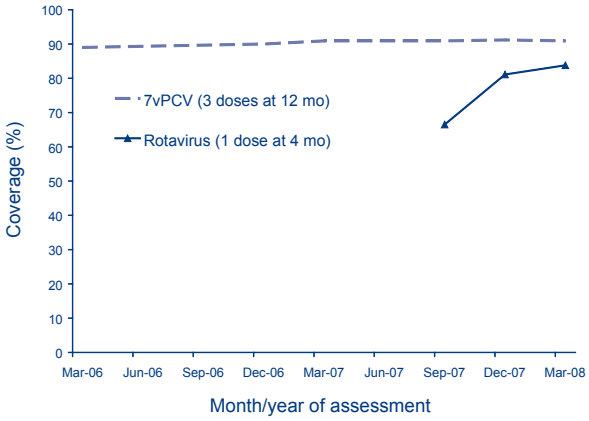


Figure 8: Trends in coverage for meningococcal C (Men C) and varicella vaccines

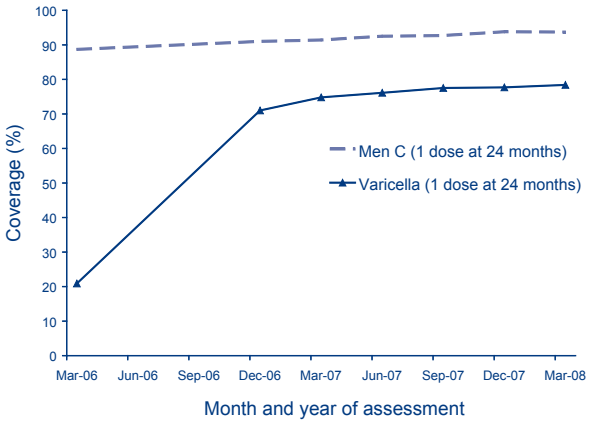


Table 7: Vaccination delay, by Indigenous and remoteness status for the cohort of children born in 2005, Australia

Vaccine dose	Indigenous status	Remoteness	1–6 months delay %	> 6 months delay %
DTP3	Indigenous	Accessible	31	11
		Remote	36	9
	Non-Indigenous	Accessible	19	3
		Remote	20	3
MMR1	Indigenous	Accessible	34	7
		Remote	32	6
	Non-Indigenous	Accessible	27	3
		Remote	27	2

Varicella

Varicella vaccine was added to the NIP in November 2005. Figure 8 shows coverage for this vaccine has consistently been 10–15 percentage points lower than that for meningococcal C vaccine, with coverage just below 80% for the latest assessment. This is probably partly due to the shorter time varicella has been on the NIP, the presence of pre-existing immunity as a reason for non-vaccination and lower acceptance by parents and doctors of the need for varicella vaccination, and the recommendation to give the vaccine at 18 months of age, which was historically associated with lower coverage and is not as well established as a milestone, especially following removal of the 18-month pertussis booster in 2003. Varicella vaccine coverage does vary by jurisdiction from 75.8% in Western Australia to greater than 81% in Queensland and Tasmania (Table 8). Data are also available from the ACIR on the numbers of reports from GPs stating that children, born since May 2004, have natural immunity to varicella and do not require varicella vaccination. Reports of natural immunity to varicella slowly increased from 109 in January 2006 to a peak of 2,440 in July 2007, but have decreased since then to around 1,000 reports per quarter (not shown). However, the number of natural immunity reports as a proportion of the ACIR child population is small and would not have an important effect on varicella coverage estimates.

Hepatitis A

Hepatitis A vaccine was available in Australia prior to the development of the ACIR in 1996 and has been included on the NIP for Indigenous children in the Northern Territory, South Australia, Western Australia, and in Queensland since November 2005. Since December 2006, coverage of 2 doses of hepatitis A vaccine by 30 months of age for Indigenous children has increased from below 20% to just under 50% (Figure 9). There is a large variation in reported hepatitis A vaccine coverage by jurisdiction, from a low of 23.6% in South Australia to a high of 79.9% in the Northern Territory (Table 8).

23vPPV

The 23vPPV has been available in Australia since 1983 and recommended for Indigenous children in those 4 jurisdictions as a booster at 18–24 months of age since 2001; coverage has consistently been

Figure 9: Trends in coverage for hepatitis A and pneumococcal polysaccharide (23vPPV) vaccines for Indigenous children

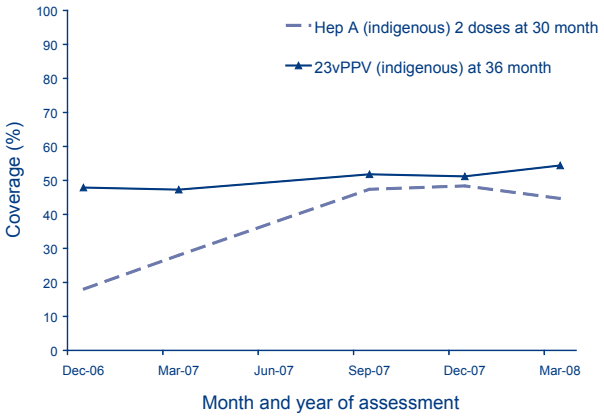


Table 8: Vaccination coverage for 7vPCV, rotavirus, meningococcal C, varicella, hepatitis A (Indigenous only) and 23vPPV (Indigenous only) in 2007, by state or territory, assessment date 31 March 2008

State or territory	Vaccine type					
	7vPCV*	Rotavirus†	Men C‡	Varicella§	Hep A (Indigenous only)‖	23vPPV (Indigenous only)¶
ACT	93.8	91.0	94.8	76.0	na	na
NSW	90.9	83.4	93.4	76.8	na	na
NT	90.5	87.2	94.4	80.5	79.9	74.2
Qld	91.1	84.5	93.5	81.8	32.3	50.3
SA	90.2	85.9	93.6	78.7	23.6	37.0
Tas	91.8	80.3	93.8	81.1	na	na
Vic	91.7	83.7	94.5	78.4	na	na
WA	88.5	81.5	92.7	75.8	50.1	53.5
Aust	90.9	83.8	93.7	78.4	44.7	54.4

* 3 doses at 12 months of age.
† 1 dose at 4 months of age.
‡ 1 dose at 24 months of age.
§ 1 dose at 24 months of age.
‖ 2 doses at 30 months of age.
¶ 1 dose at 36 months of age.

