

IMMUNISATION COVERAGE ANNUAL REPORT, 2009

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Abstract

This, the third annual immunisation coverage report, documents trends during 2009 for a range of standard measures derived from Australian Childhood Immunisation Register data, including overall coverage at standard age milestones and for individual vaccines included on the National Immunisation Program (NIP). Coverage by Indigenous status and mapping by smaller geographic areas as well as trends in timeliness is also summarised according to standard templates. With respect to overall coverage, the Immunise Australia Program targets have been reached for children at 12 and 24 months of age but not for children at 5 years of age. Coverage at 24 months of age exceeds that at 12 months of age, but as receipt of varicella vaccine at 18 months is excluded from calculations of 'fully immunised' this probably represents delayed immunisation, with some contribution from immunisation incentives. Similarly, the decrease in coverage estimates for immunisations due at 4 years of age from March 2008 is primarily due to changing the assessment age from 6 years to 5 years of age from December 2007. With respect to individual vaccines, a number of those available on the NIP are not currently assessed for 'fully immunised' status or for eligibility for incentive payments. These include pneumococcal conjugate and meningococcal C conjugate vaccines, for which coverage is comparable with vaccines that are assessed for 'fully immunised' status, and rotavirus and varicella vaccines for which coverage is lower. Coverage is also suboptimal for vaccines recommended for Indigenous children only (i.e. hepatitis A and pneumococcal polysaccharide vaccine) as previously reported for other vaccines for both children and adults. Delayed receipt of vaccines is an important issue for vaccines recommended for Indigenous children and has not improved among non-Indigenous children despite improvements in coverage at the 24-month milestone. Although Indigenous children in Australia have coverage levels that are similar to non-Indigenous children at 24 months of age, the disparity in delayed vaccination between Indigenous and non-Indigenous children remains a challenge. *Commun Dis Intell* 2011;35(2):132–148.

Keywords: immunisation coverage, immunisation delay, small area coverage reporting

Introduction

This is the third annual Australian Childhood Immunisation Register (ACIR) coverage report, following the first on 2007 data¹ and the second on 2008 data.² This series of annual reports was established to consolidate the various forms of regular coverage reports and ad hoc publications produced by the National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases using ACIR data, highlighting important trends and significant issues over the preceding 12 months.^{3–15} It follows the format of the first and second reports, providing a detailed summary for 2009 that includes vaccination coverage at standard milestone ages, coverage for vaccines not included in standard coverage assessments, timeliness of vaccination, coverage for Indigenous children, and data for small geographic areas on vaccination coverage and prevalence of conscientious objectors. Readers are referred to the first report for a more detailed explanation of the background to this series of annual reports and the range of analyses presented.¹

This report uses the long-standing international practice of reporting coverage at key milestone ages, to measure coverage against national targets and to track trends over time. No new vaccines were introduced to the NIP during 2009, with the exception of the Northern Territory, where the 10-valent pneumococcal conjugate vaccine at 2, 4, 6 and 12 months of age replaced the 7-valent conjugate and 23-valent polysaccharide vaccines. However, this report does include the 2nd full year of coverage data for rotavirus vaccine, having been introduced in 2007.

Incentives for vaccination and reporting to the Australian Childhood Immunisation Register

The Australian Government, through the Department of Health and Ageing, advises the ACIR whether calculation of coverage of the new vaccines and antigens should be included in the completed schedule assessment for eligibility for payments to parents or immunisation providers. Up to 2008, the ACIR made information payments (up to \$6) to all immunisation providers and for general practitioners (GPs), under the General Practice Immunisation Incentive (GPII) scheme. In the 2008–09 Budget, the Australian Government announced that one of the components of the GPII Scheme, the GPII Service Incentive Payment (SIP), would stop from 1 October 2008. Service Incentive Payments (\$18.50) were made for reporting a vaccination that completed a schedule point on the NIP,

at 6, 12, 18 months and 5 years.¹⁶ However, the GPII Outcomes Payments, which paid practices that achieve 90 per cent or greater levels for full immunisation, was maintained. The vaccines and antigens required for full immunisation in assessment for the Outcomes Payment in 2009 were the same as in recent years, i.e. diphtheria, *Haemophilus influenzae* type b (Hib), hepatitis B, measles, mumps, pertussis, polio, rubella and tetanus. Vaccines included in the NIP in 2009 but not part of the completed schedule assessment for provider payments were: meningococcal C vaccine (Men C); 7-valent pneumococcal conjugate vaccine (7vPCV); and rotavirus vaccine. Varicella vaccine was also not included for coverage assessment but eligible providers received an information and SIP payment (up to October 2008) for reporting, as varicella vaccine is currently the only vaccine required for completion of the 18-month schedule point. While the ACIR records vaccines given only to Indigenous children in Queensland, Northern Territory, Western Australia and South Australia (hepatitis A and pneumococcal polysaccharide vaccines (23vPPV)) and vaccines not included in the National Immunisation Program, such as bacille Calmette-Guérin, reporting of these vaccines does not attract a GPII payment.

Table 1 shows the Australian National Immunisation Program Schedule in 2009.

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 likely to be 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 2008–09 Budget, in addition to the changes mentioned above, 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 and 3 months to 5 years of age. This came into effect during the period of this report in January 2009. To meet the requirements of these changes the ACIR changed the National Due and Overdue Rules for Childhood Immunisation. From 1 January 2009 the overdue rule changed for all children born from 1 January 2005 onwards. The ACIR National Due and Overdue Rules now state that a child is due for their 4-year-old vaccinations at 4 years and overdue at 4 years 1 month of age, instead of overdue at 5 years of age.

Methods

The Australian Childhood Immunisation Register

The ACIR was established on 1 January 1996, by incorporating demographic data from Medicare on all enrolled children under the age of 7 years.⁴ 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.⁴ 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 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.

Immunisations recorded on the Register must be rendered in accordance with the guidelines issued by

Table 1: Australian National Immunisation Program Schedule for children in 2009

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

* 3rd dose of *Haemophilus influenzae* type b (Hib) vaccine at 6 months is dependent on vaccine brand used in state or territory.

† 3rd dose of rotavirus vaccine at 6 months is dependent on vaccine brand used in state or territory.

‡ Aboriginal and Torres Strait Islander children in Western Australia and the Northern Territory.

§ Aboriginal and Torres Strait Islander children in Queensland and South Australia.

the National Health and Medical Research Council as stated in *The Australian Immunisation Handbook*.¹⁷ 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)¹⁸ since the ACIR's inception. 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 5 years of age (for vaccines due at 4 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 5th respective birthdays are considered.¹⁸ 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.^{6,7}

Three-month birth cohorts are used for time trend analyses, while 12-month cohorts are used for other analyses in this report such as for small area coverage analysis and mapping of coverage estimates. A minimum 3-month lag is allowed for late notifications. These cohorts are children born between 1 January and 31 December 2008 for the 12-month milestone age; children born between 1 January and 31 December 2007 for the 24-month milestone age; and children born between 1 January and 31 December 2004 for the 5-year (60-month) milestone age.

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 a 3rd dose of a diphtheria (D), tetanus (T) and acellular pertussis-containing (P) vaccine (DTPa), a 3rd dose of polio vaccine, a 2nd or 3rd dose of a PRP-OMP containing Hib vaccine or a 3rd dose of any other Hib vaccine, and a 2nd or 3rd dose of a Comvax hepatitis B vaccine or a 3rd dose of dose of any other hepatitis B vaccine. 'Fully immunised' at 24 months of age is defined as a child having a record on the ACIR of a 3rd dose of a diphtheria, tetanus and acellular pertussis-containing vaccine, a 3rd dose of polio vaccine, a 3rd or 4th dose of a PRP-OMP containing Hib vaccine or a 4th dose of any other Hib vaccine, a 3rd or 4th dose of Comvax hepatitis B vaccine or a 4th dose of any other hepa-

titis B vaccine, and a 1st dose of a measles, mumps and rubella-containing (MMR) vaccine. 'Fully immunised' at 5 years of age is defined as a child having a record on the ACIR of a 4th or 5th dose of a diphtheria, tetanus and acellular pertussis-containing vaccine, a 4th dose of polio vaccine, and 2nd dose 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: a 3rd dose of 7vPCV and 2nd or 3rd dose of rotavirus vaccine by 12 months of age; a 1st dose of varicella vaccine and a 1st dose of meningococcal C vaccine by 24 months of age; a 2nd dose of hepatitis A vaccine in Indigenous children by 30 or 36 months of age; and a dose of 23-valent pneumococcal polysaccharide vaccine in Indigenous children by 36 months of age.

