Immunisation coverage annual report, 2013

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Executive summary

This 7th annual immunisation coverage report shows data for 2013 from the Australian Childhood Immunisation Register (ACIR) and National Human Papillomavirus (HPV) Vaccination Program Register. From July 2013, 2 new combined vaccines were included on the National Immunisation Program (NIP): *Haemophilus influenzae* type b-meningococcal C conjugate and measles-mumps-rubella-varicella (MMRV), the latter involving moving the 2nd dose of MMR vaccine from 48 months to 18 months of age. For the first time, from December 2013, the definition of 'fully immunised' at 12 months of age included pneumococcal conjugate vaccine. This report includes coverage in 2013 for 'fully immunised' and individual vaccines by Indigenous status at standard age milestones, and assessment of timeliness of vaccination.

Immunisation coverage

The proportion of Australian children classified as 'fully immunised' at 12 months of age was 90.8%, at 24 months 92.1% and at 60 months 91.2%. Vaccines available on the NIP but not assessed during 2013 for 'fully immunised' status or eligibility for incentive payments included pneumococcal conjugate and rotavirus vaccines at 12 months of age and meningococcal C conjugate and varicella vaccines at 24 months of age. Coverage for pneumococcal conjugate (90.9%) and meningococcal C conjugate (93.2%) vaccines was similar to that for other vaccines administered at the same schedule points. Coverage was lower for rotavirus vaccine (for which upper age limits apply) at 12 months of age (83.6%) and for varicella vaccine at 24 months of age (84.8%). However, varicella coverage increased 3.5 percentage points (jurisdictional range 0.7 to 5.1) in the first 6 months following the introduction of MMRV. For HPV vaccine at the national level, 71.0% of females aged 14–15 years had 3 documented doses (jurisdictional range 62.8% to 80.0%). Coverage for the 1st dose was 82.0%. Recorded coverage among women in their 20s vaccinated largely outside of school (64.0% for 1 dose, 48.0% for 3 doses) was lower.

Indigenous immunisation coverage

Coverage for 'fully immunised' at 12 months of age among Indigenous children was lower than for non-Indigenous children in all jurisdictions, with the differential varying from 11.6 percentage points in South Australia to 1.4 percentage points in the Northern Territory. However, coverage was similar for Indigenous children at 24 months of age and higher at 60 months of age. Hepatitis A vaccine and the additional pneumococcal vaccine booster dose, recommended for Indigenous children only, had sub-optimal recorded coverage of 60.1% and 59.9%, respectively.

Timeliness

Disparity in on-time vaccination between Indigenous and non-Indigenous children remained similar to previous years. It declined progressively from 21.6% at 12 months to 12.9% at 24 months of age and 5.8% at 60 months of age. By late 2013, the percentage of children who received the 1st dose of diphtheria-tetanus-pertussis acellular (child formulation) (DTPa)-containing vaccine at less than 8 weeks of age was greater than 50.0% in all but 1 jurisdiction and greater than 70.0% in 5 jurisdictions. By late 2013, the percentage of children who received the 4th dose of DTPa-containing vaccine dose at less than 4 years of age was greater than 35.0% in 3 jurisdictions.

Vaccination objection

In 2013, the proportion of children whose parents were registered objectors to vaccination was 1.9% at the national level, with large regional variations. This percentage has increased slowly over time.

Keywords: immunisation coverage, immunisation delay, Indigenous immunisation coverage, vaccination objection, human papillomavirus vaccine coverage

Introduction

This is the 7th annual immunisation coverage report, with the 1st report having focused on 2007 data.[1–6] It complements other reports providing data on immunisation coverage in Australia[7] and highlights important trends and significant issues. It follows the format of the previous reports, providing a detailed summary for 2013 that includes vaccination coverage at standard milestone ages, coverage for vaccines not included in standard coverage assessments, timeliness of vaccination, coverage for Indigenous children, analysis of 'partially immunised' children, and data for small geographic areas on the prevalence of vaccination objectors. This report also includes data

on adolescents outside the Australian Childhood Immunisation Register (ACIR) age group from previously published sources. Readers are referred to the 1st 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 at key milestone ages to measure coverage against national targets and to track trends over time. Table 1 shows the Australian National Immunisation Program Schedule for 2013.

High levels of reporting to the ACIR are maintained by a system of incentive payments for immunisation providers and carers. These have been discussed in detail elsewhere.[6,8] Some recent changes to immunisation policy, the incentive payment system and changes to the 'fully immunised' coverage algorithms are highlighted in the Box and also referred to in this report.

Table 1: Australian National Immunisation Program Schedule for children, adolescents and adults in 2013

Age	Vaccine									
Childhood vaccines										
Birth	Hep B									
2 months	Hep B	DTPa	Hib	Polio				13vPCV	Rotavirus	
4 months	Hep B	DTPa	Hib	Polio				13vPCV	Rotavirus	
6 months	Hep B	DTPa	Hib	Polio				13vPCV	Rotavirus*	
12 months			Hib-MenCCV†		MMR		Hep A‡			
18 months						MMRV§	Hep A‡‖	13vPCV‡		
24 months							Hep A‖	13vPCV‖		
48 months		DTPa		Polio	MMR¶					
Adolescent vaccines										
12 years	Hep B**	dTpa				VZV**				HPV††
15 years		dTpa							Flu‡‡,§§	23vPPV¶¶
Adult vaccines										
≥50 years									Flu‡‡,§§	23vPPV‡‡
65 years									Flu§§	23vPPV

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

† In July 2013, the combined *Haemophilus influenzae* type b (Hib) and meningococcal serogroup C conjugate (MenCCV) vaccine, Menitorix®, was added to the National Immunisation Program (NIP) Schedule at 12 months of age. This combination vaccine replaces the single dose of monovalent MenCCV vaccine and booster dose of monovalent Hib vaccine previously scheduled at 12 months of age.

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

§ Measles-mumps-rubella-varicella vaccine introduced onto the NIP Schedule on 1 July 2013.

‖ Aboriginal and Torres Strait Islander children in Queensland and South Australia. The hepatitis A vaccination schedule for Indigenous children changed in July 2013 so that now dose 1 is administered to Indigenous children at 12 months of age and dose 2 at 18 months of age in all 4 jurisdictions (the Northern Territory, Queensland, South Australia and Western Australia).

¶ The dose of measles-mumps-rubella vaccine at 4 years of age will cease on 1 January 2016.

** Catch-up only.

†† From February 2013, males and females aged 12–13 years received the human papillomavirus vaccine at school. Males aged 14–15 years also received the vaccine as part of a catch-up program until the end of the 2014 school year.

‡‡ For Aboriginal and Torres Strait Islander people only.

§§ Annual vaccination, all aged ≥6 months with medical risk factors, non-Indigenous adults aged ≥65 years.

¶¶ Aboriginal and Torres Strait Islander adults with medical risk factors.

Box: Recent significant changes in immunisation policy, immunisation incentives and coverage calculation algorithms

- July 2013: The combined *Haemophilus influenzae* type b (Hib)-meningococcal serogroup C conjugate vaccine, (MenCCV) Menitorix®, was added to the National Immunisation Program (NIP) Schedule at 12 months of age. This combination vaccine replaces the single dose of monovalent MenCCV and booster dose of monovalent Hib vaccine previously scheduled at 12 months of age.
- A combination measles-mumps-rubella-varicella (MMRV) vaccine for children aged 18 months was added to the NIP, replacing the separate measles-mumps-rubella (MMR) vaccine previously given at 4 years, and the varicella vaccine (for chickenpox) previously given at 18 months. MMR vaccination at 4 years of age is to continue in parallel until the first cohort eligible for MMRV vaccine reaches 4 years of age.
- Pneumococcal vaccine was added to the list of immunisations that children need to receive to be assessed as 'fully immunised' at 12 months of age. The expansion of the definition of 'fully immunised' reinforces the importance of vaccines by linking them to payments to families and immunisation providers.[9]
- The hepatitis A vaccination schedule for Indigenous children changed so that now dose 1 is administered to Indigenous children at 12 months of age and dose 2 at 18 months of age in all 4 relevant jurisdictions (the Northern Territory, Western Australia, Queensland and South Australia).
- February 2013: The human papillomavirus vaccine was funded under the NIP for males aged 12–13 years, delivered in school-based programs.
- July 2012: Eligibility for the Family Tax Benefit Part A supplement requires that children are assessed as fully immunised, replacing the Maternity Immunisation Allowance. To meet the immunisation requirements for the Family Tax Benefit Part A supplement parents need to have their children immunised during the financial years that each child turns 1, 2 and 5 years of age. Children need to be up-to-date with immunisation or have an approved exemption.
- October 2011: Prevenar 13® (13-valent pneumococcal conjugate vaccine, 13vPCV) replaced 23vPPV as a booster dose in Indigenous children living in the Northern Territory, Western Australia, Queensland and South Australia.
- July 2011: Prevenar 13® (13-valent pneumococcal conjugate vaccine, 13vPCV) replaced Prevenar® (7-valent pneumococcal conjugate vaccine, 7vPCV) on the NIP for children at 2, 4 and 6 months of age in all states and territories except the Northern Territory (adopted 13vPCV from 1 October 2011).
- September 2009: Changes in the coverage calculation algorithms occurred that tightened the rules regarding receipt of Hib and hepatitis B vaccines for children aged 12 and 24 months.
- October 2009: Recommendation by the Australian Technical Advisory Group on Immunisation (ATAGI) that the 4th dose of diphtheria-tetanus-pertussis acellular (child formulation) (DTPa)-containing vaccine can be given from 3.5 years of age instead of the previously recommended 4 years of age.
- March 2009: Recommendation by ATAGI to parents and immunisation providers to consider bringing the 1st dose of DTPa forward to 6 weeks of age to provide earlier protection.
- January 2009: Changes to the overdue rules so that children were classified as overdue for preschool boosters at 4 years and 1 month instead of the previous 5 years of age. This applied to parental and provider incentive payments.
- December 2007: The coverage algorithm for immunisations due at 48 months of age was changed to assess children at 60 months rather than 72 months 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.[10] Participation in the ACIR is opt-out so it constitutes a nearly complete population register, as approximately 99.0% of children are registered with Medicare by 12 months of age.[10] 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 automatically from medical practice software or through the internet using the Medicare Australia website or by submitting paper encounter forms. The existence of medical contraindications and vaccination 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 ACIR must be rendered in accordance with the guidelines issued by the Australian Technical Advisory Group on Immunisation (ATAGI).[11] 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)[12] 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 60 months of age (for vaccines due at 48 months). A minimum 3-month lag period is allowed for late notification of immunisations to the ACIR, but only immunisations given on or before a child's 1st, 2nd or 5th respective birthdays are considered.[12] 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.[13,14]

Three-month birth cohorts are used for time trend analyses, while 12-month wide cohorts are used for other analyses in this report such as for small area coverage. The 12-month wide cohorts used in this report are children born between 1 January and 31 December 2012 for the 12-month milestone age; children born between 1 January and 31 December 2011 for the 24-month milestone age; and children born between 1 January and 31 December 2008 for the 5-year (60-month) milestone age.