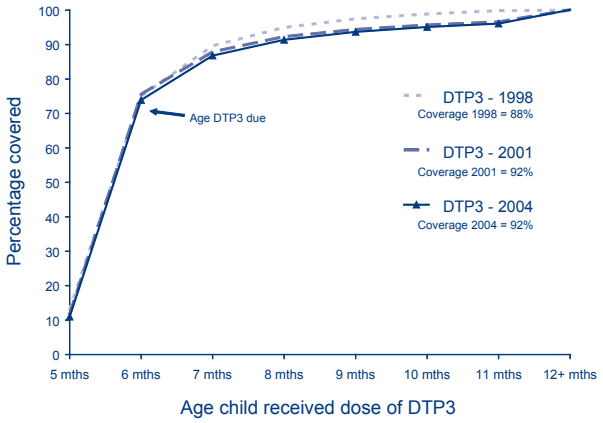
around 50% (Figure 9). There is a large variation in 23vPPV coverage by jurisdiction from a low of 37% in South Australia to a high of 74.2% in the Northern Territory (Table 8).

Timeliness of immunisation

Timeliness has been examined for vaccines requiring both multiple doses (DTP, 7vPCV and MMR) and a single dose (Men C) at 12 and 24 months of age.

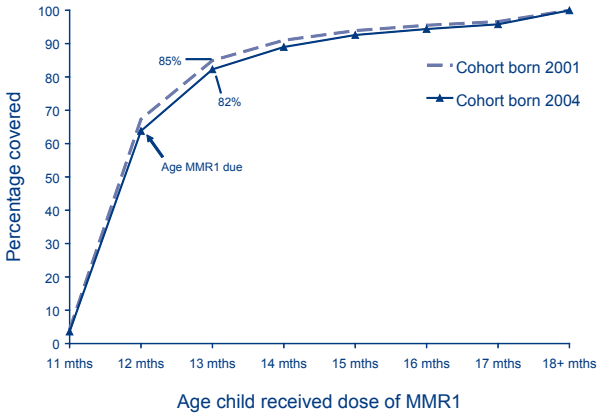
Since 1998, the proportion with timely receipt of DTP vaccine has decreased slightly, although coverage increased over this period from 88% to 92% (Figure 10). Across the 4-year period, 2001–2004, timely receipt of 1 dose of MMR vaccine also decreased by 3 percentage points, although estimated coverage by 24 months of age remained stable at almost 94% (Figure 11).

Figure 10: Trends in timeliness of the 3rd dose of DTP vaccine (DTP3) – cohorts born in 1998, 2001 and 2004*



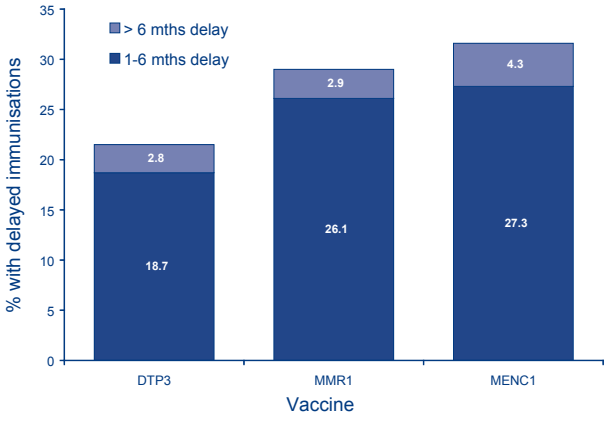
* Percentage covered = number of children who received vaccine dose at particular ages/the total number of children who received the vaccine dose.

Figure 11: Trends in timeliness of the 1st dose of MMR vaccine (MMR1) – cohorts born in 2001 and 2004*



* Percentage covered = number of children who received vaccine dose at particular ages/the total number of children who received the vaccine dose.

Figure 12: Vaccination delay for the 3rd dose of DTP vaccine (DTP3), and the 1st doses of MMR (MMR1) and Men C (MENC1) vaccines for Australia – cohort born in 2004

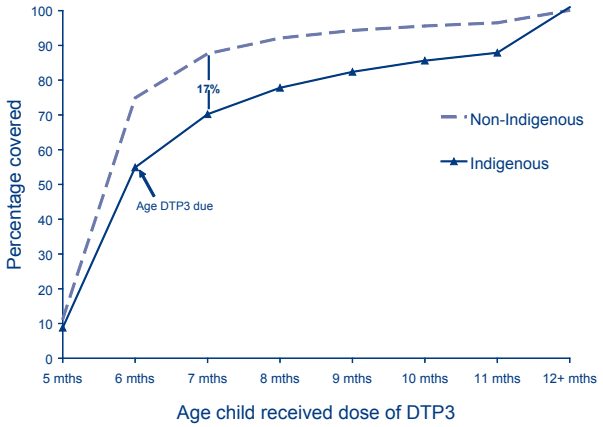


A comparison of vaccination delay for the 3rd dose of DTP, due at 6 months of age, and the 1st doses of MMR and meningococcal C, due at 12 months of age, for the 2004 cohort is shown in Figure 12. As demonstrated in previous studies, the proportion with vaccination delay increased with vaccine doses given at an older age. The greatest proportion with any delay was seen with meningococcal C vaccine with more than 30% of doses given late and over 4% given more than 6 months late.

Figures 13 and 14 provide a comparison of timeliness of immunisation between Indigenous and non-Indigenous children in Australia for the 3rd dose of DTP vaccine, and the 1st dose of MMR vaccine, respectively. For the 3rd dose of DTP, there was significantly greater delay for Indigenous children than non-Indigenous children, with a 17% differential at 7 months of age. A similar 17% differential was seen for the 3rd dose of 7vPCV (not shown). The same pattern was found for timeliness of the 1st dose of MMR, but with a smaller differential of 11%. Although Indigenous children had similar coverage levels to non-Indigenous children by 24 months of age, they were more likely to have delayed vaccination.