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, the outcome measure for each dose is categorised as either vaccine dose 'no delay' (age-appropriately immunised), 'delay of between 1 to 6 months', or 'delay greater than 6 months'. Doses received 'too early' (greater than 30 days prior to when it was due), and doses never administered or recorded, were excluded. Timeliness is measured in 12 month cohorts. Children included in the timeliness analysis were assessed at 1–2 years after doses were due to allow time for late vaccinations to be recorded. Therefore, cohorts assessed for timeliness are not the same as those assessed for coverage milestones. 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 and Remoteness Index of Australia (ARIA), which was developed by the Department of Health and Ageing, and proposed as the national standard measure of remoteness for inclusion in the Australian Bureau of Statistics (ABS) 2001 census.¹⁹ The two ARIA categories with most restricted access to services were defined as 'remote' (approximately 2.6% of the Australian population) and all other areas defined 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 two categories of children were considered: 'Indigenous' and 'non-Indigenous', children with unknown Indigenous status were presumed to be 'non-Indigenous'. Coverage estimate time trends are presented from 2004 only, due to poor rates of reporting Indigenous status prior to then.²⁰

Small area coverage

Coverage was calculated for ABS-defined Statistical Subdivisions (SSD).²¹ The ABS-defined SSDs were chosen as the areas to be mapped because each is small enough to show differences within jurisdictions but not too small to render maps unreadable. Maps were created using version 10 of the MapInfo mapping software²² and the ABS Census Boundary Information. As postcode is the only geographical indicator available from the ACIR, the ABS Postal Area to Statistical Local Area 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.²³

Conscientious objection and 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. The percentage of children with no vaccines recorded on the ACIR was used as a proxy measure of the number of these children.¹⁵ 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 2003 and 31 December 2008. At the time of data extraction on 31 March 2010, they were between 12 and 72 months of age. This cohort was chosen when calculating proportions so that children under the age of 12 months were not included, to allow sufficient time for registration of objection and to exclude infants late for vaccination.

Results

Coverage estimates

Overall

In 2009, coverage estimates for full-year birth cohorts at the 3 milestone ages of 12 months, 24 months and 5 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

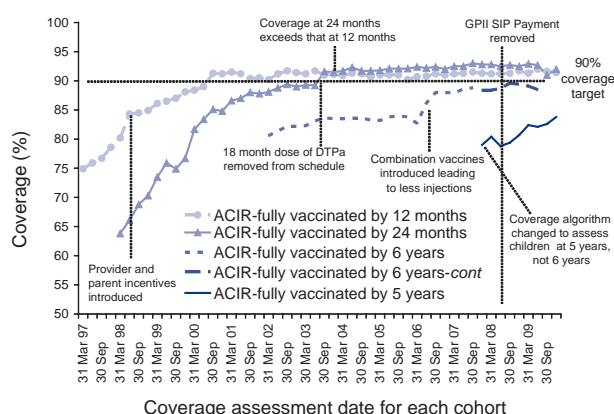
groups exceeded the Immunise Australia Program's target of 90%. Recorded national coverage for the 5-year age group was well below the target, at 83% for all vaccines and lower in particular jurisdictions.

Figure 1 shows time trends in 'fully immunised' childhood vaccination coverage in Australia, assessed at 12 months, 24 months, and at 60 months of age, for 3-month cohorts born from 1 January 1996 to 31 December 2008. The proportion 'fully immunised' at 1 year of age increased steadily from 75% for the 1st cohort in 1997 to 91.4% by 31 December 2009. At the 24 month milestone, 'fully immunised' coverage estimates also increased steadily from 64% for the 1st cohort to 92% by December 2009. 'Fully immunised' coverage estimates at 6 years of age, for vaccines due at 4 years, were first reported in *CDI* in 2002, and increased steadily from 80.6% in early 2002 to 87.3% in late 2007, including a noticeable increase in June 2006, corresponding with the introduction of combination vaccines. However, from the beginning of 2008, when the assessment age was changed from 6 years to 5 years, 'fully immunised' coverage was substantially lower at 80.7% in December 2008, related to delayed immunisation. However, during 2009, coverage for this age group gradually rose to 83.8%. Figure 1 shows that coverage calculated at 6 years was unchanged at 89% during 2009.

Coverage estimates for the 24-month age group increased substantially and suddenly in 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 all age groups assessed, with the 2 youngest age cohorts having the highest cover-

Figure 1: Trends in 'fully immunised' vaccination coverage, Australia, 1997 to 2009, by age cohort



age. 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 until 2009 where they are now both similar.

Individual vaccines

The trends in childhood vaccination coverage in Australia for individual vaccines at 12 months of age (DTPa, polio, Hib, hepatitis B, rotavirus and

Table 2: Percentage of children immunised at 12 months of age in 2009, by vaccine and state or territory*

Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,820	97,550	3,807	62,150	19,601	6,533	70,800	30,714	295,975
Diphtheria, tetanus, pertussis (%)	94.4	92.7	90.1	92.2	91.8	92.6	92.9	90.2	92.3
Poliomyelitis (%)	94.3	92.6	90.0	92.2	91.8	92.6	92.9	90.2	92.3
<i>Haemophilus influenzae</i> type b (%)	95.7	95.1	94.6	94.6	94.6	95.0	95.2	93.6	94.8
Hepatitis B (%)	95.6	95.0	95.3	94.4	94.4	94.9	95.0	93.4	94.7
Rotavirus (%)	89.2	86.5	82.4	81.7	83.4	85.4	82.4	82.2	83.9
7vPCV (%)	93.3	91.9	89.7	91.4	91.1	92.2	91.9	89.2	91.5
Fully immunised (%)	93.8	92.2	89.4	91.8	91.4	92.4	92.3	89.5	91.8
Fully immunised (incl rotavirus and 7vPCV) (%)	88.1	84.7	79.9	85.9	86.9	83.9	85.6	80.2	84.8

* For the birth cohort born in 2008.

Table 3: Percentage of children immunised at 24 months of age in 2009, by vaccine and state or territory*

Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,720	98,175	3,783	62,169	19,704	6,465	71,498	30,641	297,155
Diphtheria, tetanus, pertussis (%)	95.6	94.6	94.8	94.1	94.7	95.0	95.4	93.6	94.6
Poliomyelitis (%)	95.5	94.6	94.8	94.0	94.7	95.0	95.4	93.6	94.6
<i>Haemophilus influenzae</i> type b (%)	95.6	94.9	92.9	93.4	93.9	95.1	94.6	93.0	94.3
Hepatitis B (%)	96.1	95.5	96.1	94.9	95.3	95.9	96.1	94.6	95.4
Measles, mumps, rubella (%)	94.6	93.5	94.9	93.3	94.0	94.4	94.6	92.9	93.8
Varicella (%)	86.6	80.5	82.7	84.5	80.5	82.6	82.4	79.0	81.8
MenC (%)	94.3	93.2	94.1	92.8	93.9	94.3	94.3	92.2	93.4
Fully immunised (%)	93.3	92.1	92.0	91.6	92.3	93.2	93.0	90.3	92.2
Fully immunised (incl varicella and MenC) (%)	85.0	78.5	80.2	82.3	79.0	81.2	80.6	76.6	79.8

* For the birth cohort born in 2007.

Table 4: Percentage of children immunised at 5 years of age in 2009, by vaccine and state or territory*

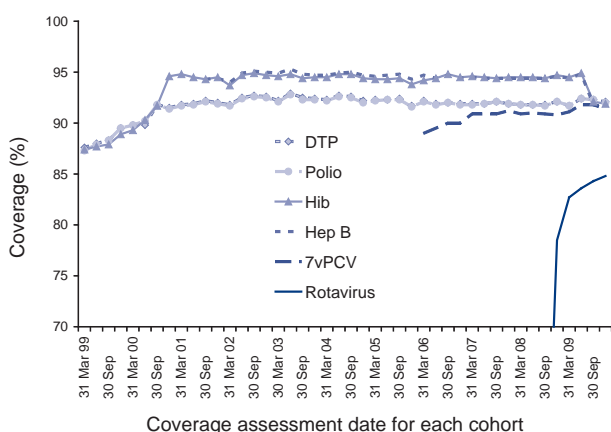
Vaccine	State or territory								Aust
	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	
Total number of children	4,379	88,407	3,350	56,160	17,993	5,821	65,164	27,860	269,134
Diphtheria, tetanus, pertussis (%)	86.5	82.6	82.3	83.3	79.4	84.4	86.4	81.5	83.4
Poliomyelitis (%)	86.5	82.6	82.6	83.2	79.5	84.6	86.4	81.5	83.4
Measles, mumps, rubella (%)	86.2	82.4	82.4	83.2	79.3	84.4	86.1	81.2	83.2
Fully immunised (%)	85.8	81.9	81.4	82.5	78.8	83.7	85.7	80.5	82.7

* For the birth cohort born in 2004.

7vPCV) are shown in Figure 2, for 3-month cohorts born from 1 January 1998 to 31 December 2008.

Coverage estimates for all vaccines except Hib and hepatitis B remained relatively stable throughout the latter part of 2001 to 2009. Prior to the change in algorithm to measure coverage that occurred in the latter half of 2009, coverage for the Hib and hepatitis B vaccines at 12 months of age was greater than DTPa and polio. The change led to measures of Hib and hepatitis B vaccine coverage becoming similar to those for DTPa and polio in the last two cohorts of 2009 (Figure 2). Coverage for 7vPCV rose steadily from below 90% in early 2006 to be just below that for all other vaccines due at this age at around 92%, except for rotavirus vaccine. Rotavirus vaccine coverage rose steeply from late 2008 from below 70% to almost 85% in late 2009.