The proportion of children designated as 'fully immunised' is calculated using the number of 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 was defined as a child having a record on the ACIR of a 3rd dose of the combined DTPa-hepB-IPV-Hib vaccine (and a 3rd dose of pneumococcal conjugate vaccine since the December 2013 quarterly coverage report). 'Fully immunised' at 24 months of age was defined as a child having a record on the ACIR of a 3rd dose of the combined DTPa-hepB-IPV-Hib vaccine, a 4th dose of *Haemophilus influenzae* type b (Hib) (PRP-T) vaccine, and a 1st dose of a measles-mumps-rubella (MMR)-containing vaccine. 'Fully immunised' at 60 months of age was defined as a child having a record on the ACIR of a 4th dose of combined DTPa-IPV vaccine and a 2nd dose of an MMR-containing vaccine.

Immunisation coverage estimates were also calculated for individual National Immunisation Program (NIP) vaccines, including the 6 NIP vaccines not routinely reported in the quarterly coverage reports published in *Communicable Diseases Intelligence*[15] and not part of 'fully immunised' calculations at 12 and 24 months of age. They were: a 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 conjugate 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 pneumococcal vaccine in Indigenous children by 30 months of age. In July 2013, the hepatitis A vaccination schedule for Indigenous children changed so that now dose 1 is administered to Indigenous children at 12 months of age and dose 2 at 18 months of age in all 4 jurisdictions (the Northern Territory, Queensland, South Australia and Western Australia). However, hepatitis A coverage data presented in this report uses the old calculation with assessment by 30 or 36 months of age as the new assessment ages do not apply to the cohort analysed in this report.

Changes to immunisation policy and changes to the 'fully immunised' coverage algorithms have had an impact on vaccination coverage presented in this report. In December 2007, the coverage algorithm for immunisations due at 48 months of age was changed to assess children at 60 months

rather than 72 months of age. In January 2009, changes were made to the overdue rules so that children were classified as overdue for pre-school boosters at 49 months instead of the previous 60 months of age. In March 2009, a recommendation was made by ATAGI to parents and immunisation providers to consider bringing the 1st dose of diphtheria-tetanus-pertussis acellular (child formulation) (DTPa) forward to 6 weeks of age to provide earlier protection against pertussis infection. From the September 2009 coverage assessment date onwards, changes were made in the coverage calculation algorithms that tightened the rules regarding receipt of Hib and hepatitis B vaccines for children aged 12 and 24 months of age. Prior to September 2009, if a child aged 12 months had a record on the ACIR of a 2nd or 3rd dose of any Hib vaccine, he or she was considered 'fully immunised'. From September 2009, a child needed a record on the ACIR of a 3rd dose of any Hib vaccine or a 2nd dose of either PedvaxHIB or Comvax to be assessed as 'fully immunised'. Prior to September 2009, if a child aged 12 months had a record on the ACIR of a 2nd or 3rd dose of any hepatitis B vaccine, he or she was considered 'fully immunised'. From September 2009, a child needed a record on the ACIR of a 3rd dose of any hepatitis B vaccine or a 2nd dose of either Engerix-B (paediatric), Comvax or H-B-VAX II (paediatric) to be assessed as 'fully immunised' at 12 months of age. In October 2009, a recommendation was made by ATAGI that the 4th dose of DTPa-containing vaccine can be given from 42 months (3.5 years) of age instead of the previously recommended 48 months of age. From the December 2013 quarterly coverage report, the 3rd dose of pneumococcal conjugate vaccine was included in coverage requirements for 'fully immunised' at the 12-month milestone.

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 DTPa (due at 60 days of age) when he or she was more than 90 days of age was classified as late for that dose. For descriptive purposes, we categorised the outcome measure for each dose as either 'no delay', 'delay of between 1 and 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 birth cohorts. Children included in the timeliness analysis were assessed at 1–3 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 'Major cities', 'Inner regional', 'Outer regional', 'Remote', and 'Very remote' using the Accessibility/Remoteness Index of Australia (ARIA),[16] which was developed by the National Centre for Social Applications of GIS (now the Australian Population and Migration Research Centre) as a joint project with the Australian Government Department of Health in 1997–1998. ARIA is an unambiguously geographical approach to defining remoteness. The most widely used ARIA product is ARIA+. ARIA+ is a continuous varying index with values ranging from 0 (high accessibility) to 15 (high remoteness), and is based on road distance measurements from over 12,000 populated localities to the nearest Service Centres in 5 categories based on population size. For the timeliness analysis, we combined the 2 'Regional' categories ('Inner Regional' and 'Outer Regional') into 1 category and the 2 'Remote' categories ('Remote' and 'Very Remote') into 1 category.

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'; children with unknown Indigenous status were presumed to be 'non-Indigenous'. Coverage estimate time trends are presented from 2002 only, due to poor rates of reporting Indigenous status prior to then.[17]

Small area analysis

Analysis for small areas was done by Australian Bureau of Statistics (ABS)-defined Statistical Area 3 (SA3) areas,[18] chosen because each is small enough to show differences within jurisdictions but not too small to render maps unreadable. Maps were created using version 12 of the MapInfo mapping software[19] and the ABS Census Boundary Information. As postcode is the only geographical indicator available from the ACIR, the ABS Postal Area to SA3 Concordance 2011 was used to match ACIR postcodes to SA3s, in order to create an SA3 field for each child in the relevant study cohort.[20]

Vaccination objection and incomplete immunisation

A child must be registered with Medicare before its parent(s) can lodge an objection to vaccination. Registered vaccination objectors are eligible for parent incentive payments even if their children are unvaccinated. However, some parents may object to vaccination but not lodge any registered objection to the ACIR. Such 'silent' vaccination objectors may have either some or no vaccines recorded on the ACIR. We calculated the proportions of children with vaccination objector status and no vaccines recorded on the ACIR, vaccination objector status and at least 1 vaccine recorded on the ACIR, no vaccination objector status and no vaccines recorded on the ACIR, and no vaccination objector status and not fully immunised by 24 months of age, from the cohort of children registered with Medicare and born between 1 January and 31 December 2011. Some of the children in the latter 2 groups may be 'silent objectors'. We chose this cohort 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.

Human papillomavirus vaccine coverage

The National Human Papillomavirus (HPV) Vaccination Program is listed on the NIP Schedule, funded under the Immunise Australia Program, and delivered to females and, since 2013, males through an on-going school-based program usually in the 1st year of secondary school. From 2007 to 2009, there was a time-limited catch-up program delivered through schools, general practices and community immunisation services for females up to age 26. Males were offered a time-limited catch-up program in 2013–2014, at the age of 14–15 years. A full course of HPV immunisation was defined as 3 doses of quadrivalent HPV vaccine. Data on the National HPV Vaccination Program are provided by the National HPV Vaccination Program Register, which is operated by the Victorian Cytology Services Incorporated. Data for males were not available during preparation of this report. The purpose of this legislated register is to support the implementation of the vaccination program and to provide data for monitoring and evaluation. States and territories provide data to the HPV Register from their school-based programs. Doses administered in general practice or by community providers outside of the school program are notified on a voluntary basis, with a notification payment provided only to general practitioners (GPs) during the 2007–2009 catch-up program. The World Health Organization proposes using 15 years as the reference age for HPV vaccination coverage for the purposes of international comparison.

Coverage in the elderly

As there has not been an Adult Vaccination Survey[21] undertaken in Australia since 2009, no data are presented in this 2013 report on influenza or pneumococcal (23vPPV) vaccination coverage over the age of 65 years.

Results

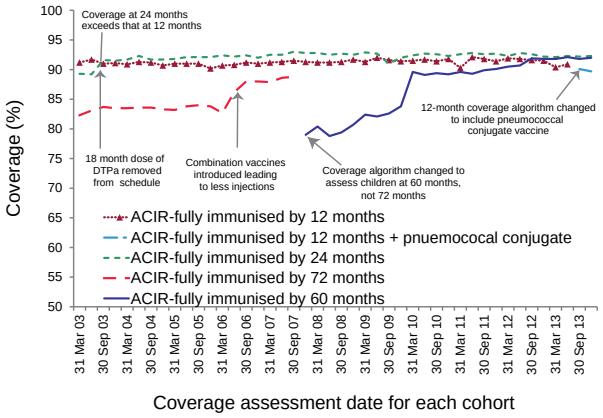
Coverage estimates

Overall

Coverage estimates in 2013 for full-year birth cohorts at the 3 milestone ages of 12 months, 24 months and 60 months are provided in Tables 2, 3 and 4. Nationally and for almost all jurisdictions, 'fully immunised' coverage and coverage for all individual vaccines (except rotavirus and varicella vaccines) for the 12-month, 24-month and 60-month age groups exceeded the target of 90%. However, coverage at 60 months of age in Western Australia was below this target for almost all vaccines and 'fully immunised'.

Figure 1 shows time trends in 'fully immunised' childhood vaccination coverage in Australia, assessed at 12 months, 24 months and 60 months of age, for 3-month cohorts born from 1 January 1999 to 31 December 2012. Coverage has been stable for the 12– and 24-month milestone age groups since late 2003. However, during 2013, coverage for the 12-month age group for vaccines due at 6 months of age declined by 1.8 percentage points. Half

Figure 1: Trends in 'fully immunised' vaccination coverage estimates, Australia, 2000 to 2013*



* By 3-month birth cohorts born between 1 January 1999 and 31 December 2012. Coverage assessment date was 12 months after the last birth date of each cohort.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Table 2: Percentage of children in 2013 immunised by 12 months of age, by vaccine and state or territory*

Vaccine	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	5,484	100,605	3,757	62,985	20,043	5,860	75,921	33,480	308,495
Diphtheria, tetanus, acellular pertussis	94.4	91.2	91.5	91.9	91.4	90.8	91.9	91.3	91.6
Poliomyelitis	94.3	91.1	91.5	91.9	91.3	90.7	91.8	91.2	91.5
Haemophilus influenzae type b	94.0	90.7	91.2	91.7	91.0	90.4	91.4	90.8	91.2
Hepatitis B	93.7	90.7	91.3	91.5	90.9	90.7	91.3	90.5	91.1
Fully immunised†	93.3	90.4	91.0	91.4	90.7	90.3	91.0	90.1	90.8
Rotavirus	88.2	86.4	86.1	81.2	83.3	86.1	82.4	78.3	83.6
Pneumococcal conjugate vaccine	93.7	90.6	91.1	91.4	90.8	90.3	91.1	90.4	90.9
Fully immunised† + pneumococcal conjugate vaccine	93.0	89.9	90.5	91.1	90.3	89.6	90.5	89.7	90.3

* Cohort born in 2012.