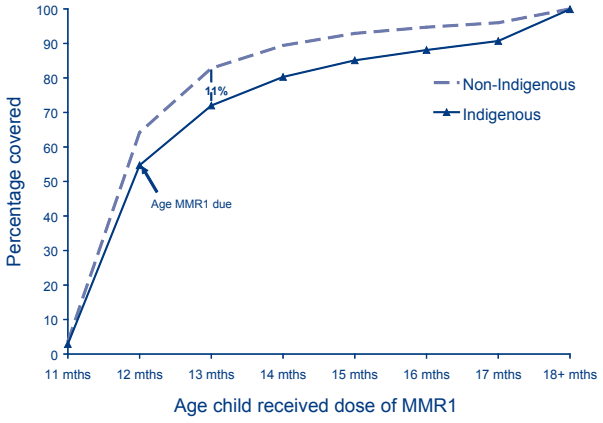
Vaccination delay for Indigenous children for 7vPCV varied by jurisdiction, with greater delays in Western Australia and South Australia (Figure 15). There were no important differences in vaccination delay for non-Indigenous children by jurisdiction (not shown).

Figure 13: Timeliness of the 3rd dose of DTP vaccine (DTP3) by Indigenous status – cohort born in 2004*



Percentage covered = number of children who received vaccine dose at particular ages/the total number of children who received the vaccine dose

Figure 14: Timeliness of the 1st dose of MMR vaccine (MMR1) by Indigenous status – cohort born in 2004*



Percentage covered = number of children who received vaccine dose at particular ages/the total number of children who received the vaccine dose

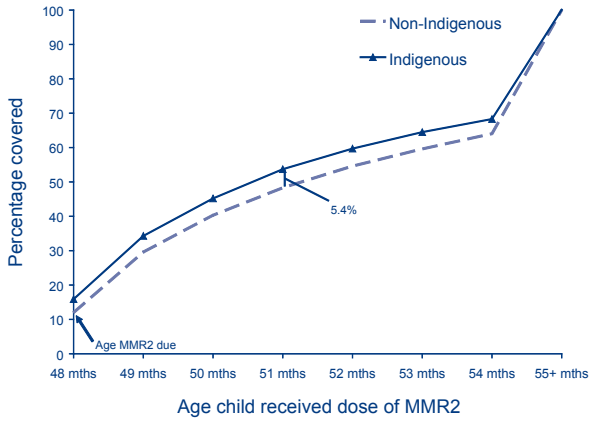
In contrast to earlier ages, analysis of timeliness of immunisation for a vaccine due at 4 years of age, the 2nd dose of MMR, showed more delay in receiving this vaccine for non-Indigenous children than Indigenous children, with a 5.4% differential at 4 years and 3 months of age (Figure 16).

Small area coverage

'Fully immunised' coverage for Australia by SSD for the 12-month, 24-month and 6-year milestone age groups, respectively, is shown in Figures 17–19. All 3 maps demonstrate that immunisation coverage in Australia in 2007 varies substantially within

Figure 15: Vaccination delay for Indigenous children for the 3rd dose of 7vPCV in selected jurisdictions – cohort born in 2005

Figure 16: Timeliness of the 2nd dose of MMR vaccine (MMR2) by Indigenous status – cohort born in 2001*



Percentage covered = number of children who received vaccine dose at particular ages/the total number of children who received the vaccine dose

jurisdictions, with some having recorded coverage below the level required to prevent outbreaks of some highly contagious diseases such as measles.

The proportions of children recorded as conscientious objectors and with no vaccines recorded are presented by SSD in Figures 20 and 21, respectively. No vaccines recorded may represent either non-immunisation (parents refusing any vaccines and also not registered as a conscientious objector) or, and probably much less commonly, non-reporting by a provider. The percentage of children with no vaccines recorded nationally (3.4%) is greater than those recorded as conscientious objectors (1.1%).

The map of the proportion of conscientious objectors to immunisation (Figure 20) shows pockets of high levels of objection within jurisdictions in

Figure 17: 'Fully immunised' coverage at 12 months of age, Australia, 2008, by Statistical Sub-Division