Figure 2: Trends in vaccination coverage estimates for individual vaccines at 12 months of age (DTP, polio, hepatitis B, Hib, 7vPCV and rotavirus)*



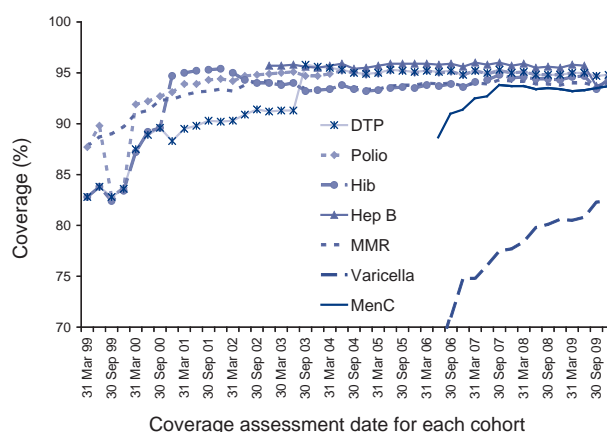
Source: Australian Childhood Immunisation Register.

By 3-month birth cohorts born between 1 January 1996 and 31 December 2008. Coverage assessment date was 12 months after the last birth date of each cohort.

* 3rd dose of diphtheria-tetanus-pertussis (DTP) and polio, 2nd or 3rd dose of *Haemophilus influenzae* type b (Hib) and hepatitis B.

The trends in childhood vaccination coverage in Australia for individual vaccines at 24 months of age (DTPa, polio, Hib, hepatitis B, MMR, Men C and varicella) are shown in Figure 3, for the 3-month cohorts born from 1 January 1997 to 31 December 2007. For most of the study period, hepatitis B coverage was higher than for all other vaccines, at just under 95%, due to the different coverage algorithm described above. Coverage was lowest for MMR and Hib, the only vaccines that have a 12-month dose used in calculations. The overall coverage estimates for 24-month-olds are more than 90% for all vaccines except varicella.

Figure 3: Trends in vaccination coverage estimates for individual vaccines at 24 months of age (DTP, polio, hepatitis B, Hib and MMR)*



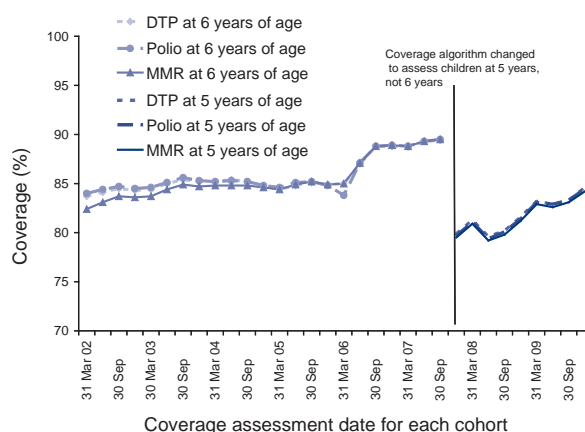
Source: Australian Childhood Immunisation Register.

By 3-month birth cohorts born between 1 January 1996 and 31 December 2007. Coverage assessment date was 24 months after the last birth date of each cohort.

* 3rd or 4th dose of DTP, 3rd dose of polio, 3rd or 4th dose of Hib, 2nd or 3rd dose of Hep B, and 1 dose of MMR.

The trends in childhood vaccination coverage in Australia for individual vaccines (DTPa, polio and MMR) at 6 years of age (5 years of age from December 2007) are shown in Figure 4 for the 3-month cohorts born from 1 January 1998 to 31 December 2004. There has been little difference for the different vaccines in recent years.

Figure 4: Trends in vaccination coverage estimates for individual vaccines (DTP, polio, and MMR),* at 6 years of age (5 years from December 2007)



Source: Australian Childhood Immunisation Register.

By 3-month birth cohorts born between 1 January 1996 and 31 December 2004. Coverage assessment date was 72 months after the last birth date of each cohort up to December 2007 and then 60 months after the last birth date of each cohort.

* 4th dose of diphtheria-tetanus-pertussis (DTP) and polio, 2nd dose of measles-mumps-rubella (MMR).

Coverage estimates and vaccination timeliness for Indigenous children

Vaccination coverage estimates in 2009 for the three 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 the 12-month, 24-month and 5-year age milestones for most vaccines, 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. The coverage differential between Indigenous and non-Indigenous children for individual vaccines varies, with coverage at 24 months of age for most vaccines being almost identical for both groups and greater among Indigenous children for hepatitis B, MMR and Men C vaccines.

The trends in 'fully immunised' childhood vaccination coverage in Australia at 12 months, 24 months, and 6 years of age (5 years of age from December 2007) for Indigenous children since 2004 are shown in Figure 5, for the 3-month cohorts

assessed from 1 March 2004 to 31 December 2009. Coverage for all vaccines due by 24 months of age has consistently remained higher than at 12 months and 6 years of age. Since the beginning of 2006,

Figure 5: Trends in 'fully immunised' vaccination coverage for Indigenous children in Australia, 2004 to 2009, by age cohorts

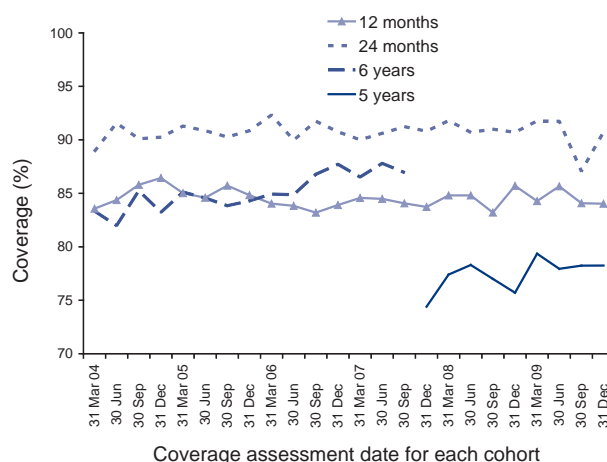


Table 5: Vaccination coverage estimates by age, vaccine and Indigenous status, 2009

Vaccine	Milestone age	Indigenous	Non-Indigenous
DTP	12 months*	85.3	92.7
	24 months†	94.2	94.7
	5 years‡	79.2	83.6
Polio	12 months*	85.2	92.6
	24 months†	94.2	94.6
	5 years‡	79.4	83.6
Hib	12 months*	93.2	94.9
	24 months†	93.1	94.3
	5 years‡	N/A§	N/A§
Hep B	12 months*	93.5	94.7
	24 months†	97.0	95.4
	5 years‡	N/A§	N/A§
MMR	12 months*	N/A§	N/A§
	24 months†	94.1	93.7
	5 years‡	79.6	83.4
Varicella	12 months*	N/A§	N/A§
	24 months†	80.7	81.9
	5 years‡	N/A§	N/A§
Meningococcal C	12 months*	N/A§	N/A§
	24 months†	93.7	93.4
	5 years‡	N/A§	N/A§
7vPCV	12 months*	85.0	91.8
	24 months†	N/A§	N/A§
	5 years‡	N/A§	N/A§
Rotavirus	12 months*	71.5	84.5
	24 months†	N/A§	N/A§
	5 years‡	N/A§	N/A§

* Birth cohort born 1 January to 31 December 2008.

‡ Birth cohort born 1 January to 31 December 2004.

† Birth cohort born 1 January to 31 December 2007.

§ Not included in coverage estimates for that group.

coverage for Indigenous children at 6 years of age was greater than coverage at 12 months of age, until falling below 80% in December 2007 when assessed at 5 years, due to delayed immunisation.

Table 6 shows 'fully immunised' vaccination coverage estimates in 2009 for Indigenous children at the three milestone ages, by state or territory. At age 12 months, the overall proportion of Indigenous children fully vaccinated was 85%, compared with 92.2% for non-Indigenous children. Although coverage was lower among Indigenous children in all jurisdictions, the extent of the difference varied, reaching more than 13 percentage points in Western Australia. However, by age 24 months, coverage disparities between Indigenous and non-Indigenous children had greatly reduced nationally, at 90.6% fully vaccinated for Indigenous and 92.2% for non-Indigenous children.

At 5 years of age, the proportion recorded as being 'fully vaccinated' was lower than that at earlier age milestones. At the national level, the coverage for Indigenous and non-Indigenous children was 78.6% and 82.9%, respectively, a greater disparity than in 2008 (2.7%). There was dramatic variation between individual jurisdictions, ranging from 11.9% lower in Indigenous children in South Australia to 8.2% higher in the Northern Territory, compared with non-Indigenous 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. Vaccination was delayed by more than one month for 30%–34% of Indigenous children and 18%–26% of non-Indigenous children. 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 no great differences between accessible and remote areas or vaccines. Delays of 1–6 months were also more frequent for Indigenous children, although less marked, especially for the 1st dose of MMR. The proportion with short delays was greater among Indigenous children residing in remote areas than in accessible areas for the 3rd dose of DTP vaccine (35% versus 31%), but not for the 1st dose of MMR.

Coverage for National Immunisation Program vaccines not routinely reported elsewhere

7vPCV and rotavirus

7vPCV was first added to the NIP in January 2005. Since coverage was first calculated for this vaccine in early 2006, it has remained high, with a slight increase from 89% to 91.5% (Figure 2). Coverage is similar in all jurisdictions at greater than or approaching 90% (Table 2).