† 'Fully immunised' – 3 doses of a DTPa-containing vaccine, 3 doses of polio vaccine, 2 or 3 doses of PRP-OMP-containing Hib vaccine or 3 doses of any other Hib vaccine, and 3 doses of any hepatitis B vaccine or 2 doses of either Engerix-B (paediatric), Comvax or H-B-VAX II (paediatric). From July 2013, the 3rd dose of pneumococcal conjugate vaccine was included in the coverage algorithm for the 12-month milestone.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Table 3: Percentage of children in 2013 immunised by 24 months of age, by vaccine and state or territory*

Vaccine	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	5,473	99,099	3,687	62,498	19,847	6,219	73,885	33,415	304,123
Diphtheria, tetanus, acellular pertussis	95.1	94.6	95.3	94.9	94.7	95.8	95.2	93.6	94.8
Poliomyelitis	95.1	94.6	95.4	94.8	94.7	95.8	95.2	93.6	94.7
Haemophilus influenzae type b	95.2	94.8	95.8	94.7	94.5	95.7	95.1	93.5	94.7
Hepatitis B	94.5	94.0	95.1	94.4	94.2	95.4	94.6	95.4	94.1
Measles, mumps, rubella†§	94.4	93.7	94.9	94.2	93.9	94.6	94.1	92.7	93.9
Fully immunised‡	92.8	91.8	93.5	92.8	92.1	93.4	92.4	90.4	92.1
Varicella§	88.4	84.4	86.9	87.4	83.4	84.2	84.2	82.5	84.8
Meningococcal C	93.6	93.0	94.4	93.7	93.4	94.2	93.4	91.9	93.2

* Cohort born in 2011.

† A combination MMRV vaccine for children aged 18 months was added to the National Immunisation Program. The MMRV vaccine replaces the separate MMR vaccine previously given at 4 years, and the varicella vaccine (for chickenpox) previously given at 18-months.

‡ Fully immunised: 3 or 4 doses of a DTPa-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of PRP-OMP-containing Hib vaccine or 4 doses of any other Hib vaccine, 3 or 4 doses of Engerix-B (paediatric), Comvax or H-B-VAX II (paediatric) hepatitis B vaccine or 4 doses of all other hepatitis B vaccines, and 1 dose of an MMR-containing vaccine.

§ MMRV coverage for children born July to December 2011 not shown due to data system issues.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Table 4: Percentage of children in 2013 immunised by 60 months of age, by vaccine and state or territory*

Vaccine	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	5,211	100,460	3,514	65,215	20,346	6,556	74,384	33,834	309,970
Diphtheria, tetanus, acellular pertussis	92.6	92.5	91.4	92.3	91.5	93.4	92.9	89.9	92.2
Poliomyelitis	92.6	92.5	91.4	92.3	91.5	93.3	92.9	90.0	92.2
Measles, mumps, rubella	92.3	92.4	91.7	92.3	91.5	93.7	92.8	89.8	92.2
Fully immunised †	92.3	91.2	90.5	91.4	90.2	92.2	92.4	88.9	91.2

* Cohort born in 2008.

† Fully immunised: 4 or 5 doses of a DTPa-containing vaccine, 4 doses of polio vaccine, and 2 doses of an MMR-containing vaccine.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

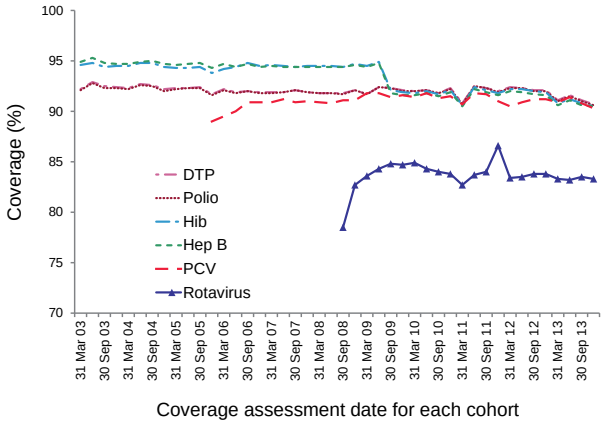
a percentage point of this decrease is due to the recent inclusion of 13-valent pneumococcal conjugate vaccine in the coverage calculation algorithm for 'fully immunised' at 12 months of age, as seen by comparison of coverage calculated according to the new and old algorithms (Table 2). For vaccines due at 48 months of age, 'fully immunised' coverage dropped to 80.4% in January 2008, following the change in assessment age from 72 months to 60 months. However, 'fully immunised' coverage for the 60-month age group then rose substantially in 2009 and 2010 and kept increasing throughout 2011–2013 to a level comparable with that in the 24-month age group (92.0%).

Individual vaccines

Coverage at 12 months of age for individual antigens in the relevant combination vaccine (DTPa-hepB-IPV-Hib) also decreased in 2013 (Figure 2). Coverage for 3 doses of pneumococcal conjugate vaccine (PCV) by 12 months of age rose slightly from 89.0% in late 2005 to 90.3% in late 2013, just below that for all other vaccines due at this age, except for rotavirus vaccine. Rotavirus vaccine coverage rose steeply from late 2008 from 78.5% to 83.4% in late 2011 and then decreased from early 2012 to 83.4%. Rotavirus coverage remained at below 84.0% during 2013.

At 24 months of age, hepatitis B coverage was higher than for all other vaccines, at just under 95.0%, until the change in the coverage algorithm in late 2009 (Figure 3). In previous years, coverage has been lowest for MMR and Hib vaccines, the only vaccines that have a 12-month dose used in calculations, but in 2013 coverage was similar for all vaccines (except varicella) at just below 95.0%.

Figure 2: Trends in vaccination coverage estimates for individual vaccines* at 12 months of age, Australia, 2000 to 2013



By 3-month birth cohorts born between 1 January 1999 and 31 December 2012. Coverage assessment date was 12 months after the last birth date of each cohort.

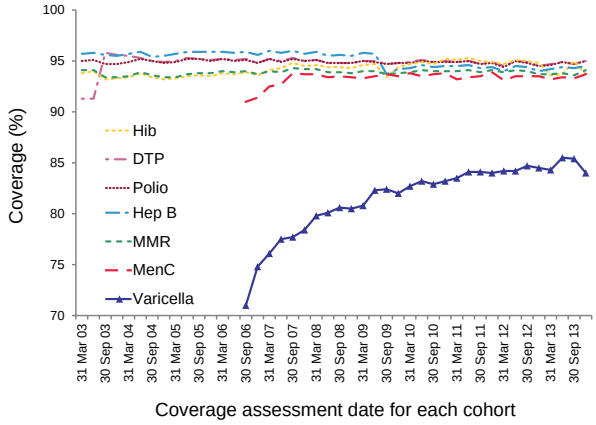
* 3rd dose of DTP, polio and 7-valent pneumococcal, 2nd or 3rd dose of Hib, hepatitis B and rotavirus.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

For vaccines due at 48 months of age, trends in individual vaccine coverage were similar to that seen for 'fully immunised coverage' i.e. a marked drop in January 2008 following the change in assessment age from 72 months to 60 months, followed by a marked increase in 2009 and 2010 and on-going increase to a level higher than when coverage was assessed at 72 months of age (Figure 4). Coverage for both vaccines due at 48 months (DTPa and MMR) was greater than 92.0% in 2013.

Figure 3: Trends in vaccination coverage estimates for individual vaccines* at 24 months of age, Australia, 2000 to 2013



By 3-month birth cohorts born between 1 January 1998 and 31 December 2011. Coverage assessment date was 24 months after the last birth date of each cohort.

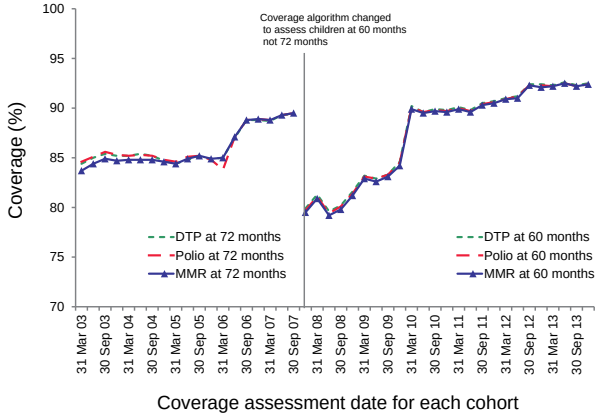
MMRV coverage for children born July to December 2011 not shown due to data system issues.

* 3rd or 4th dose of DTP, 3rd dose of polio, 3rd or 4th dose of Hib, 2nd or 3rd dose of hepatitis B, 1 dose of MMR, meningococcal C conjugate and varicella.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Figure 4: Trends in vaccination coverage estimates for individual vaccines* at 60 months of age prior to December 2007), Australia, 2002 to 2013



By 3-month birth cohorts born between 1 January 1996 and 31 December 2008. 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 DTP and polio, 2nd dose of MMR.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Coverage estimates for Indigenous children

Immunisation coverage in 2013 continued to be lower for Indigenous children than for non-Indigenous children in the 12 months age group. Coverage was similar for Indigenous children at 24 months of age and higher at 60 months of age (Tables 5 and 6). The coverage differential between Indigenous and non-Indigenous children for individual vaccines varied, with coverage lower for Indigenous children for all vaccines at 12 months of age, but higher at 24 months of age for hepatitis B, Hib, MMR and meningococcal C conjugate vaccines, and at 60 months of age for DTP, polio, and MMR.

Table 5: Vaccination coverage estimates percentages, Australia, 2013, by age, vaccine and Indigenous status

Vaccine	Milestone age	Indigenous	Non-Indigenous
DTPa	12 months*	86.5	91.9
	24 months†	94.3	94.8
	60 months‡	93.4	92.2
Polio	12 months*	86.4	91.8
	24 months†	94.3	94.7
	60 months‡	93.3	92.2
Hib	12 months*	86.3	91.4
	24 months†	94.8	94.7
	60 months‡	N/I	N/I
Hep B	12 months*	86.4	91.3
	24 months†	94.3	93.8
	60 months‡	N/I	N/I
MMR	12 months*	N/I	N/I
	24 months†	94.3	93.9
	60 months‡	93.7	92.1
Varicella	12 months*	N/I	N/I
	24 months†	82.4	84.9
	60 months‡	N/I	N/I
MenC	12 months*	N/I	N/I
	24 months†	93.7	93.2
	60 months‡	N/I	N/I
PCV	12 months*	86.4	91.2
	24 months†	N/I	N/I
	60 months‡	N/I	N/I
Rotavirus	12 months*	72.2	83.9
	24 months†	N/I	N/I
	60 months‡	N/I	N/I

* Cohort born 1 January 2012 to 31 December 2012.

† Cohort born 1 January 2011 to 31 December 2011.

‡ Cohort born 1 January 2008 to 31 December 2008.