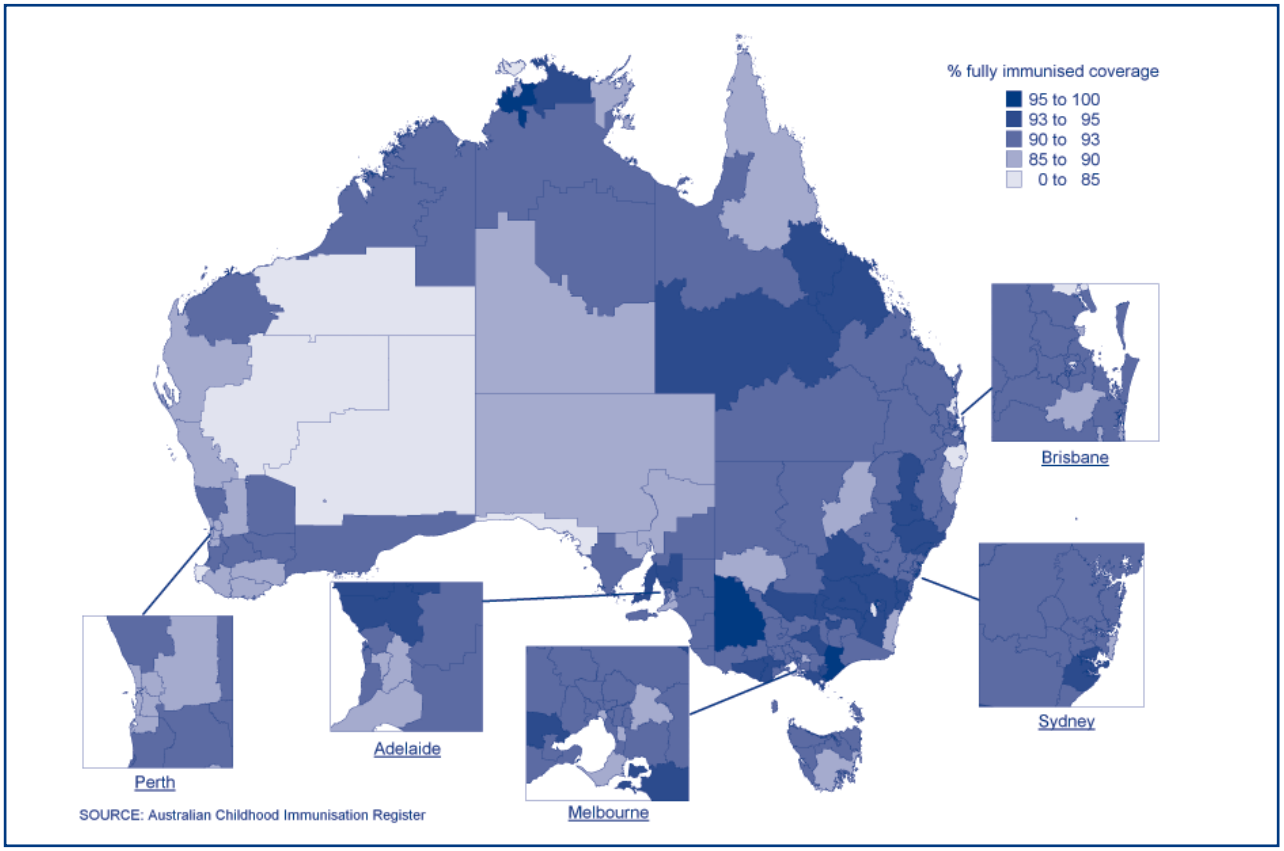


Figure 18: 'Fully immunised' coverage at 24 months of age, Australia, 2008, by Statistical Sub-Division

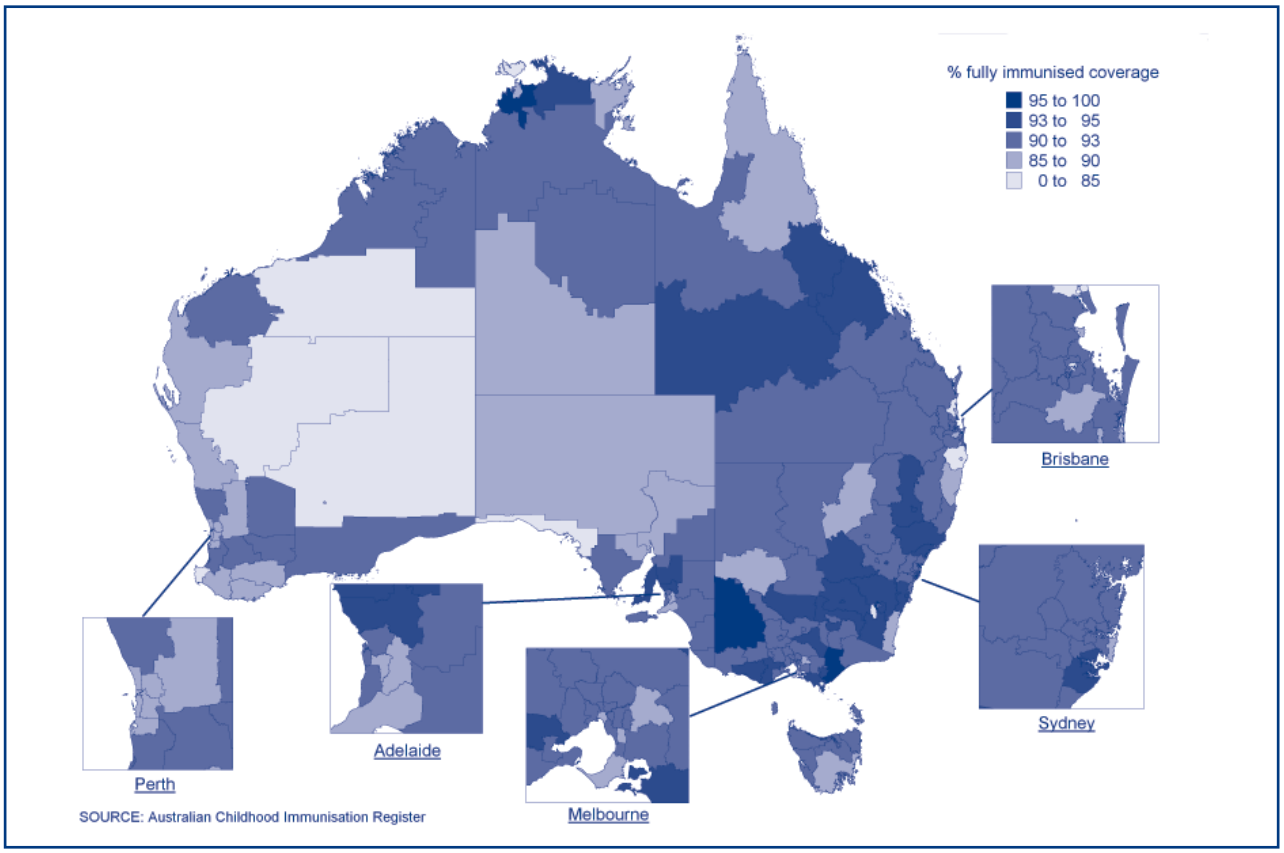


Figure 19: 'Fully immunised' coverage at 6 years of age, Australia, 2008, by Statistical Sub-Division