Table 6: Percentage of children fully immunised at 12 months, 24 months and 5 years of age, 2009, by Indigenous status and state or territory

	State or territory								Australia
	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	
12 months – fully immunised (%)*									
Indigenous	92.1	87.4	86.9	85.7	80.2	77.2	89.6	85.8	85.0
Non-Indigenous	93.8	92.4	92.4	92.3	91.8	90.3	92.7	91.9	92.2
12 months – fully immunised (including rotavirus and 7vPCV) (%)									
Indigenous	85.2	76.4	78.0	75.5	74.3	63.2	78.5	69.7	73.7
Non-Indigenous	88.2	85.0	85.7	86.7	87.4	81.3	84.4	86.9	85.4
24 months – fully immunised (%)†									
Indigenous	90.6	91.4	92.7	91.4	90.3	84.4	94.2	92.4	90.6
Non-Indigenous	93.3	92.2	93.0	91.6	92.4	90.7	93.1	91.7	92.2
24 months – fully immunised (including varicella and MenC) (%)									
Indigenous	77.7	76.5	76.4	79.4	74.8	70.3	81.0	82.8	77.3
Non-Indigenous	85.1	78.6	80.7	82.5	79.1	77.0	81.2	78.3	79.3
5 years – fully immunised (%)‡									
Indigenous	85.2	78.0	80.5	79.6	67.3	74.1	80.2	86.1	78.6
Non-Indigenous	85.8	82.0	85.8	82.7	79.2	80.9	83.9	77.9	82.9

* 'Fully immunised' – 3 doses of a diphtheria (D), tetanus (T) and pertussis-containing (P) vaccine, 3 doses of polio vaccine, 2 or 3 doses of PRP-OMP-containing *Haemophilus influenzae* type b (Hib) vaccine or 3 doses of any other Hib vaccine, and 2 or 3 doses of Comvax hepatitis B vaccine or 3 doses of all other hepatitis B vaccines.

† 'Fully immunised' – 3 or 4 doses of a DTPa-containing vaccine, 3 doses of polio vaccine, 3 or four doses of PRP-OMP-containing Hib vaccine or 4 doses of any other Hib vaccine, 3 or 4 doses of Comvax hepatitis B vaccine or 4 doses of all other hepatitis B vaccines, and 1 dose of a measles, mumps and rubella-containing (MMR) vaccine.

‡ 'Fully immunised' – 4 or 5 doses of a DTPa-containing vaccine, 4 doses of polio vaccine, and 2 doses of an MMR-containing vaccine.

Table 7: Vaccination delay for the cohort of children born in 2007, Australia, by Indigenous and remoteness status

Vaccine dose	Indigenous status	Remoteness	1–6 months delay %	> 6 months delay %
DTP3	Indigenous	Accessible	30	9
		Remote	33	7
	Non-Indigenous	Accessible	18	2
		Remote	18	2
MMR1	Indigenous	Accessible	33	6
		Remote	34	4
	Non-Indigenous	Accessible	26	2
		Remote	26	2

Rotavirus vaccine was added to the NIP in July 2007, so coverage for 2 or 3 doses (depending on vaccine) at 12 months of age could be calculated only from the December 2008 quarter. Rotavirus coverage was lower nationally, and had greater variation between jurisdictions compared to other vaccines given at 2, 4 and 6 months, which may be due to the strict upper age limits for this vaccine. Reported coverage for 2 or 3 doses (Rotarix® versus Rotateq®) of rotavirus vaccine at 12 months of age varied from 81.7% in Queensland (Rotateq®) to 86.5% and 89.2% in New South Wales and the Australian Capital Territory (both Rotarix®) respectively (Table 2).

Meningococcal C and varicella

Meningococcal C vaccine was added to the NIP in January 2003. 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 around 93% (Figure 3). There was little variation by jurisdiction with all jurisdictions experiencing coverage levels greater than 92% (Table 3).

Varicella vaccine was added to the NIP in November 2005. Figure 3 shows reported coverage for this vaccine has consistently been 10–15 percentage points lower than that for meningococcal C vaccine, being just above 80% for the latest assessment. This is probably partly due to the shorter time varicella has been on the NIP and the recommendation to give the vaccine at 18 months of age, which was historically associated with lower coverage when there was a 18-month pertussis booster prior to 2003, as well as a gap when no vaccine was administered at 18 months over 2 years. Reported varicella vaccine coverage also shows considerable variation by jurisdiction from 79% in Western Australia to 86.6% in the Australian Capital Territory (Table 3). Data are also available from the ACIR on the number 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 total greater than 15,000 since

May 2004 (not shown), corresponding to approximately 1.1% of the cohort. It is likely that there is under-reporting of presumed natural immunity by GPs but this is unlikely to fully account for lower varicella coverage.

Hepatitis A and 23vPPV

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, but was used earlier than this in North Queensland. 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 59% in December 2009 (Figure 6). However, the figure for December 2009 is calculated differently from all previous figures. The calculation now gives an equal amount of assessment time for all four relevant jurisdictions, so 2 doses are assessed at 30 months for Western Australia and the Northern Territory and 2 doses are assessed at 36 months for Queensland and South Australia. An additional 9% of children had received 1 dose of hepatitis A vaccine by 18 or 24 months of age, increasing national coverage for at least 1 dose of hepatitis A vaccine to 68% in Indigenous children (Table 8). The 23vPPV has been recommended for Indigenous children in the same 4 jurisdictions as a booster at 18–24 months of age since 2001; coverage has gradually increased from 47% in December 2006 to 55% in December 2009 (Figure 6). There is a large variation in 23vPPV coverage by jurisdiction from a low of 38% in South Australia to a high of 78.9% in the Northern Territory (Table 8). Similarly, there is a variation in reported hepatitis A vaccine coverage by jurisdiction, from a low of 36% in South Australia to a high of 86.2% in the Northern Territory (Table 8).

Timeliness of immunisation

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

Since 2001, the proportion with timely receipt of the 3rd dose of DTP vaccine has remained at 88% (Figure 7). Across the 7-year period, 2001–2007, timely receipt of 1 dose of MMR vaccine initially decreased by 3 percentage points but then rose 2 percentage points, although estimated coverage by 24 months of age remained stable at almost 94% (Figure 8).

A comparison of vaccination delay for the 3rd dose of DTPa, due at 6 months of age; the 1st doses of MMR and meningococcal C, due at 12 months of age; and the 2nd dose of MMR, due at 4 years of age, is shown in Figure 9. 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 the 2nd dose of MMR vaccine with 80% of doses given late and almost 35% given more than 6 months late.

Figure 6: Trends in coverage for hepatitis A* and pneumococcal polysaccharide (23vPPV) vaccines for Indigenous children

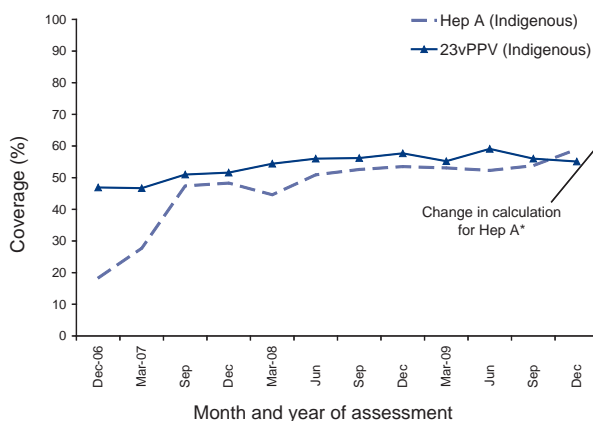
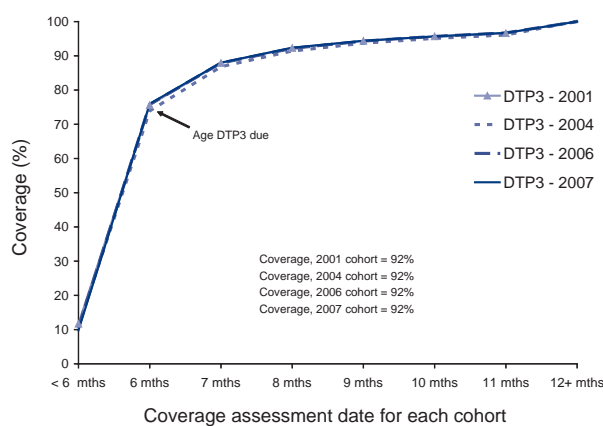


Figure 7: Trends in timeliness of the 3rd dose of DTP vaccine (DTP3) for cohorts born in 2001, 2004, 2006 and 2007*



* Two doses assessed at 30 months for Western Australia and the Northern Territory. Two doses assessed at 36 months for Queensland and South Australia. (Prior to December 2009, 2 doses assessed at 30 months for Western Australia, the Northern Territory, Queensland and South Australia).