N/I Not included in coverage estimates for that group.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

Table 6: Percentage of children fully immunised by 12 months, 24 months and 60 months of age, Australia, 2013, by Indigenous status and state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
12 months – fully immunised*									
Indigenous	91.7	88.1	90.1	85.7	79.5	87.8	86.6	82.7	86.3
Non-Indigenous	93.4	90.5	91.5	91.9	91.1	90.5	91.0	90.6	91.0
12 months – fully immunised (including pneumococcal conjugate vaccine)									
Indigenous	90.8	88.0	89.7	85.5	79.4	87.3	86.3	82.4	86.0
Non-Indigenous	93.0	90.0	91.0	91.5	90.7	89.7	90.5	90.1	90.6
24 months – fully immunised†									
Indigenous	93.2	91.6	95.9	93.0	85.8	93.7	90.6	90.4	92.0
Non-Indigenous	92.8	91.8	92.0	92.8	92.3	93.4	92.5	90.4	92.1
60 months – fully immunised‡									
Indigenous	95.1	93.8	95.3	93.9	87.4	94.2	91.5	90.3	93.0
Non-Indigenous	91.7	91.9	88.4	91.7	91.2	92.7	92.4	89.2	91.6

* 'Fully immunised' – 3 doses of a DTPa-containing vaccine, 3 doses of polio vaccine, 2 or 3 doses of PRP-OMP-containing 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 4 doses of PRP-OMP-containing Hib vaccine or 4 doses of any other Hib vaccine, 3 or 4 doses of Engerix-B (paediatric), Comvax or H-B-VAX II (paediatric) or 4 doses of all other hepatitis B vaccines, and 1 dose of an MMR-containing vaccine.

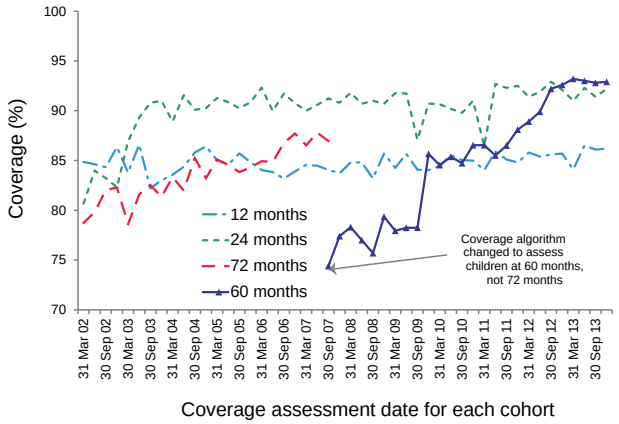
‡ 'Fully immunised' – 4 or 5 doses of a DTPa-containing vaccine, 4 doses of polio vaccine, and 2 doses of an MMR-containing vaccine.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

The proportion of Indigenous children 'fully immunised' by 24 months of age was consistently higher than at 12 and 60 months of age until 2012, when coverage at 60 months rose to levels comparable with those at 24 months (Figure 5).

Figure 5: Trends in 'fully immunised' vaccination coverage estimates for Indigenous children in Australia, 2002 to 2013, by age cohorts



Source: Australian Childhood Immunisation Register.

Coverage at 12 months of age was lower among Indigenous versus non-Indigenous children in all jurisdictions. Differentials reached 11.6 and 8 percentage points in South Australia and Western Australia, respectively, but in the Northern Territory, with the highest proportion of Indigenous children, the differential was only 1.4 percentage points (Table 6). At the age of 24 months, the coverage in Indigenous compared with non-Indigenous children varied from 3.9 percentage points higher in the Northern Territory to 6.5 percentage points lower in South Australia (Table 6).

At 60 months of age, coverage at the national level was 1.4 percentage points higher in Indigenous versus non-Indigenous children but there was variation between individual jurisdictions, ranging from coverage of 6.9 percentage points higher in the Northern Territory to 3.8 percentage points lower for Indigenous children in South Australia (Table 6).

Coverage for other National Immunisation Program vaccines not routinely reported in quarterly coverage reports

Pneumococcal conjugate vaccine and rotavirus

The 7vPCV was first added to the NIP in January 2005 and was replaced in July 2011 by 13vPCV for all Australian children at 2, 4 and 6 months of age. Since coverage was first calculated for this vaccine in late 2006, it has remained high, although slightly lower than for DTPa, polio, Hib and hepatitis B vaccines. Coverage has increased slightly from 89.0% in 2006 to 90.3% in late 2013 (Figure 2) and is greater than the 1993 Immunise Australia Program target of 90% in all jurisdictions (Table 2). In July 2013, the 3rd dose of pneumococcal conjugate vaccine was included in the coverage algorithm for the 12-month milestone.

Rotavirus vaccine was added to the NIP in July 2007, so coverage for 2 or 3 doses (depending on vaccine brand) at 12 months of age could be calculated only from the December 2008 quarter onwards. Rotavirus coverage was lower nationally (Figure 2) and had greater variation between jurisdictions than other vaccines given at 2, 4 and 6 months of age. Reported coverage in 2013 at 12 months of age varied from 88.2% and 86.4% in the Australian Capital Territory and New South Wales, respectively, for 2 doses of Rotarix® vaccine, to 78.3% in Western Australia for 3 doses of RotaTeq® vaccine (Table 2).

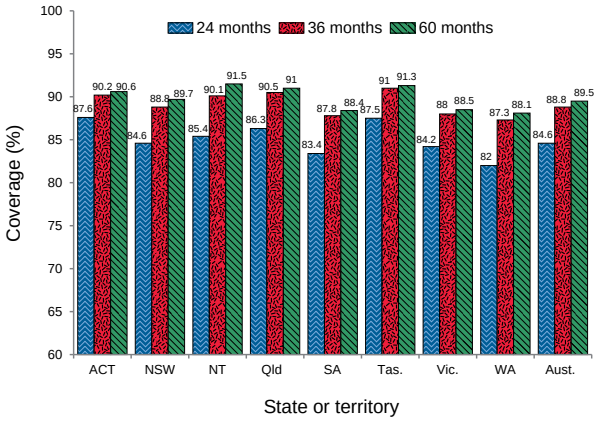
Meningococcal C and varicella

Meningococcal C conjugate vaccine was added to the NIP in January 2003. Since coverage was first calculated for this vaccine in mid-2006, it has remained at high levels, increasing from 91.0% in late 2006 to 93.7% in late 2013 (Figure 3). There was little variation in 2013 by jurisdiction with all jurisdictions experiencing coverage levels greater than 91% and the Northern Territory and Tasmania approaching 95% (Table 3).

Varicella vaccine was added to the NIP in November 2005. Reported coverage for this vaccine has consistently been 10 to 15 percentage points lower than for all the other vaccines assessed at the 24-month milestone, being 84.0% for the latest assessment in 2013 (Figure 3). Reported varicella vaccine coverage in 2013 also showed considerable variation by jurisdiction from 82.5% in Western Australia to 88.4% in the Australian Capital Territory (Table 3).

As the 18-month schedule point was historically associated with lower coverage, as there is only a 6-month time period to catch-up for varicella vaccination, we compared varicella coverage assessed at 36 months and 60 months to that assessed at 24 months by jurisdiction (Figure 6). Coverage by jurisdiction varied between 2.6 and 5.3 percentage points higher at 36 months and 3.0 to 6.1 percentage points higher at 60 months, with 4 jurisdictions reaching over 90.0% varicella coverage when assessed at 60 months.

Figure 6: Comparison of 1-dose varicella vaccine coverage assessed in 2013 at 24 months of age versus 36 months of age and 60 months of age, by state or territory



Cohort born October to December 2010.

Source: Australian Childhood Immunisation Register.

A comparison of varicella coverage before and after introduction of measles-mumps-rubella-varicella vaccine

In July 2013, the combination varicella and MMR vaccine (MMRV) was recommended and funded for the single dose of varicella vaccine scheduled at 18 months of age, at the same time lowering the age of administration of the 2nd dose of a measles-containing vaccine from 48 to 18 months of age.

Table 7 provides varicella coverage for two 3-month wide birth cohorts before and after introduction of MMRV vaccine. For Australia as a whole, varicella coverage increased by 3.5 percentage points from pre– to post-introduction of MMRV. Increases occurred in all jurisdictions except the Northern Territory, ranging from a 0.7 percentage point increase in Tasmania to a 5.1 percentage point increase in South Australia.

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

Table 7: Comparison of varicella coverage (%) before and after introduction of measles-mumps-rubella-varicella vaccine, by state or territory

	State or territory								
	ACT	NSW	NT	Qld.	SA	Tas.	Vic.	WA	Aust.
Before MMRV* introduction	87.2	85.2	89.2	87.9	83.7	87.1	84.9	83.9	85.6
After MMRV† introduction	92.0	89.1	88.4	90.2	88.8	87.8	89.1	87.0	89.1

* Cohort born 1 April to 30 June 2011, assessed at 24 months.

† Cohort born 1 April to 30 June 2012, assessed at 24 months.

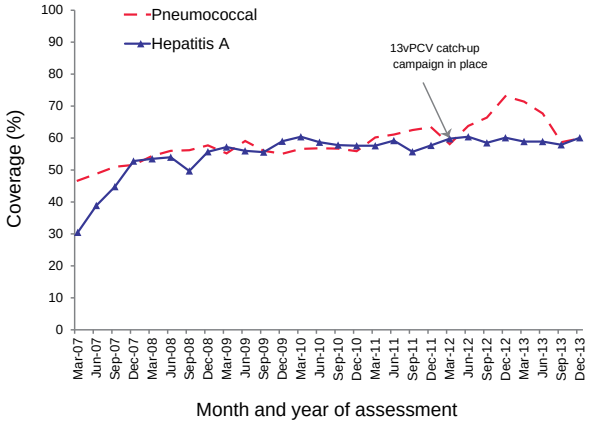
Source: Australian Childhood Immunisation Register.

greater than 30,533 since May 2004 (not shown), corresponding to approximately 1.1% of the entire cohort, a percentage that has remained stable since 2004. It is likely that there is some under-reporting of presumed natural immunity by GPs who consequently recommend that the varicella vaccine is not needed.

Pneumococcal booster and hepatitis A for Indigenous children in some jurisdictions

Hepatitis A vaccine was available in Australia prior to the development of the ACIR in 1996. It has been included on the NIP since November 2005 for Indigenous children in the Northern Territory, Queensland, South Australia and Western Australia, but was used earlier than this in North Queensland. Since March 2007, coverage of 2 doses of hepatitis A vaccine for Indigenous children by 30 months of age in Western Australia and the Northern Territory and 36 months of age in Queensland and South Australia has increased from 30.5% in early 2007 to 60.1% in December 2013 (Figure 7). An additional 10.4% of children had received 1 dose of hepatitis A vaccine by 18 or 24 months of age, putting national coverage for at least 1 dose of hepatitis A vaccine for 2013 at 70.5% in Indigenous children compared with 60.1% for 2 doses (Table 8). There was variation in reported hepatitis A vaccine coverage by jurisdiction, from a low of 42.2% in South Australia to a high of 85.9% in the Northern Territory (Table 8).