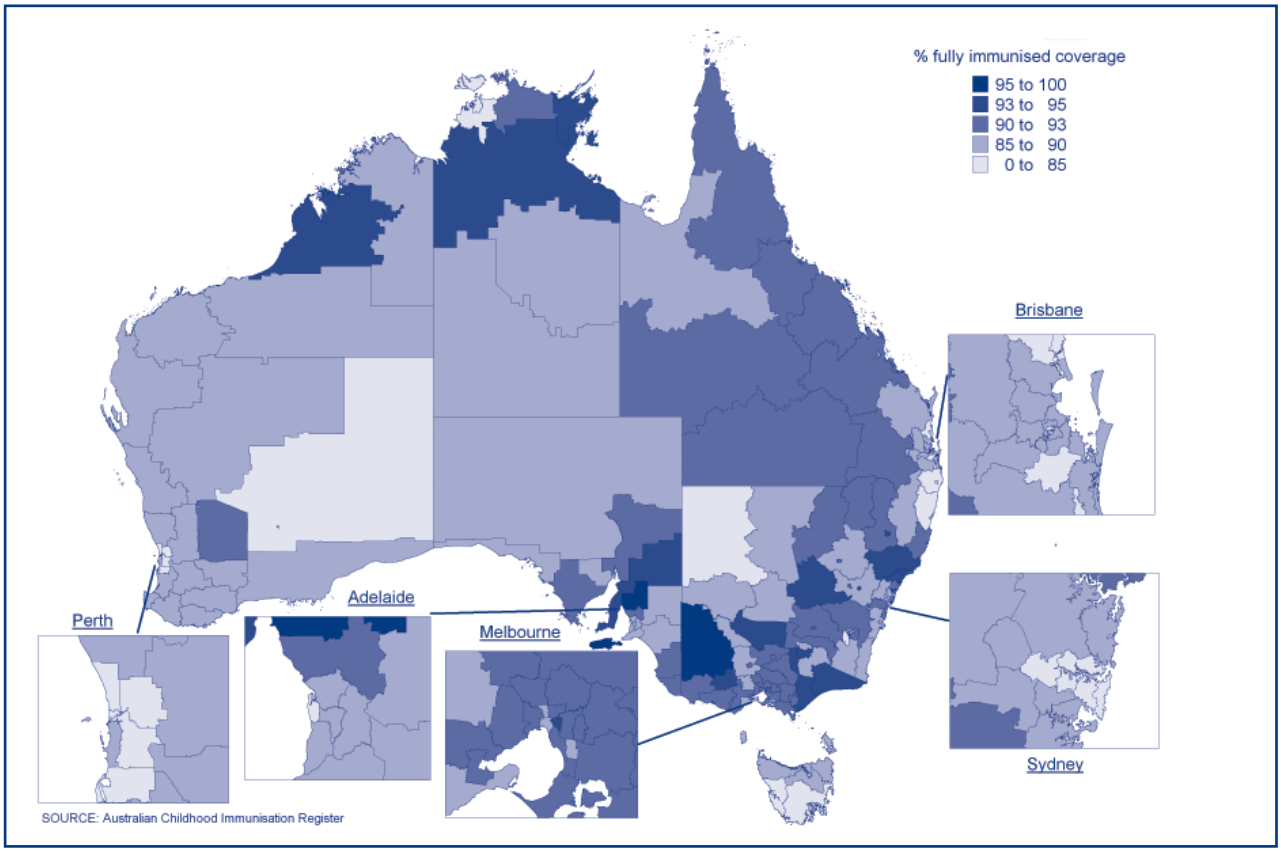
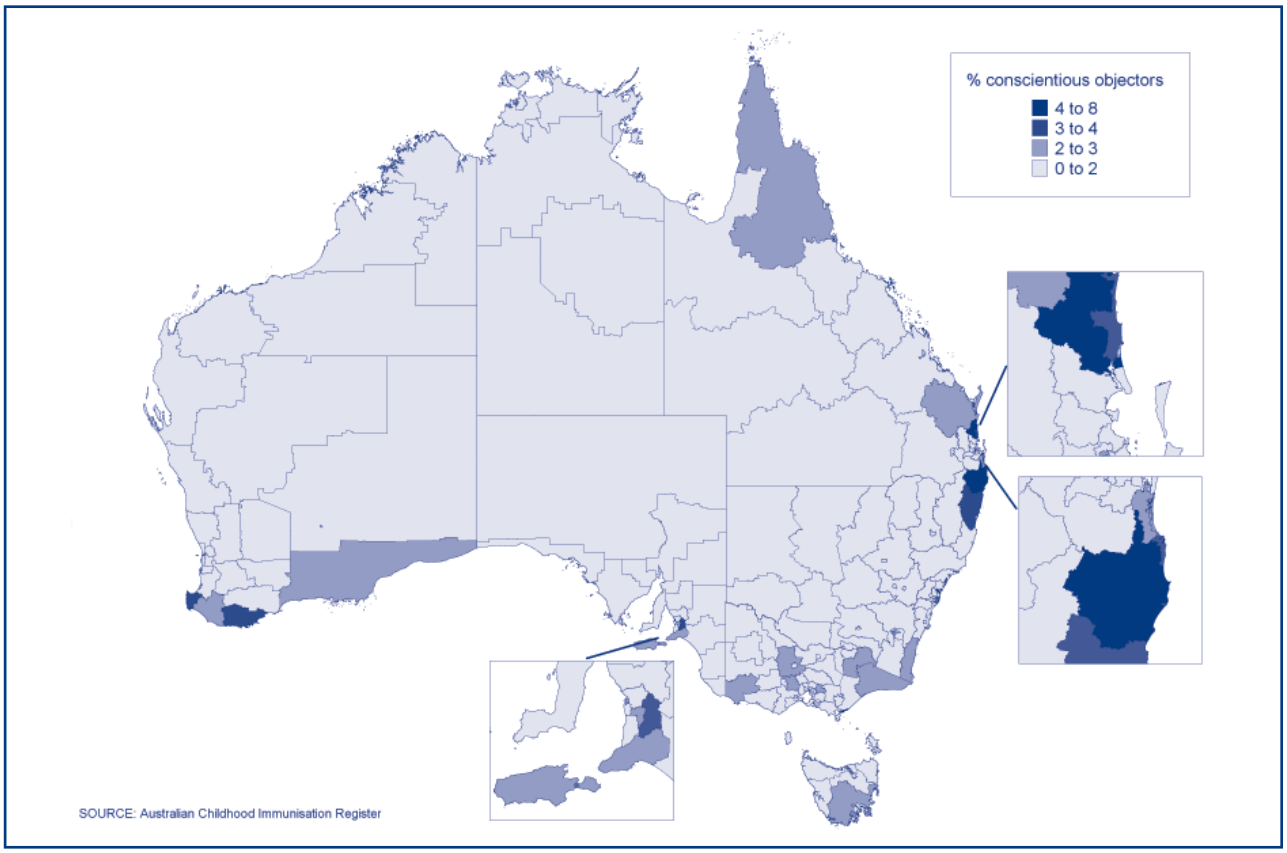


Figure 20: Proportion of official conscientious objectors to immunisation, Australia, 2007 (cohort born 1 January 2001 to 31 December 2006)



2007, particularly in coastal areas of south-east Queensland, northern New South Wales, Adelaide and south-western Western Australia, which would be hidden if these data were reported at broader geographical levels.