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

Table 8: Vaccination coverage for 7vPCV, rotavirus, meningococcal C, varicella, hepatitis A (Indigenous only) and 23vPPV (Indigenous only) for the last 3-month cohort assessable in 2009, by state or territory

State or territory	Vaccine type					
	7vPCV*	Rotavirus†	Men C‡	Varicella§	Hep A	23vPPV¶
ACT	93.2	88.8	95.0	87.2	Na	Na
NSW	91.5	87.2	93.5	81.1	Na	Na
NT	89.8	82.6	92.1	82.4	86.2 (82.8)	78.9
Qld	91.5	82.6	93.3	85.2	49.3 (60.8)	47.5
SA	90.9	84.1	93.6	81.5	36.0 (44.0)	38.1
Tas	92.4	87.2	94.6	83.3	Na	Na
Vic	92.1	83.8	93.3	82.1	Na	Na
WA	89.2	83.2	94.3	80.6	60.3 (65.9)	57.0
Aust	91.4	84.8	93.7	82.4	59.0 (68.1)**	55.1**

Na Not applicable.

* 3 doses at 12 months of age.

† 2 or 3 doses at 12 months of age.

‡ 1 dose at 24 months of age.

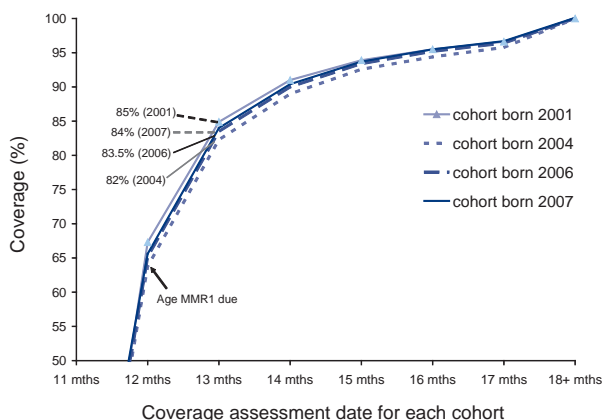
§ 1 dose at 24 months of age.

|| Indigenous only: 2 doses by 30 months of age for Western Australia and the Northern Territory (1 dose by 18 months of age), 2 doses by 36 months of age for Queensland and South Australia (1 dose by 24 months of age).

¶ Indigenous only: 1 dose by 36 months of age.

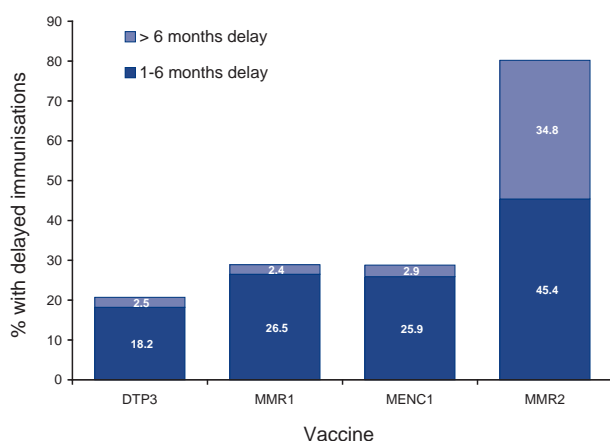
** Northern Territory, Queensland, South Australia and Western Australia only.

Figure 8: Trends in timeliness of the 1st dose of MMR vaccine (MMR1) – cohorts born in 2001, 2004, 2006 and 2007*



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

Figure 9: Vaccination delay for cohorts born in 2007 (DTP3, MMR1, MENC1) and 2003 (MMR2)



DTP3 = 3rd dose of a diphtheria (D), tetanus (T) and pertussis-containing (P) vaccine.

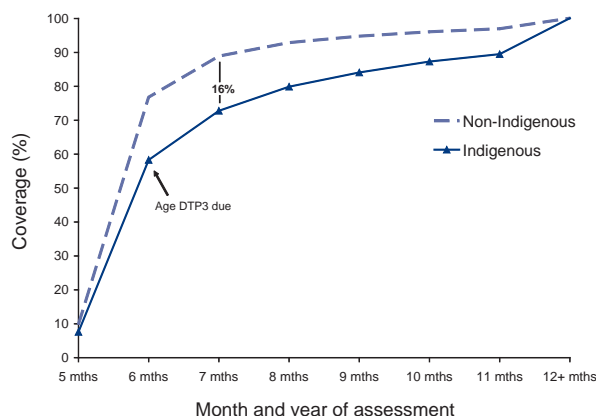
MMR1 = 1st dose of a measles, mumps and rubella vaccine.

MENC1 = 1st dose of a meningococcal C vaccine.

MMR2 = 2nd dose of a measles, mumps and rubella vaccine.

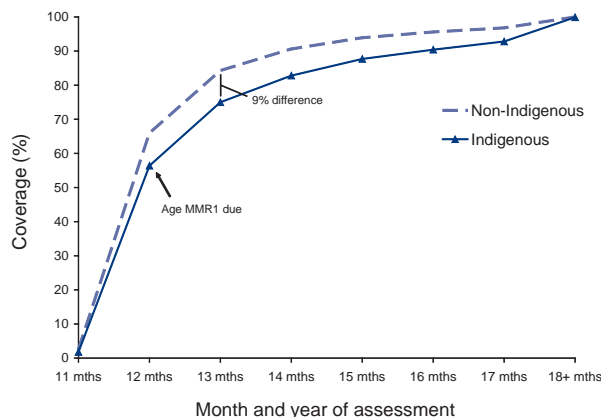
Figures 10 and 11 provide a comparison of timeliness of immunisation between Indigenous and non-Indigenous children in Australia for the 3rd dose of DTPa vaccine, and the 1st dose of MMR vaccine, respectively. For the 3rd dose of DTPa, there was a significantly greater delay for Indigenous children than non-Indigenous children, with a 16% differential at 7 months of age. This is a slight improvement from the previous annual report which found an 18% differential. The same pattern was found for timeliness of the 1st dose of MMR, but with a smaller differential of 9%, again a 2 percentage point improvement from

Figure 10: Timeliness of the 3rd dose of DTP vaccine (DTP3) for the cohort born in 2007,* by Indigenous status



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

Figure 11: Timeliness of the 1st dose of MMR vaccine (MMR1) for the cohort born in 2007,* by Indigenous status



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

the previous report. Although Indigenous children had only slightly lower coverage than non-Indigenous children by 24 months of age, they were more likely to have delayed vaccination.

Vaccination delay for Indigenous children for selected jurisdictions was measured for 7vPCV, with greater delays in Western Australia and South Australia (Figure 12). The proportion of children with long delays in receipt of the 3rd dose of 7vPCV vaccine in Western Australian and South Australian Indigenous children was about twice that in Queensland Indigenous children. There were no important differences in vaccination delay for non-Indigenous children by jurisdiction (not shown).

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 similar delay in receiving this vaccine for non-Indigenous children and Indigenous children, with only a 0.4% differential at 4 years and 3 months of age (Figure 13).

Figure 12: Vaccination delay for Indigenous children for the 3rd dose of 7vPCV in selected jurisdictions, for the cohort born in 2007

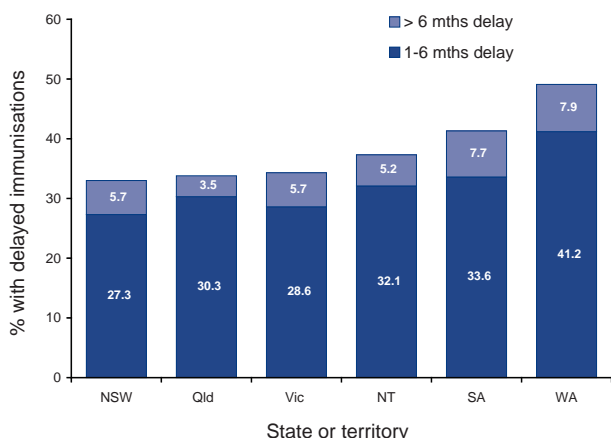
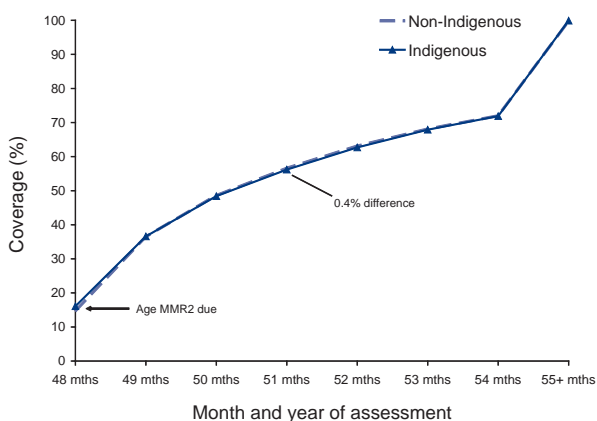


Figure 13: Timeliness of the 2nd dose of MMR vaccine (MMR2) for the cohort born in 2003,* by Indigenous status



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

Small area coverage

‘Fully immunised’ coverage for Australia by SSD for the 12-month, 24-month and 5-year milestone age groups, respectively, is shown in Figures 14–16. All three maps demonstrate that immunisation coverage in Australia in 2009 varies substantially within jurisdictions, with some areas having recorded coverage below the level required to prevent outbreaks of

some highly contagious diseases such as measles. In particular, there are very few small areas in Australia where recorded ‘fully immunised’ coverage for vaccines due at 4 years of age is above the 90% level required to prevent disease.