Figure 7: Trends in coverage estimates for hepatitis A* and pneumococcal† vaccines for Indigenous children, Australia,‡ 2007 to 2013



* 2 doses by 30 months of age for the Northern Territory and Western Australia (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). In July 2013, the hepatitis A vaccination schedule for Indigenous children changed so that now dose 1 is administered to Indigenous children at 12 months of age and dose 2 at 18 months of age in all 4 jurisdictions. However, hepatitis A coverage data presented in this report uses the old calculation with assessment by 30 or 36 months of age as the new assessment ages apply only to half the year.

† 18-month dose assessed at 30 months of age.

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

Source: Australian Childhood Immunisation Register.

A pneumococcal booster dose at 18 to 24 months of age has been recommended and funded for Indigenous children in 4 jurisdictions (the Northern Territory, Queensland, South Australia and Western Australia) since 2001; firstly as 23-valent pneumococcal polysaccharide vaccine then as 13-valent pneumococcal conjugate vaccine, from July 2013 in Queensland, South Australia and Western Australia, and from October 2013 in the Northern Territory. Coverage gradually increased from 46.7% in March 2007 to 59.9% in December 2013 (Figure 7). From 2011 to 2012, coverage increased by almost 10 percentage points to 73.1%, due mainly to the 13vPCV catch-up campaign that took place in 2012. There was a large variation in coverage for a 4th dose of pneumococcal vaccine by jurisdiction, from a low of 29.5% in South Australia to a high of 86.2% in the Northern Territory (Table 8).

Hepatitis B birth dose

Hepatitis B birth dose coverage is not included in this report due to substantial under-reporting. Most doses are given in maternity hospitals, many of which lack mechanisms for reporting

Table 8: Vaccination coverage* percentage for hepatitis A and pneumococcal for Indigenous children, Australia,† 2013, by state or territory

State or territory	Hepatitis A‡		Pneumococcal§	13vPCV‖
	2 doses	1 dose		
Northern Territory	85.9	87.5	86.2	85.9
Queensland	57.1	66.7	57.7	56.3
South Australia	42.2	54.1	29.5	21.4
Western Australia	67.0	71.1	59.9	54.8
Australia†	60.1	70.5	59.9	57.3

* For the last 3-month cohorts assessable in 2013.

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

‡ 2 doses by 30 months of age for the Northern Territory and Western Australia (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). In July 2013, the hepatitis A vaccination schedule for Indigenous children changed so that now dose 1 is administered to Indigenous children at 12 months of age and dose 2 at 18 months of age in all 4 jurisdictions. However, hepatitis A coverage data presented in this report uses the old calculation with assessment by 30 or 36 months of age as the new assessment ages do not apply yet.

§ 1 dose of 13vPCV (4th dose) or 23vPPV (1st dose) or 10vPCV (4th dose in the Northern Territory) by 30 months of age.

‖ 1 dose of 13vPCV (4th dose) by 30 months of age.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

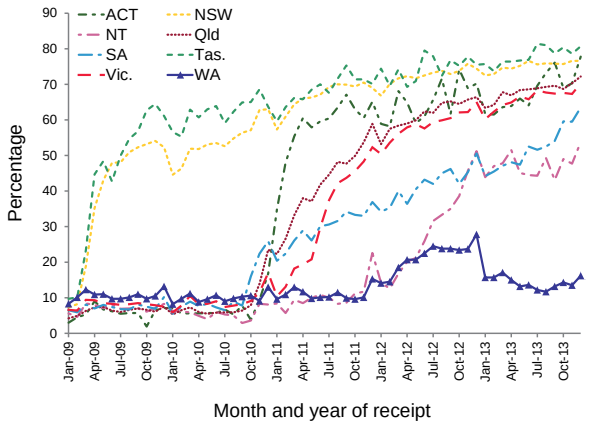
to the ACIR. A 2006 unpublished report found a minimum estimate for coverage of the birth dose of hepatitis B vaccine of 85%, based on provider-completed parent-held written records.[22]

Recommendations on 1st and 4th dose of diphtheria-tetanus-acellular pertussis (child formulation)

In response to a pertussis epidemic and to provide early protection to young infants, in March 2009 ATAGI recommended that immunisation providers give the 1st dose of DTPa vaccine at 6 weeks of age instead of 8 weeks (2 months) of age. This was promoted in that year during epidemics in New South Wales and Tasmania (and later in other jurisdictions). Prior to this, very few children received the vaccine dose at less than 8 weeks of age but over the next 4 years the percentage rose and in the Australian Capital Territory, New South Wales, Queensland, Tasmania and Victoria more than 70.0% of children were receiving the dose prior to 8 weeks of age by December 2013 (Figure 8). By late 2013, this percentage was greater than 50.0% in all jurisdictions except Western Australia.

ATAGI also recommended in October 2009 that the pre-school booster dose of DTPa-IPV could be given from 3.5 rather than 4 years of age. Take-up of this recommendation was slower with no jurisdiction giving the vaccine in any great numbers at 3.5 to 4 years of age until November 2010 (Figure 9). As at December 2013, more than 35.0% of children in 3 jurisdictions (the Australian Capital Territory, the Northern Territory and South Australia) were receiving the dose at 3.5 to 4 years of age (Figure 9).

Figure 8: Percentage of children who received the 1st dose of DTP/Hexa vaccine at age 6 to <8 weeks, by state or territory and month of receipt



* DTP/Hexa = Combined DTPa-IPV-Hib-Hep B vaccine.

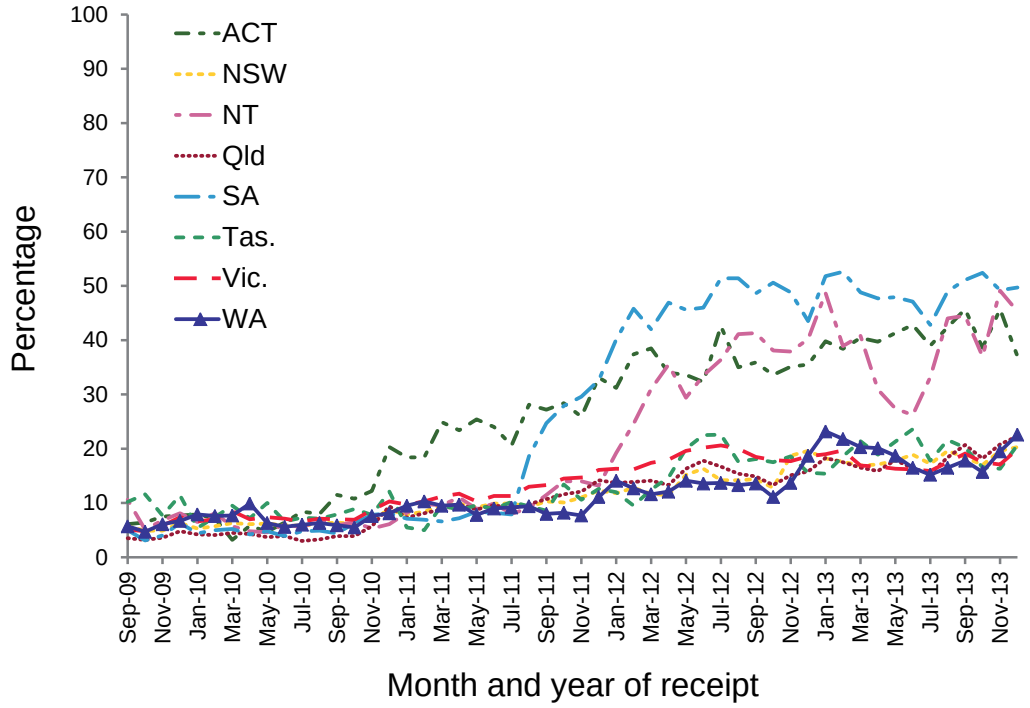
A list of vaccine abbreviations is contained in the glossary.

Source: Australian Childhood Immunisation Register.

Timeliness of immunisation

We examined the timeliness of immunisation in 2013, for both vaccines requiring multiple doses (DTP and MMR) and a single dose (MenCCV) at 12, 24 and 60 months of age.

Figure 9: Percentage of children who received the 4th dose of DTPa-IPV vaccine at age 3.5 years to <4 years, by state or territory and month of receipt

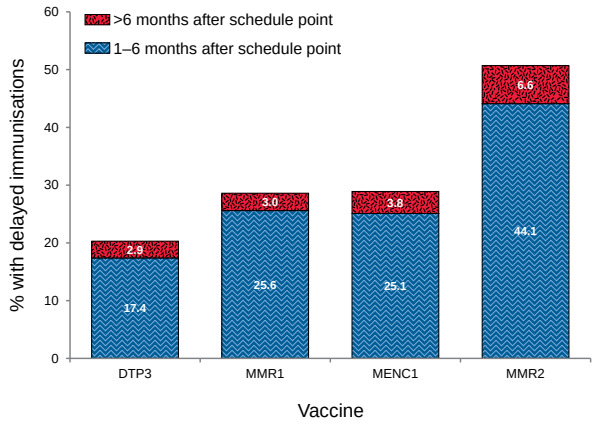


A list of vaccine abbreviations is contained in the glossary.

Source: Australian Childhood Immunisation Register.

As demonstrated in previous reports, the proportion with vaccination delay increased with older age (Figure 10). The greatest proportion with any delay was seen with the 2nd dose of MMR vaccine, with 50.7% of doses given late and 6.6% given more than 6 months late. These figures are an improvement from the 2012 report, which were 57.0% and 8.9%, respectively.

Figure 10: Vaccination delay for cohorts born in 2011 (DTP3, MMR1, MENC1) and 2007 (MMR2), Australia



DTP3 3rd dose of a diphtheria-tetanus-acellular pertussis-containing vaccine.

MMR1 1st dose of a measles-mumps-rubella vaccine.

MENC1 1st dose of a meningococcal C conjugate vaccine.

MMR2 2nd dose of a measles-mumps-rubella vaccine.

Source: Australian Childhood Immunisation Register.

For the 3rd dose of DTPa vaccine, there was greater delay for Indigenous children than for non-Indigenous children, with a 21.6% differential in on-time vaccination at less than 7 months of age (Figure 11). The same pattern was found for timeliness of the 1st dose of MMR vaccine, but with a smaller differential of 12.9% (Figure 12). Although Indigenous children had similar coverage to non-Indigenous children by 24 months of age, they were more likely to have delayed vaccination. This differential in on-time vaccination between Indigenous and non-Indigenous children remained high (the corresponding differentials for the 3rd dose of DTPa and 1st dose of MMR from the 2012 report were 21.5% and 13%, respectively). In contrast to the 3rd dose of DTPa and the 1st dose of MMR, analysis of timeliness of immunisation for a vaccine due at 48 months of age, the 2nd dose of MMR, showed a much smaller differential in delayed receipt of this vaccine between non-Indigenous children and Indigenous children of 5.8% at <49 months of age (Figure 13).