The map of the proportion of children with no vaccines recorded (Figure 21) shows some additional areas not evident from maps of official conscientious objection, such as the eastern suburbs of Sydney and regional Victoria.

Provider type

The proportion of immunisations recorded on the ACIR as given by GPs, municipal councils and other providers in Australia by jurisdiction is shown in Figure 22. GPs administer the large majority of immunisations in Australia; the proportion given by GPs has increased over the past 10 years by almost 5% (not shown). Local government clinics also administer a substantial proportion of immunisations, especially in some jurisdictions. The only other category of provider administering major numbers of immunisations nationally is community health centres. Regional differences are marked, with immunisations almost entirely administered by GPs in some jurisdictions, while in others a majority are given by local government and community health clinics.

Discussion

Since its inception, the ACIR has grown to hold records for over 5.8 million children and receives reports from over 21,000 providers of immuni-

Figure 22: Proportion of immunisations on the ACIR given by various provider types, by state or territory, 2007

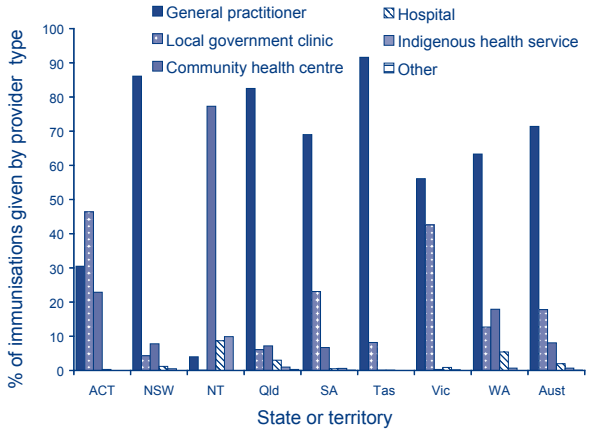
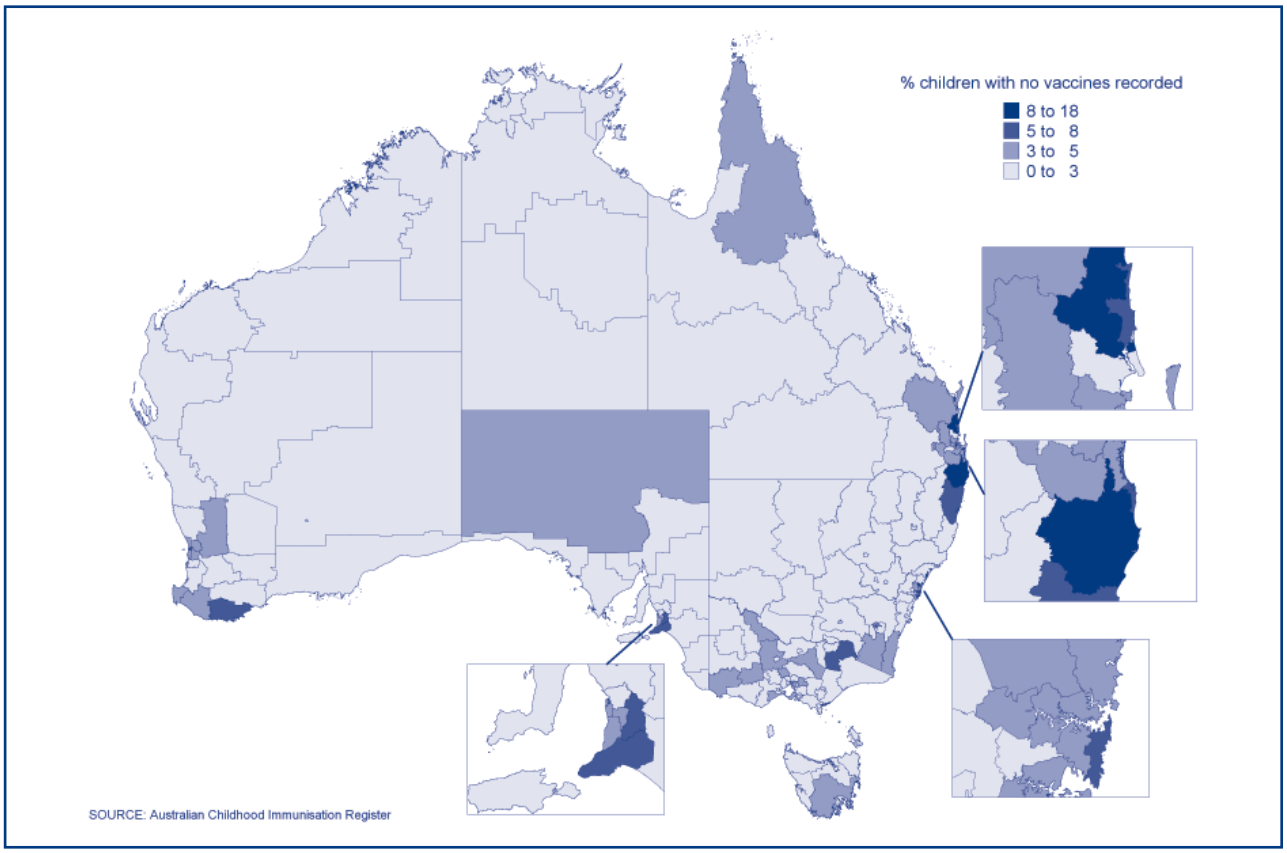


Figure 21: Proportion of children with no vaccines recorded on the ACIR, Australia, 2007 (cohort born 1 January 2001 to 31 December 2006)



sation services. It has become an increasingly valuable resource for administering and facilitating the National Immunisation Program as well as providing immunisation coverage data to monitor program performance. One of the main strengths of the ACIR is that it is a virtual census of children under 7 years of age in Australia, and, as such, has served as a model for other developed countries.[36,37]

However, there are some limitations to ACIR data. The only socio-demographic data collected by the ACIR are the age, postcode, sex and the Indigenous status of the child. This means public health researchers who use data from the ACIR to conduct research into immunisation coverage and other related issues are quite limited in the scope of the research they can undertake. Linkage with other datasets should be pursued in future to enhance its value in assessing control of vaccine preventable diseases. There are also limitations in data quality, which mainly relate to provider reporting. Improvements in coverage estimates can reflect improvements in provider reporting and timeliness as well as in actual coverage.