The proportions of children recorded as conscientious objectors and with no vaccines recorded are presented by SSD in Figures 17 and 18, respectively. No vaccines recorded may represent either non-immunisation (parents refusing any vaccines) or, and probably much less commonly, non-reporting by a provider. The percentage of children with no vaccines recorded nationally (3.1%) is greater than those recorded as conscientious objectors (1.5%).

The map of the proportion of conscientious objectors to immunisation (Figure 17) shows pockets of high levels of objection within jurisdictions in 2009, particularly in coastal areas of south-east Queensland, northern New South Wales, Adelaide and south-west 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 18) shows some additional areas not evident from maps of official conscientious objection.

Provider type

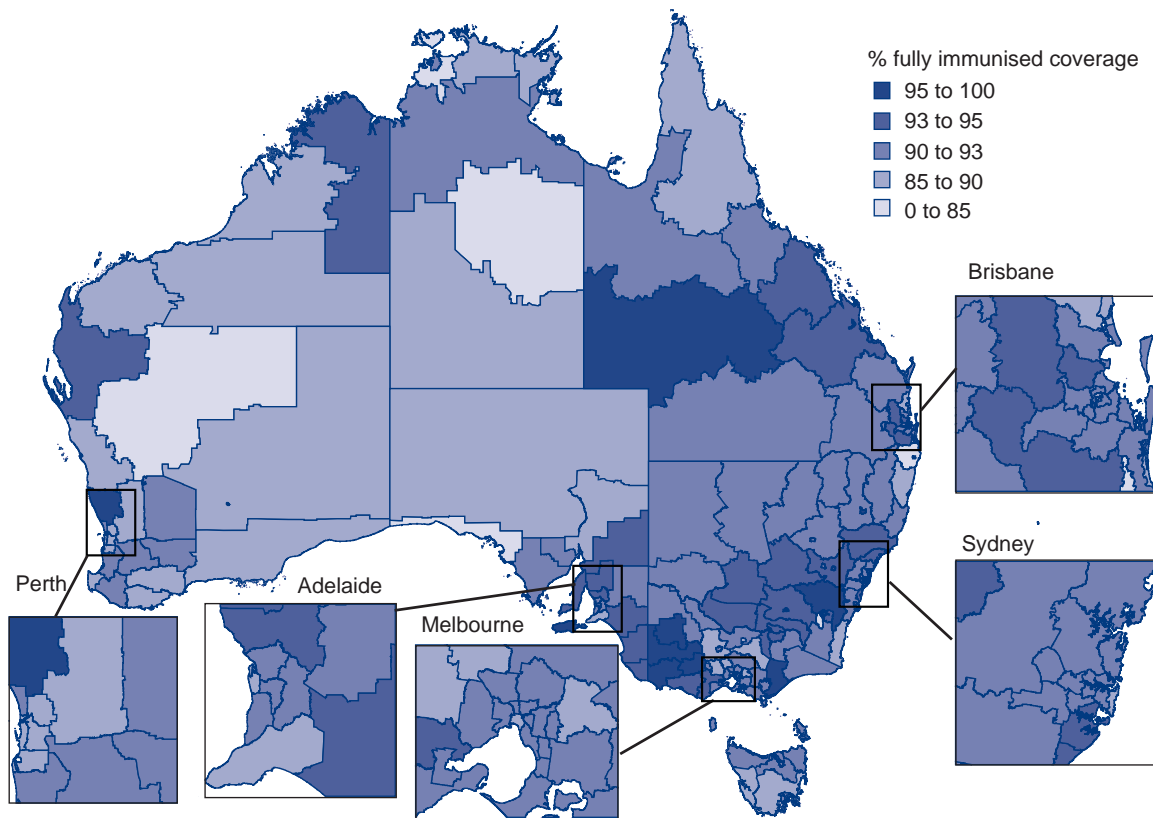
The proportion of immunisations recorded on the ACIR as given by GPs, municipal councils and other providers in Australia by jurisdiction is shown in Figure 19. GPs administer the large majority of immunisations in Australia; the proportion given by GPs has increased over the past 10 years by almost 5% (not shown). Local government clinics also administer a substantial proportion of immunisations, especially in some jurisdictions. The only other category of provider administering a major number 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

These data reveal that Immunise Australia Program coverage targets have been reached for children both 12 and 24 months of age. However, this is not the case for children 5 years of age where coverage is below the target in all jurisdictions.

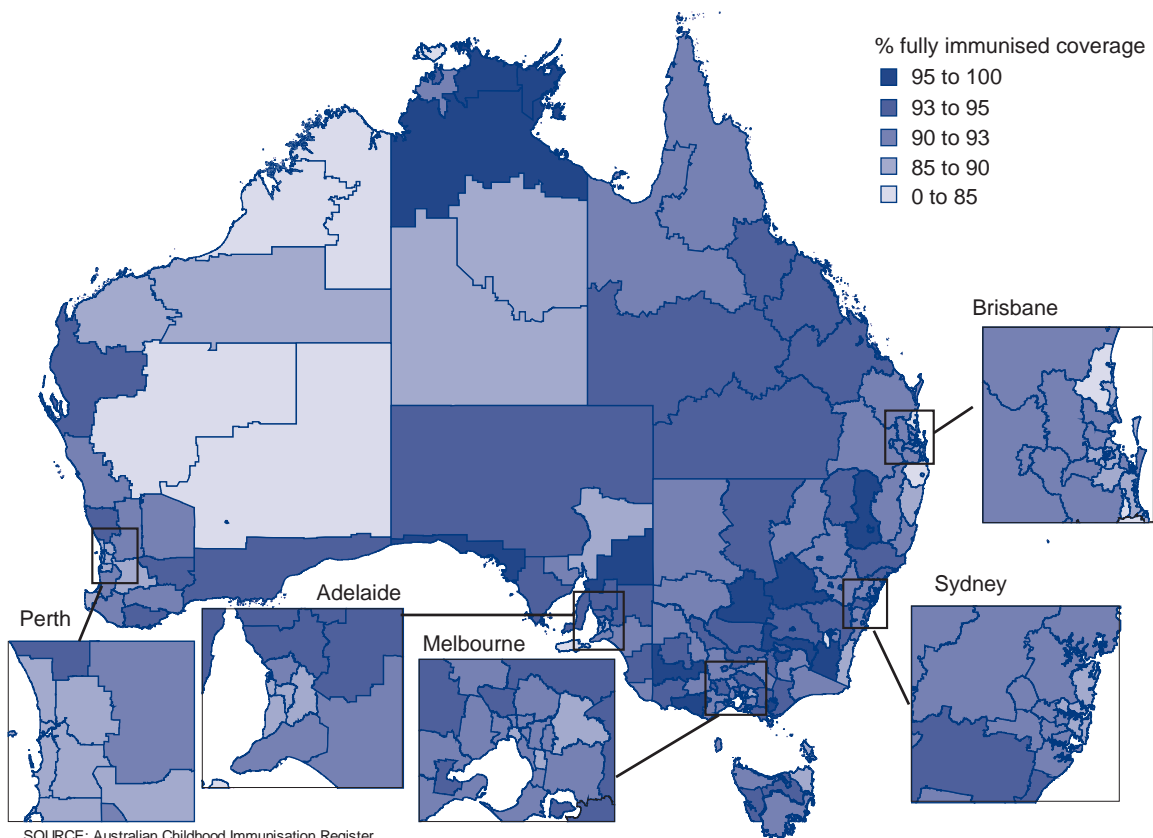
Coverage at 24 months of age exceeds that at 12 months of age, and this is likely related to the exclusion of the varicella vaccine at 18 months from

Figure 14: 'Fully immunised' coverage at 12 months of age, by Statistical Subdivision, Australia, 2009



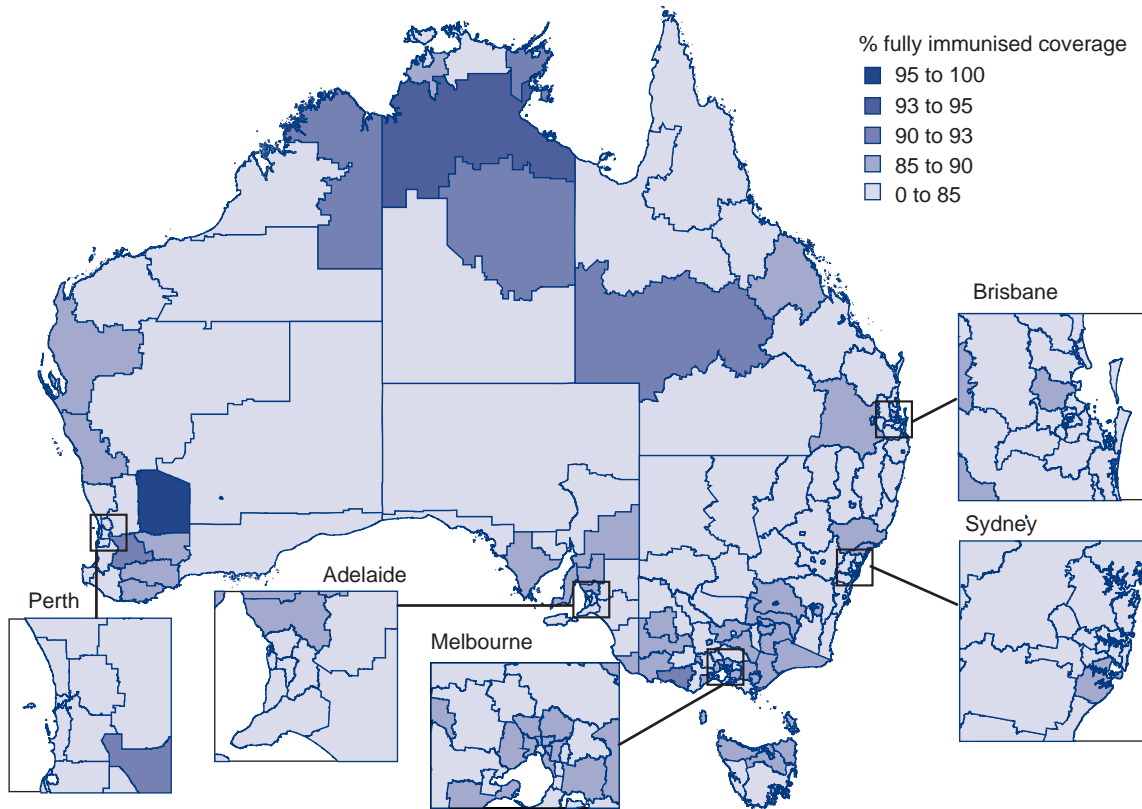
SOURCE: Australian Childhood Immunisation Register