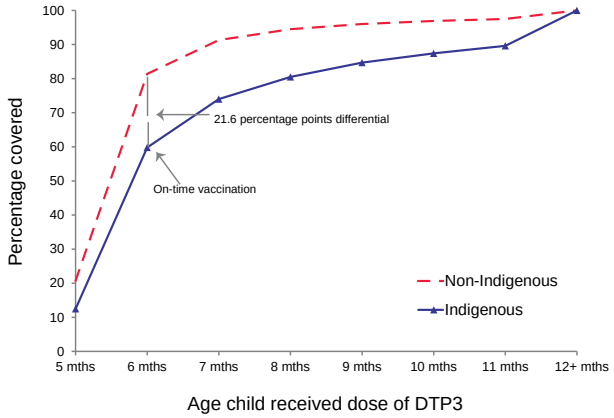
Delayed receipt of the 3rd dose of DTPa and the 1st dose of MMR by more than 1 month was found in 28.0% to 37.2% of Indigenous children and 16.5% to 26.3% of non-Indigenous children, depending

on remoteness status (Table 9). Vaccination delay was greater for Indigenous children than for non-Indigenous children for both vaccines across all categories (major cities, inner/outer regional and remote/very remote areas).

Vaccination delay for Indigenous children by jurisdiction was measured for the 3rd dose of PCV, with greater proportions experiencing delays of 1 to 6 months in Western Australia (37.4%) and South Australia (35.6%) (Figure 14). This is an increase from 2012 where the corresponding figures were 35.7% and 32.0%, respectively. The proportion of Indigenous children with long delays (>6 months) also increased from 2012 in South Australia (from 9.8% to 12.1%) and Western Australia (from 11.1% to 13.8%).

Trends in timeliness of the 3rd dose of pneumococcal vaccine and the 1st dose of MMR vaccine by Indigenous status are provided in Figures 15

Figure 11: Timeliness* of the 3rd dose of diphtheria-tetanus-acellular pertussis vaccine, Australia, by Indigenous status

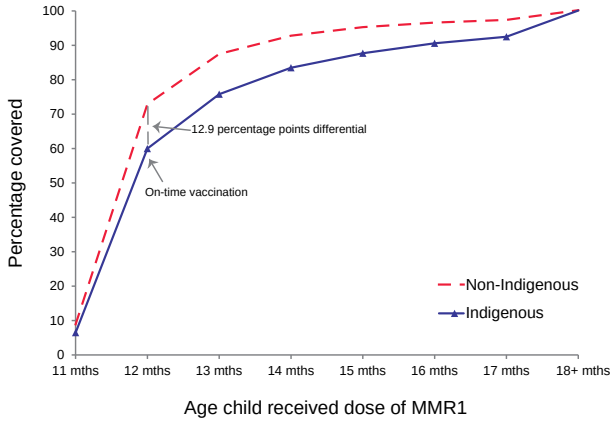


* Percentage covered = number of children who received vaccine dose at particular ages / the total number of children who received the vaccine dose, expressed as a percentage.

Cohort born in 2011.

Source: Australian Childhood Immunisation Register.

Figure 12: Timeliness* of the 1st dose of measles-mumps-rubella vaccine, Australia, by Indigenous status

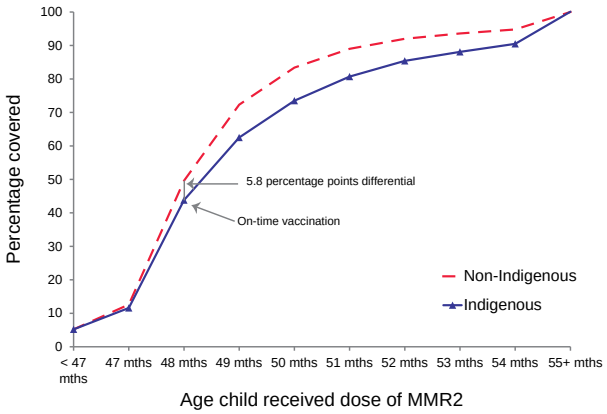


* Percentage covered = number of children who received vaccine dose at particular ages / the total number of children who received the vaccine dose, expressed as a percentage.

Cohort born in 2011.

Source: Australian Childhood Immunisation Register.

Figure 13: Timeliness* of the 2nd dose of measles-mumps-rubella vaccine, Australia, by Indigenous status

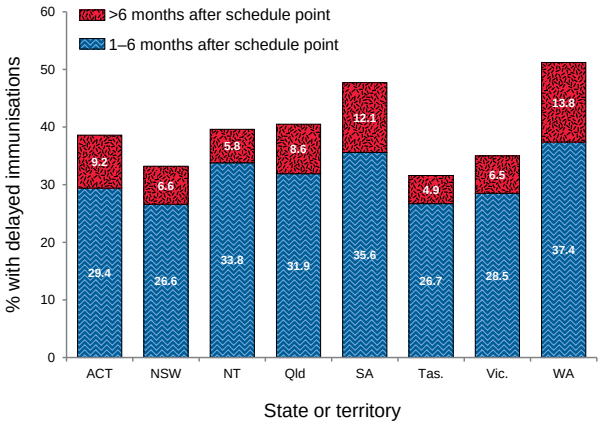


* Percentage covered = number of children who received vaccine dose at particular ages / the total number of children who received the vaccine dose, expressed as a percentage.

Cohort born in 2007.

Source: Australian Childhood Immunisation Register.

Figure 14: Vaccination delay for Indigenous children for the 3rd dose of pneumococcal conjugate vaccine, Australia, 2013, by state or territory



Cohort born in 2011.

Source: Australian Childhood Immunisation Register.

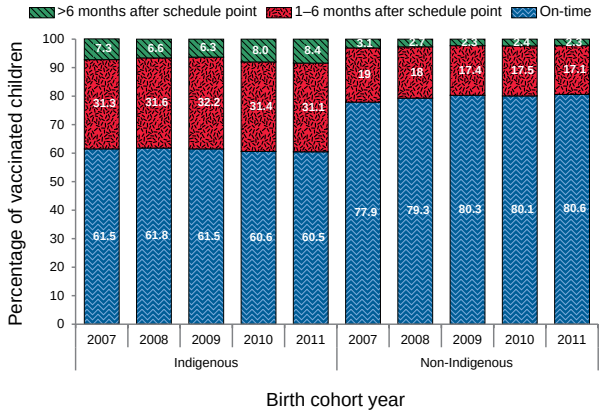
Table 9: Vaccination delay, for children aged 2 years, Australia, 2013, by Indigenous and remoteness status

Vaccine dose Indigenous status	Remoteness	1–6 months after schedule point %	>6 months after schedule point %
Diphtheria-tetanus-acellular pertussis dose 3			
Indigenous	Major cities	28.0	10.2
	Inner and Outer regional	29.4	10.9
	Remote and Very remote	37.2	9.8
Non-Indigenous	Major cities	16.5	2.4
	Inner and Outer regional	17.3	2.9
	Remote and Very remote	17.0	2.5
Measles-mumps-rubella dose 1			
Indigenous	Major cities	32.7	7.6
	Inner and Outer regional	34.1	7.8
	Remote and Very remote	32.8	6.5
Non-Indigenous	Major cities	25.3	2.8
	Inner and Outer regional	25.0	2.7
	Remote and Very remote	26.3	2.3

Source: Australian Childhood Immunisation Register.

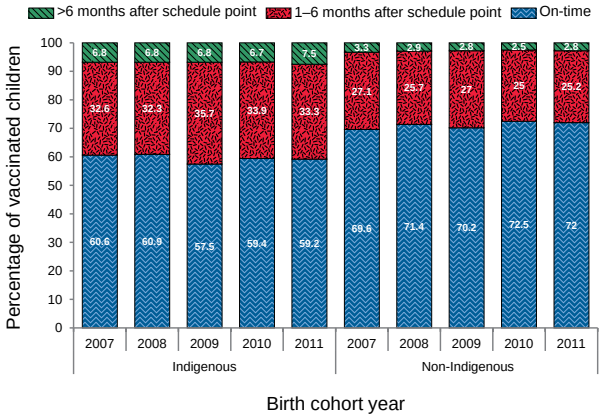
and 16. Timeliness for the 3rd dose of pneumococcal vaccine improved marginally over time for non-Indigenous children, from 77.9% in the 2007 birth cohort to 80.6% in the 2011 birth cohort; however, no improvements were seen for Indigenous children (Figure 15). Timeliness for the 1st dose of MMR vaccine improved marginally over time for non-Indigenous children, from 69.6% in the 2007 birth cohort to 72.0% in the 2011 birth cohort. In contrast, timeliness decreased marginally over time for Indigenous children, from 60.6% in the 2007 birth cohort to 59.2% in the 2011 birth cohort (Figure 16).

Figure 15: Timeliness of the 3rd dose of pneumococcal vaccine, Australia, 2007 to 2011, by Indigenous status and year of birth



Source: Australian Childhood Immunisation Register.

Figure 16: Timeliness of the 1st dose of measles-mumps-rubella vaccine, Australia, 2007 to 2011, by Indigenous status and year of birth



Source: Australian Childhood Immunisation Register.

Vaccination objection and incomplete immunisation

The percentage of registered vaccination objectors, with or without vaccines recorded on the ACIR, and children not registered as objectors but with either no vaccines recorded or some vaccines but not fully immunised, for all jurisdictions and Australia is shown in Table 10. Of the 4 groups, the largest is those parents who are not registered as objecting and whose children are not fully immunised by 24 months of age. Some of these children, and some of those children not registered as objectors but with no vaccines recorded, may be 'silent objectors'.

The rate of registered objection in 2013 for Australia was 1.9% and this varied by jurisdiction with a high of 2.5% in Queensland and a low of 1.0% in the Northern Territory.

The proportion of children whose parents are registered as objecting to vaccination are presented by Statistical Area 3 (SA3) in Figure 17. The map shows pockets of high levels of registered objection within jurisdictions in 2013, particularly in coastal areas of northern and south-east Queensland, northern New South Wales, inner Melbourne and Fremantle, with rates of objection reaching over 6.0% in many areas. These areas have had consistently high levels of registered objection over many years.