These data reveal that Immunise Australia Program coverage targets have been reached for children both 12 and 24 months of age and are being approached for children 6 years of age. With up to 3% of Australian parents not immunising their children for philosophical or religious reasons,[28] it will be difficult for 'fully immunised' coverage estimates to exceed 95%, especially as the reporting of immunisation encounters is still not totally complete.

Coverage at 24 months of age exceeded that at 12 months of age for the first time at the end of 2003 and has remained higher since that time. This is likely related to the removal of the 18-month booster dose of DTP, as well as the impact of immunisation incentives. Coverage estimates for the 6-year age group also increased noticeably in June 2006. A possible factor in this increase in coverage is the introduction of the multivalent combination vaccine Infanrix-IPV in November 2005, which decreased the number of vaccines needing to be given and recorded on the ACIR. Other factors that may have had an impact at the local level include promotional campaigns targeting childcare or school entry.

Immunisation incentives have also positively impacted coverage estimates over time. In 2004/05, the means test to qualify for the Maternity Immunisation Allowance (MIA) was removed. This payment, of $233 per child in 2008, is substantial enough to provide motivation both to complete immunisation and for parents to prompt their provider to notify any outstanding reports to the ACIR before the child reaches 24 months of age. In the 2008 budget, it was announced that the MIA payment would be paid in 2 equal amounts of $167, with eligibility for the 2nd payment assessed at 4–5 years of age. This policy change was designed to encourage immunisations in the older age groups where coverage estimates are lower compared with the younger age groups. It remains to be seen whether this will impact coverage for vaccines due after 24 months of age. In the same budget it was announced that GPII Service Incentive Payments would be removed from the incentives program in immunisation. It will be important to monitor the impact of these changes in future reports.

A number of vaccines in the NIP are not included when calculating 'fully immunised' status or in determining eligibility for incentive payments. Despite this, coverage data for the 7vPCV and meningococcal C vaccines is comparable with currently reported vaccines, while coverage for varicella is lower. However, there are variations by state and territory. As these vaccines have been routinely incorporated into the childhood immunisation schedule for some time, their inclusion in the official coverage assessments for 'fully immunised' should be considered, although addition of more antigens will inevitably decrease coverage estimates for the various 'fully immunised' age categories.

Coverage for vaccines recommended for Indigenous children only (i.e. hepatitis A and pneumococcal polysaccharide vaccine) remain sub-optimal. This has been previously reported for other vaccines for both children[26] and adults,[38] and could be at least partly due to a lack of provider knowledge about the recommendations, poor identification of Indigenous children, and poor notification to the ACIR of vaccines for which there are no incentive payments. Differences in schedules between jurisdictions may also contribute. For hepatitis A, the 1st dose is given at 12 months of age in the Northern Territory and Western Australia, whereas in Queensland and South Australia it is given at 18 months of age. Coverage in jurisdictions where it is given at 12 months of age is higher. Similarly, differences in the scheduling of pneumococcal polysaccharide vaccine by jurisdiction may partially explain the variation in coverage seen, with the Northern Territory and Western Australia giving the 1st dose of this vaccine at 18 months of age, while Queensland and South Australia give it at 24 months of age.

Although coverage data reveal that most children eventually complete the scheduled vaccination series by the 24-month milestone, many still do not do so in a timely manner. While there have been significant improvements in coverage in Australia over the past 4–5 years, vaccination delay as measured in this report has increased slightly. This is a concern, especially for diseases where multiple vaccine doses are required for protection and the disease

risk among young infants is significant (e.g. pertussis). Immunisation at the earliest appropriate age should be a public health goal for countries such as Australia where high levels of vaccine coverage at milestone ages have been achieved.

Author details

Brynley Hull
Shelley Deeks
Rob Menzies
Peter McIntyre

National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, The Children's Hospital at Westmead and University of Sydney, Westmead, New South Wales

Correspondence: Mr Brynley Hull, National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, The Children's Hospital at Westmead, Locked Bag 4001, WESTMEAD NSW 2145.