Figure 15: 'Fully immunised' coverage at 24 months of age, by Statistical Subdivision, Australia, 2009



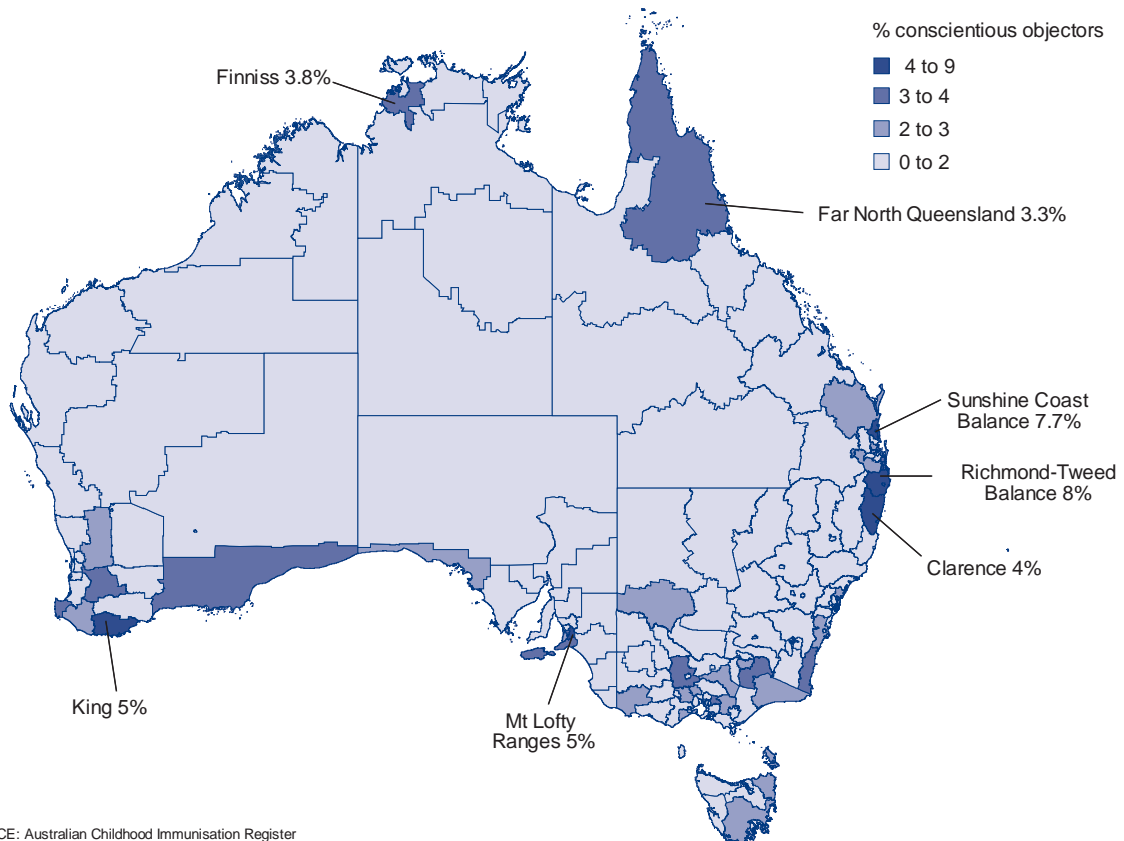
SOURCE: Australian Childhood Immunisation Register

Figure 16: 'Fully immunised' coverage at 5 years of age, by Statistical Subdivision, Australia, 2009



SOURCE: Australian Childhood Immunisation Register

Figure 17: Proportion of official conscientious objectors to immunisation, Australia, 2009 for the cohort born January 2003 to December 2008



SOURCE: Australian Childhood Immunisation Register

Figure 18: Proportion of children with no vaccines recorded on the Australian Childhood Immunisation Register, Australia, 2009 for the cohort born January 2003 to December 2008

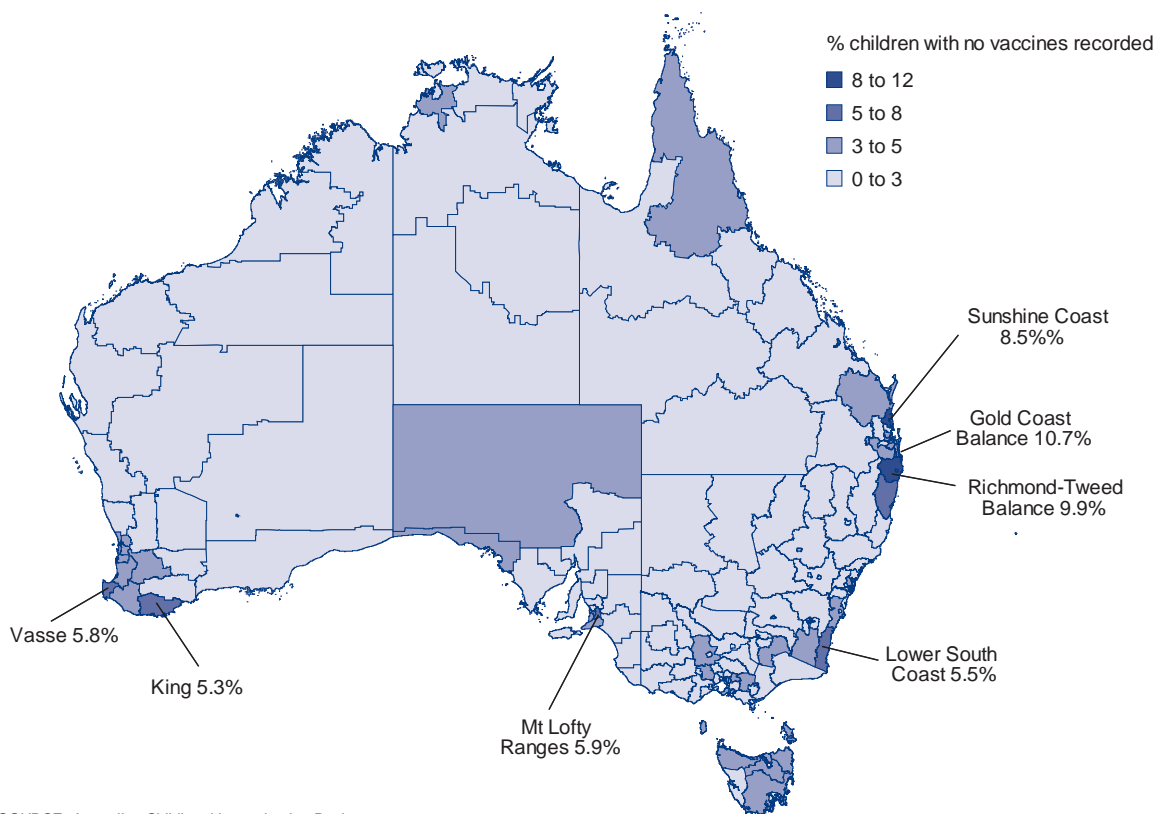
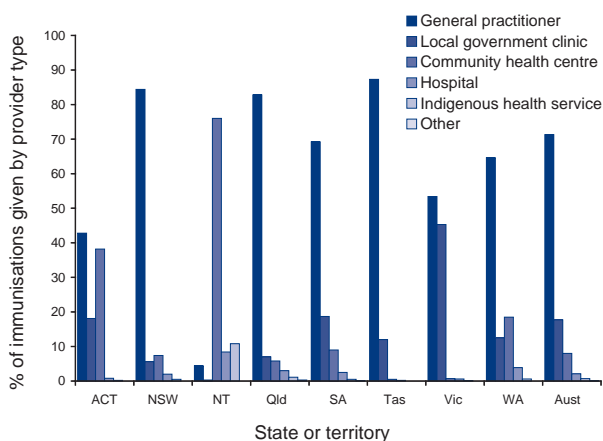


Figure 19: Proportion of immunisations on the Australian Childhood Immunisation Register given by various provider types, by state or territory, 2009



the calculation of ‘fully vaccinated’, the absence of any other vaccines administered between those ages, and the impact of immunisation incentives. The change in December 2007 in assessment age from 6 to 5 years for vaccines due at 4 years, resulted in lower coverage estimates for vaccines due at this age and has revealed that many children are not fully protected in a timely way for the diseases these vaccines guard against. This

has been of particular concern during the pertussis epidemic of 2008 and 2009, when children aged 5 to 9 years were seriously affected.²⁴

There is earlier evidence that immunisation incentives positively impacted coverage estimates.¹⁴ However, there have been significant changes to incentives during 2008 for both providers and parents, in particular the removal of SIP payments and the reduction in the age cut-off for eligibility for payments for the 4 year vaccination. The initial analyses in this report provide no evidence of a reduction in coverage associated with the removal of SIP payments, while coverage at 5 years has increased following the age cut-off changes. However, more analysis is required to examine the impact of these changes in more detail.