Partially immunised children

The percentage of 'partially immunised' children (excluding those whose parents have registered as vaccination objectors) who are up-to-date for specific vaccines due by 24 months of age is shown in Table 11. The vaccine that 'partially immu-

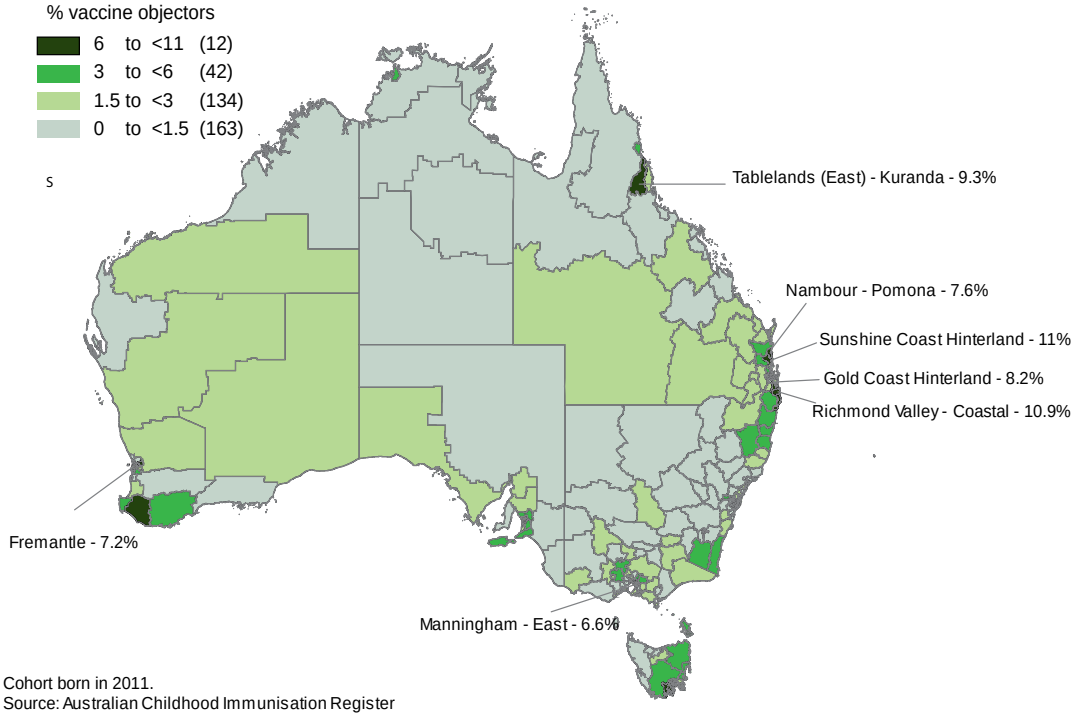
Table 10: Percentage of children aged 2 years with no or some vaccines recorded on the Australian Childhood Immunisation Register, Australia, 2013, by whether registered vaccination objection and state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	5,473	99,099	3,687	62,498	19,847	6,219	73,885	33,415	304,123
Object* and no vaccines recorded	0.9	1.0	0.5	1.6	1.3	1.1	1.0	1.2	1.2
Object* and at least 1 vaccine recorded	0.6	0.6	0.5	0.9	0.9	0.5	0.6	0.9	0.7
No objection and no vaccines recorded	2.2	2.0	1.9	1.8	1.7	1.2	1.9	2.6	2.0
No objection and partially immunised by 24 months of age	3.8	4.8	3.8	3.3	4.3	3.8	4.2	5.2	4.3

* Recorded on the Australian Childhood Immunisation Register as parent having lodged an 'Immunisation exemption conscientious objection' form to the Australian Government Department of Human Services.

Source: Australian Childhood Immunisation Register.

Figure 17: Proportion of vaccination objectors, Australia, 2013, by Australian Bureau of Statistics Statistical Area 3



Cohort born in 2011.
Source: Australian Childhood Immunisation Register

nised' children were most commonly missing by 24 months of age was the 1st dose of MMR, with only 38.1% up-to-date nationally, and 26.9% in Tasmania. Five per cent more partially immunised children were up-to-date for meningococcal C conjugate vaccine, which is due at the same age of 12 months, compared with MMR nationally.

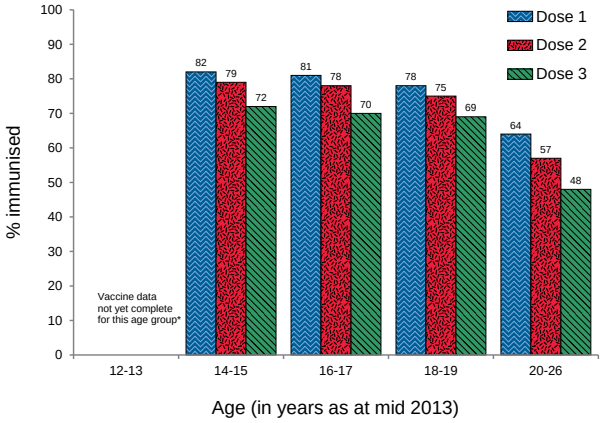
Human papillomavirus vaccine coverage

Vaccination coverage, as notified to the HPV Register, for dose 3 of the HPV vaccine for females aged 15 years in 2013 is shown in Table 12. For Australia, 71.0% of females completed a full course of the vaccine; the same figure as in 2012. Coverage varied by jurisdiction from a low of 62.8% in Tasmania to a high of 80.0% in the Northern Territory. Coverage in all age groups was higher for earlier doses; as high as 82.0% for the 1st dose in females aged 14–15 years (Figure 18). Coverage was higher in the younger age groups than the older age groups, with only 48.0% of females aged 20–26 years fully vaccinated according to data notified to the HPV Register. HPV coverage by Indigenous status was not available due to limitations in Indigenous status reporting on the HPV Register.

Provider type

GPs administer the large majority of immunisations in Australia (Figure 19); the proportion given by GPs has increased over the past 11 years by almost 5.0% (not shown). Regional differences are marked, with over 80.0% of immunisations administered by GPs in New South Wales, Queensland, and Tasmania, but the majority given by other providers in Victoria, the Australian Capital Territory, and the Northern Territory.

Figure 18: Human papillomavirus vaccination coverage for females vaccinated between April 2007 and June 2014, Australia by dose number



* In some states those aged 12–13 years in 2013 are not eligible for vaccination until 2014. Notification of 2014 doses to the Register is in progress.

Technical notes:

Includes valid doses and 'too close' doses for Clinically Complete Consumers.

Population is Estimated Resident Population provided by the Australian Bureau of Statistics – Cat 3101.0 Australia Demographic Statistics, Tables 51 to 58: Estimated Resident Population by single year of age by state and territory, published December 2013.

Age is age as at date of Estimated Resident Population estimate.

Coverage is calculated as doses administered and reported to the Human Papillomavirus (HPV) Register / estimated resident population, expressed as a percentage.

Excludes consumers who do not wish their details to be recorded on the HPV Register.

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Source: National HPV Vaccination Program Register, July 2014.

Table 11: Percentage of 'partially immunised' 2-year-old children* by whether up-to-date for vaccines due by 24 months of age, Australia, 2013, by state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	55	1,244	35	490	250	78	855	393	3,400
3 doses of DTPa	61.8	55.7	31.4	57.4	50.4	57.7	58.7	52.7	55.9
3 doses of IPV	61.8	55.0	31.4	56.3	50.0	57.7	57.4	52.7	55.1
4 doses of Hib	61.8	61.2	48.6	50.8	47.6	57.7	61.3	59.8	58.4
3 doses of Hep B	58.2	47.2	28.6	44.7	44.0	50.0	51.7	41.2	47.1
1 dose of MenCCV	38.2	40.8	48.6	49.2	44.4	34.6	42.8	41.7	42.8
1 dose of MMR	30.9	36.5	40.0	44.1	40.0	26.9	36.6	40.5	38.1

* Record of at least 1 vaccine recorded on the Australian Childhood Immunisation Register, the child's parent(s) are not vaccination objectors, and the child is not 'fully immunised' by 24 months of age. Cohort born 1 October to 31 December 2011 and assessed in 2013.

Source: Australian Childhood Immunisation Register.

A list of vaccine abbreviations is contained in the glossary.

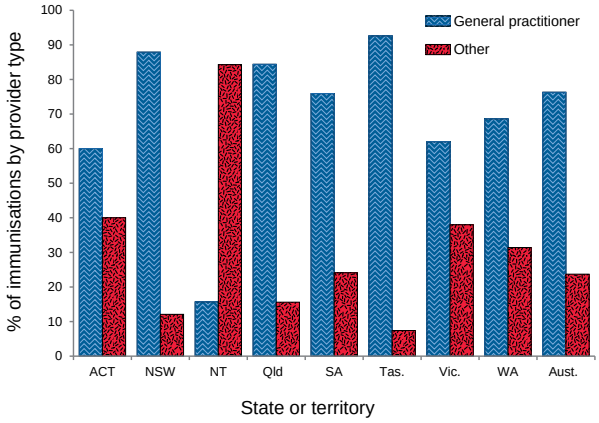
Table 12: Percentage of girls turning 15 years in 2011, 2012 and 2013 immunised for dose 3 of human papillomavirus vaccine, by state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
2011	73.2	72.7	79.5	70.2	66.0	64.0	74.5	64.8	71.2
2012	74.0	70.7	84.1	68.7	70.1	62.6	73.6	69.9	70.8
2013	73.2	68.4	80.0	70.5	71.7	62.8	74.8	70.8	71.0

Includes valid doses and 'too close' doses for Clinically Complete Consumers.

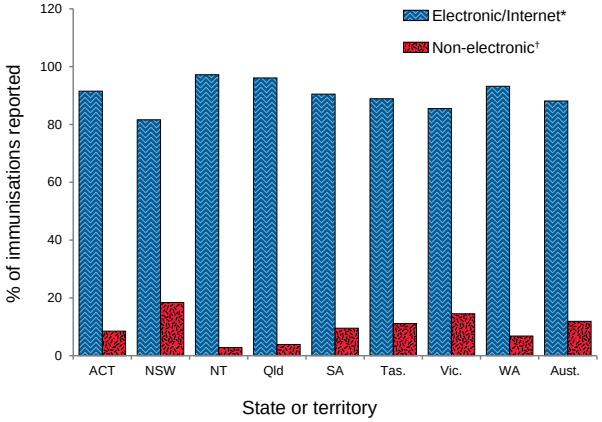
Source: National Human Papillomavirus Vaccination Program Register, July 2014.

Figure 19: Proportion of immunisations on the Australian Childhood Immunisation Register given by provider type, January to December 2013, by state or territory



Source: Australian Childhood Immunisation Register.

Figure 20: Proportion of immunisations on the Australian Childhood Immunisation Register lodged by type of reporting mechanism, January to December 2013, by state or territory



* Online claiming: Medicare Australia online claiming, a software application that allows the transmission of Australian Childhood Immunisation Register (ACIR) data via the immunisation provider's desktop software or Internet Data Interchange (IDI): approved immunisation providers can send immunisation details using the IDI upload facility through the ACIR secure area within Medicare Australia's website or record encounter: approved immunisation providers can send immunisation details using the record encounter facility through the ACIR secure area within Medicare Australia's website.