References

1. Commonwealth of Australia. Communicable Diseases Surveillance – additional reports: Childhood immunisation coverage. *Commun Dis Intell* 2008;32:122–123.
2. Brotherton J, Wang H, Schaffer A, Quinn H, Menzies R, Hull B, et al. Vaccine preventable diseases and vaccination coverage in Australia, 2003 to 2005. *Commun Dis Intell* 2007;31 Suppl:S1–S152.
3. Commonwealth of Australia. Communicable Disease Surveillance – additional reports: Australian childhood immunisation coverage. *Commun Dis Intell* 2008;32:357–359.
4. Hull BP, McIntyre PB. Timeliness of childhood immunisation in Australia. *Vaccine* 2006;24:4403–4408.
5. Dombkowski KJ, Lantz PM, Freed GL. The need for surveillance of delay in age-appropriate immunization. *Am J Prev Med* 2002;23:36–42.
6. Strine TW, Luman ET, Okoro CA, McCauley MM, Barker LE. Predictors of age-appropriate receipt of DTaP dose 4. *Am J Prev Med* 2003;25:45–49.
7. Hanna JN, Wakefield JE, Doolan CJ, Messner JL. Childhood immunisation: factors associated with failure to complete the recommended schedule by two years of age. *Aust J Public Health* 1994;18:15–21.
8. Cotter JJ, Bramble JD, Bovbjerg VE, Pugh CB, McClish DK, Tipton G, et al. Timeliness of immunizations of children in a Medicaid primary care case management managed care program. *J Natl Med Assoc* 2002;94:833–840.
9. Trauth JM, Zimmerman RK, Musa D, Mainzer H, Nutini JF. Do beliefs of inner-city parents about disease and vaccine risks affect immunization? *J Natl Med Assoc* 2002;94:820–832.
10. Ehresmann KR, White KE, Hedberg CW, Anderson E, Korlath JA, Moore KA, et al. A statewide survey of immunization rates in Minnesota school age children: implications for targeted assessment and prevention strategies. *Pediatr Infect Dis J* 1998;17:711–716.
11. Luman ET, McCauley MM, Stokley S, Chu SY, Pickering LK. Timeliness of childhood immunizations. *Pediatrics* 2002;110:935–939.
12. Luman ET, Barker LE, Shaw KM, McCauley MM, Buehler JW, Pickering LK. Timeliness of childhood vaccinations in the United States: days undervaccinated and number of vaccines delayed. *JAMA* 2005;293:1204–1211.
13. Dannetun E, Tegnell A, Hermansson G, Torner A, Giesecke J. Timeliness of MMR vaccination—influence on vaccination coverage. *Vaccine* 2004;22:4228–4232.
14. Australian Government Department of Human Services, Medicare Australia. General Practice Immunisation Incentives (GPII) Scheme. 2007. Available from: http://www.medicareaustralia.gov.au/provider/incentives/gpii/index.shtml Accessed on 18 December 2007.
15. Australian Government Department of Human Services, Medicare Australia. GPII Scheme: Service Incentive Payments (SIP). 2007. Available from: http://www.medicareaustralia.gov.au/provider/incentives/gpii/service-payments.shtml Accessed on 6 December 2007.
16. Hull B, McIntyre P. Mapping immunisation coverage and conscientious objectors to immunisation in NSW. *N S W Public Health Bull* 2003;14:8–12.
17. Hull B, Lawrence G, MacIntyre CR, McIntyre P. Immunisation coverage: Australia 2001. Canberra: Commonwealth Department of Health and Ageing, 2002.
18. Hull B, McIntyre P. Mapping immunisation coverage and conscientious objectors to immunisation in NSW. *N S W Public Health Bull* 2003;14:8–12.
19. Hull BP, McIntyre PB, Heath TC, Sayer GP. Measuring immunisation coverage in Australia. A review of the Australian Childhood Immunisation Register. *Aust Fam Physician* 1999;28:55–60.
20. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Immunisation coverage in Australia corrected for underreporting to the Australian Childhood Immunisation Register. *Aust N Z J Public Health* 2003;27:533–538.
21. Hull BP, McIntyre PB. Immunisation coverage reporting through the Australian Childhood Immunisation Register – an evaluation of the third-dose assumption. *Aust N Z J Public Health* 2000;24:17–21.
22. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Estimating immunisation coverage: is the 'third dose assumption' still valid? *Commun Dis Intell* 2003;27:357–361.
23. Hull BP, McIntyre PB. What do we know about 7vPCV coverage in Aboriginal and Torres Strait Islander children? *Commun Dis Intell* 2004;28:238–243.
24. Hull BP, McIntyre PB, Couzos S. Evaluation of immunisation coverage for Aboriginal and Torres Strait Islander children using the Australian Childhood Immunisation Register. *Aust N Z J Public Health* 2004;28:47–52.
25. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Is low immunisation coverage in inner urban areas of Australia due to low uptake or poor notification? *Aust Fam Physician* 2003;32:1041–1043.
26. Hull BP, Deeks S, Menzies R, McIntyre PB. What do we know about 7vPCV coverage in Aboriginal and Torres Strait islander children? A 2007 update. *Commun Dis Intell* 2008;32:257–260.
27. Lawrence GL, MacIntyre CR, Hull BP, McIntyre PB. Effectiveness of the linkage of child care and maternity payments to childhood immunisation. *Vaccine* 2004;22:2345–2350.

28. Lawrence GL, Hull BP, MacIntyre CR, McIntyre PB. Reasons for incomplete immunisation among Australian children. A national survey of parents. *Aust Fam Physician* 2004;33:568–571.

29. National Health and Medical Research Council. The Australian immunisation handbook. 9th ed. Canberra: Australian Government Department of Health and Ageing, 2008.

30. O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. *Commun Dis Intell* 1998;22:36–37.

31. Department of Health and Aged Care. Measuring Remoteness: Accessibility/Remoteness Index of Australia (ARIA). Occasional Papers, New Series No.14. Canberra: Department of Health and Aged Care, 2001.

32. Rank C, Menzies RI. How reliable are Australian Childhood Immunisation Register coverage estimates for indigenous children? An assessment of data quality and coverage. *Commun Dis Intell* 2007;31:283–287.

33. Australian Bureau of Statistics (ABS). Australian Standard Geographical Classification (ASGC), 2001. Cat. no. 1216.0. Canberra: ABS, 2001.

34. MapInfo [computer program]. Version 7. New York: MapInfo Corporation, 2002.

35. Australian Bureau of Statistics (ABS). Statistical Subdivision from Postal Area 2006 Concordance. Canberra: ABS, 2007. Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/39433889d406eeb9ca2570610019e9a5/5942283858e38743ca25730c00009f2e!OpenDocument Accessed on 6 December 2008.

36. New Zealand Ministry of Health. Overview of the National Immunisation Register. 2004. Available from: http://www.moh.govt.nz/moh.nsf/0/FA74067C640C0F0FCC256E58000B2089/$File/OverviewoftheNationalImmunisationRegister.pdf Accessed on 6 December 2007.

37. Canavan BC, Kurilo M, Moss T, McLaren R, Berry K, Thomas C, et al. Immunization information systems progress—United States, 2005. *MMWR Morb Mortal Wkly Rep* 2006;55:1327–1329.

38. Menzies R, Turnour C, Chiu C, McIntyre P. Vaccine preventable diseases and vaccination coverage in Aboriginal and Torres Strait Islander people, Australia 2003 to 2006. *Commun Dis Intell* 2008;32 Suppl:S2–S67.