A number of vaccines that are included in the NIP are not included when calculating ‘fully immunised’ status or in eligibility for incentive payments. Coverage estimates for 7vPCV and meningococcal C vaccines are comparable with estimates for vaccines that are included in ‘fully vaccinated’ calculations, but estimates for varicella and rotavirus are substantially lower. For rotavirus vaccines, strict upper age limits for administration may explain lower coverage, whilst varicella is the only vaccine

due at 18-months, and this milestone was historically problematic and lapsed for a 2-year period (2003–2005). The implications also vary. In the case of rotavirus vaccine, coverage of 80% or greater has been associated with substantial herd immunity and decreases in rotavirus hospitalisations in Australia and elsewhere.²⁵ In contrast, modelling studies suggest that low coverage with varicella vaccine will result in a shift of disease to older age groups with higher disease severity.²⁶ Inclusion of these and other vaccines included in the NIP in coverage assessments for 'fully immunised', and thereby in eligibility for provider and parent incentives, should be considered to drive higher coverage, especially at 18 months of age.

Coverage for vaccines recommended for Indigenous children only (i.e. hepatitis A and pneumococcal polysaccharide vaccine) remain sub-optimal. The extent of under-reporting to the ACIR for these vaccines is unknown but likely to be more than for 'universal' vaccines, given the lack of incentive payments for notification to the ACIR. However, lower coverage for vaccines targeted at Indigenous people has been a relatively consistent finding using a range of different methods for both children¹³ and adults.²⁷ Both a lack of provider knowledge about the recommendations for high risk groups, and poor identification of Indigenous children by immunisation providers, are also likely to be important contributing factors. Differences in schedules between jurisdictions may also contribute. Coverage for both vaccines is higher in the Northern Territory and Western Australia, which give the vaccines at 6 months younger (hepatitis A, 12 and 18 months, pneumococcal 18 months), than in Queensland and South Australia (18 and 24, and 24 months). The presence of other vaccines on the schedule at the same age may assist achieving higher coverage, particularly at 12 months and less so at 18 months of age. Failure to receive a 2nd dose by 9% of children also contributed to the low coverage for hepatitis A vaccine. However, protective antibody responses after 1 dose is expected from a majority of children.²⁸

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. Vaccination delay as measured in this report has improved only marginally. However, timeliness cannot be measured in the most recent cohort, as time must be allowed for late vaccination to be received. It is expected that improvements in coverage recently seen at 5 years of age will be reflected in later timeliness calculations. However, coverage 12 months after the due date of this vaccine is still less than 85%. Poorer timeliness in Indigenous children has been noted previously in infants. In this report the disparity in coverage between Indigenous and non-Indigenous at children 5 years of age has

widened from 2.7% in 2008 to 4.3% in 2009, as improvements in non-Indigenous children were not reproduced in Indigenous children. Delayed vaccination 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.

The ACIR has shown the rapid uptake of new vaccines and consistently high coverage for all vaccines, unlike some other developed countries.^{29,30} In comparison with similar countries, reported coverage at 12 months of age is higher,³¹ and, with more than 3% of children not vaccinated due to parental objection, targeting of on time vaccination is required to significantly improve the current levels of more than 91% fully immunised at 12 months of age. The reporting of national small area coverage data has not been noted elsewhere. Areas of low coverage have been identified in many remote areas and areas containing higher proportions of conscientious objectors. Vaccination timeliness has been reported elsewhere but not routinely.⁸

In conclusion, data provided by the ACIR in this report reflect continuing successful delivery of the NIP in Australia, while identifying some areas for improvement. Coverage for varicella and rotavirus vaccines are below that for other vaccines; coverage is low in some small geographic areas; timeliness of vaccination could be improved, particularly for Indigenous infants; and coverage for vaccines recommended only for Indigenous infants is lower than for other vaccines. The ACIR continues to be a very useful tool for administering the NIP and monitoring its implementation.

Author details

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References

1. Hull B, Deeks S, Menzies R, McIntyre P. Immunisation coverage annual report, 2007. *Commun Dis Intell* 2009;33(2):170–187.
2. Hull B, Mahajan D, Dey A, Menzies R, McIntyre PB. Immunisation coverage annual report, 2008. *Commun Dis Intell* 2010;34(3):241–258.
3. Hull B, Lawrence G, MacIntyre CR, McIntyre P. Immunisation coverage: Australia 2001. Canberra: Commonwealth Department of Health and Ageing, 2002.
4. 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(1):55–60.

5. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Immunisation coverage in Australia corrected for under-reporting to the Australian Childhood Immunisation Register. *Aust N Z J Public Health* 2003;27(5):533–538.
6. 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(1):17–21.
7. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Estimating immunisation coverage: is the 'third dose assumption' still valid? *Commun Dis Intell* 2003;27(3):357–361.
8. Hull BP, McIntyre PB. Timeliness of childhood immunisation in Australia. *Vaccine* 2006;24(20):4403–4408.
9. Hull BP, McIntyre PB. What do we know about 7vPCV coverage in Aboriginal and Torres Strait Islander children? *Commun Dis Intell* 2004;28(2):238–243.
10. 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(1):47–52.
11. 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(12):1041–1043.
12. Hull BP, McIntyre PB, Sayer GP. Factors associated with low uptake of measles and pertussis vaccines – an ecologic study based on the Australian Childhood Immunisation Register. *Aust N Z J Public Health* 2001;25(5):405–410.
13. 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(2):257–260.
14. Lawrence GL, MacIntyre CR, Hull BP, McIntyre PB. Effectiveness of the linkage of child care and maternity payments to childhood immunisation. *Vaccine* 2004;22(17–18):2345–2350.
15. 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(7):568–571.
16. Australian Government Department of Human Services Medicare Australia. General Practice Immunisation Incentives (GPII) Scheme. 2007. Available from: <http://www.medicare.gov.au/provider/incentives/gpii/index.jsp#N100D3>.
17. National Health and Medical Research Council. *The Australian Immunisation Handbook*. 9th edn. Australian Government Department of Health and Ageing; Canberra; 2008.
18. O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. *Commun Dis Intell* 1998;22(3):36–37.
19. 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.
20. 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(3):283–287.
21. Australian Bureau of Statistics. Australian Standard Geographical Classification (ASGC), 2001. Cat. no. 1216.0. Canberra: ABS; 2001.
22. MapInfo Corporation. MapInfo version 10.0 [computer program]. 7th edn. New York: MapInfo Corporation; 2009.
23. Australian Bureau of Statistics. Statistical Subdivision from Postal Area 2006 Concordance. Canberra: ABS; 2007. Available from: <http://www.abs.gov.au/AUSSTATS/abs@.nsf/39433889d406eeb9ca2570610019e9a5/5942283858e38743ca25730c00009f2e!OpenDocument>.
24. Australian Government Department of Health and Ageing. Communicable Diseases Surveillance – Tables: National Notifiable Diseases Surveillance System. *Commun Dis Intell* 2009;33(1):63–69.
25. Buttery JP, Lambert SB, Grimwood K, Nissen MD, Field EJ, Macartney KK, et al. Reduction in rotavirus-associated acute gastroenteritis following introduction of rotavirus vaccine into Australia's National Childhood vaccine schedule. *Pediatr Infect Dis J* 2011;301(Suppl):S25–S29.
26. Brisson M, Edmunds W, Gay N, Law B, De Serres G. Modelling the impact of immunization on the epidemiology of varicella zoster virus. *Epidemiol Infect* 2000;125(3):651–669.
27. 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.
28. Plotkin S, Orenstein WA, Offit PA. *Vaccines* 5th edn: Elsevier; 2008.
29. Centers for Disease Control and Prevention. National, state, and local area vaccination coverage among children aged 19–35 months—United States, 2008. *MMWR Morb Mortal Wkly Rep* 2009;58(33):921–926.
30. Health Protection Agency. *NHS Immunisation Statistics, England 2008–09 Report*. The Health and Social Care Information Centre, 2009.
31. World Health Organization. Reported estimates of DTP3 coverage. 2009. Available from: http://www.who.int/immunization_monitoring/en/globalsummary/timeseries/tscoveragedtp3.htm