† Manual voucher: by completing an 'immunisation encounter form' and sending it to Medicare Australia or a history form: to record a child's vaccination details that may be missing from the ACIR. This form must be completed by a doctor or immunisation provider and sent to the ACIR.

Source: Australian Childhood Immunisation Register.

Mechanisms of reporting to the Australian Childhood Immunisation Register

The proportions of vaccinations on the ACIR lodged by electronic/Internet mechanisms versus non-electronic mechanisms by jurisdiction are shown in Figure 20. Most reporting in 2013 occurred through electronic/Internet mechanisms, for all jurisdictions, with the proportion reported through this method varying from 97.2% in the Northern Territory to 81.6% in New South Wales.

Discussion

This report shows that 'fully immunised' coverage targets (90%) have been reached nationally and in most jurisdictions for children 12, 24 and 60 months of age.

Coverage has been largely stable for the 12– and 24-month age groups since late 2003. However, during 2013, coverage for the 12-month age group declined by 1.8 percentage points. Half a percentage point of this decrease was due to the inclusion of the 13-valent pneumococcal conjugate vaccine in the coverage calculation algorithm for 'fully immunised' at 12 months of age, as shown by comparison with coverage calculated according to the old algorithm. The remainder of this decrease may be due to the cessation of an ACIR mail-out to parents in late 2012. Prior to December 2012, the ACIR conducted a mail-out every quarter to parents of children who were identified as not up-to-date at 9 months of age according to ACIR records.

The children targeted were those who would have been assessed against the 12-month age cohort for the following coverage quarter. The mail-out reminder letters were reinstated in December 2014.

'Fully immunised' coverage at 24 months of age continues to be stable. Coverage at this age milestone typically exceeds that at 12 months of age, which is likely related to the longer time available for late vaccinations to be assessed and due to varicella vaccine not being included in the calculation of 'fully immunised'.

Fully immunised' coverage at 60 months of age was stable in 2013 at over 91.0%, after having reached the 90.0% target for the first time in 2012.[6] The more than 10 percentage points increase in coverage in this age group since 2009 is likely due to a focus on improved timeliness of vaccination, facilitated by a change to the ACIR overdue rules in January 2009, where children became overdue for their pre-school boosters at 49 months of age instead of the previous 60 months. This change had an impact on eligibility for parent incentive payments and outcome payments for providers.

The ACIR has shown the rapid uptake of new vaccines unlike some other developed countries[23,24] However, 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 meningococcal C conjugate vaccine in 2013 were comparable with estimates for vaccines that are included in 'fully immunised' calculations, but estimates for varicella and rotavirus remained substantially lower than for other vaccines. Varicella vaccine coverage is probably lower due to both the shorter time it has been on the NIP and the age of administration (18 months). The 18-month schedule point was historically associated with similar coverage levels prior to 2003, when there was an 18-month pertussis booster, and there was a gap of over 2 years from 2003 to 2005 when no vaccine was administered at 18 months. When we assessed varicella vaccine coverage at 36 months of age instead of 24 months we observed higher estimates across all jurisdictions, ranging from 2.6 to 5.3 percentage points higher. We also found that national varicella vaccine coverage increased by 3.5 percentage points after the introduction of MMRV vaccine in mid-2013, so further increases in coverage may occur as a result of this schedule change. For rotavirus vaccines, strict upper age limits for administration, which reduce the ability to receive late doses, may explain lower coverage when compared with other vaccines assessed at 12 months of age. The implications of lower coverage for rotavirus and varicella vaccines also differ. In the case of rotavirus vaccine, coverage of 80% or greater has resulted in substantial herd immunity and decreases in rotavirus hospitalisations in Australia and elsewhere.[25,26] In contrast, modelling studies suggest that low coverage (70.0% to 90.0%) with varicella vaccine may result in a shift of disease to older age groups with higher disease severity.[27]

Coverage for vaccines recommended for Indigenous children only (hepatitis A and a booster dose of pneumococcal polysaccharide vaccine) remained sub-optimal in 2013. The extent of under-reporting to the ACIR for these vaccines is unknown but may 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 children[28] and adults.[29] Both a lack of provider knowledge about the recommendations for high-risk groups, and poor identification of Indigenous children by immunisation providers are likely to be important contributing factors. Differences in schedules between jurisdictions may also contribute. While coverage for 2 doses of hepatitis A vaccine was only 60.1%, an additional 10.4% of Indigenous children received a single dose, which provides a protective antibody response in the majority of children.[30] From July 2013, the hepatitis A vaccination schedule for Indigenous children changed with dose 1 administered at 12 months of age and dose 2 at 18 months of age in all relevant jurisdictions (the Northern Territory, Queensland, South Australia and Western Australia). Hopefully this change to administration at standard schedule points will result in an increase in 2nd dose completion.

Although most children eventually complete the scheduled vaccination series by the 24-month milestone, many still do not do so in a timely manner. On-time vaccination in 2013 did not improve from 2012, for vaccines assessed at 12 and 24 months of age. Poorer timeliness in Indigenous children aged 2 years has been noted previously.[31] Timeliness has continued to improve for vaccines due at 48 months of age and assessed at 60 months of age, for both Indigenous and non-Indigenous children. However, as coverage and timeliness of vaccines assessed at 60 months of age has improved, the disparity in timeliness between Indigenous and non-Indigenous children remains. In 2013 more than 70.0% of children in the Australian Capital Territory, New South Wales, Queensland, Tasmania and Victoria received the 1st dose of DTPa vaccine prior to 8 weeks of age, in line with recommendations encouraging early protection of many young infants from pertussis infection. However, delayed vaccination for later doses is a concern, especially for diseases such as pertussis where the disease risk among young infants is significant.

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. This is especially so for the 2nd dose of the measles-mumps-rubella vaccine where vaccination delay has consistently been an issue. The change in scheduling of this dose to 18 months of age that occurred in mid-2013 may improve the timeliness of this dose.

There are 1.9% of children registered as having parental vaccination objection (a percentage that has slowly increased over time), and some others are likely unvaccinated due to unregistered objection. However incomplete immunisation is also often due to access and logistic issues. Further in-depth analysis and interpretation of the data on incompletely immunised children will be the subject of an upcoming National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases report. Areas of low coverage have been identified in many remote areas and areas containing higher proportions of vaccination objectors. Further vaccination coverage estimates in small areas have been provided by the National Health Performance Authority for children in 2012 to 2013.[7]

Coverage data for HPV from the National HPV Vaccination Program Register reflect a successful school-based program with lower coverage for the catch-up program.[32,33] Under-notification to the HPV Register of doses administered in general practice is likely to contribute to the apparently lower coverage in women aged 20 years or over, with independent coverage estimates from population surveys in this age group suggesting under-notification of around 5.0% to 15.0%.[33,34] The 9.0% to 16.0% drop in coverage between dose 1 and 3 across all age groups may also reflect under-notification of doses missed in school and caught up in general practice but not notified to the HPV Register, as well as demonstrating the challenges in delivering a 3-dose vaccination course to adolescents.

Australia's HPV vaccination program is the most broadly targeted program in the world, with no other country having provided a free catch-up program up to the age of 26 years. The coverage achieved in the program has been sufficient to result in demonstrable decreases in HPV prevalence in young women,[35] and in genital warts[36] and cervical abnormalities.[37]

Unfortunately, coverage data for any vaccines are not available for Indigenous adolescents. For adults, data are only available from the Aboriginal and Torres Strait Islander Health Survey, last conducted in 2004–2005.[38]

Data provided in this report reflect continuing successful delivery of the NIP in Australia, while identifying some areas for improvement. Coverage for varicella and rotavirus vaccines is below that for other vaccines. Timeliness of vaccination could be improved, particularly for Indigenous infants, and coverage for vaccines recommended only for Indigenous infants was lower than for other vaccines. From July 2013, the pneumococcal conjugate vaccine has been included in coverage assessments for 'fully immunised' at 12 months of age, and thereby in eligibility for provider and parent incentives[39] and it will be important to evaluate the impact of this change in coming years.

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List of vaccine abbreviations

7vPCV	7-valent pneumococcal conjugate vaccine
10vPCV	10-valent pneumococcal conjugate vaccine
13vPCV	13-valent pneumococcal conjugate vaccine
23vPPV	23-valent pneumococcal polysaccharide vaccine
Comvax	*Haemophilus influenzae* type b conjugate (meningococcal protein conjugate) and hepatitis B (recombinant) vaccine
dTpa	diphtheria-tetanus-acellular pertussis (adults, adolescents and children aged ≥10 years formulation)
DTPa	diphtheria-tetanus-acellular pertussis (children aged <10 years formulation)
DTPa-hepB-IPV-Hib	combined diphtheria-tetanus-acellular pertussis-hepatitis B-inactivated poliovirus-*Haemophilus influenzae* type b
DTPa-IPV	diphtheria-tetanus-acellular pertussis-inactivated poliovirus
Engerix-B	recombinant DNA hepatitis B vaccine (paediatric formulation)
Flu	influenza
H-B-VAX II	hepatitis B (paediatric formulation)
Hep A	hepatitis A
Hep B	hepatitis B
Hib	*Haemophilus influenzae* type b
Hib-MenCCV	*Haemophilus influenzae* type b-meningococcal C conjugate vaccine
HPV	human papillomavirus
IPV	inactivated poliovirus
MenCCV	meningococcal C conjugate vaccine
MMR	measles-mumps-rubella
MMRV	measles-mumps-rubella-varicella
PedvaxHIB	*Haemophilus influenzae* type b conjugate vaccine (meningococcal protein conjugate)
PCV	pneumococcal conjugate vaccine
PRP-OMP	*Haemophilus influenzae* type b conjugate vaccine
PRP-T	*Haemophilus influenzae* type b conjugate vaccine
VZV	varicella-zoster virus

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 BP, Mahajan D, Dey A, Menzies RI, McIntyre PB. Immunisation coverage annual report, 2008. *Commun Dis Intell* 2010;34(3):241–258.
3. Hull B, Dey A, Mahajan D, Menzies R, McIntyre PB. Immunisation coverage annual report, 2009. *Commun Dis Intell* 2011;35(2):132–148.
4. Hull B, Dey A, Menzies R, McIntyre P. Annual immunisation coverage report, 2010. Commun Dis Intell 2013;37(1):E21–39.
5. Hull BP, Dey A, Menzies RI, Brotherton JM, McIntyre PB. Immunisation coverage annual report, 2011. *Commun Dis Intell* 2013;37(4):E291–E312.
6. Hull BP, Dey A, Menzies RI, Brotherton JM, McIntyre PB. Immunisation coverage, 2012. *Commun Dis Intell* 2014;38(3):E208–231.
7. National Health Performance Authority. Healthy communities: Immunisation rates for children in 2012–13. 2014. Accessed on 2 December 2014. Available from: http://www.nhpa.gov.au/internet/nhpa/publishing.nsf/Content/Our-reports
8. Hull BP, Deeks SL, McIntyre PB. The Australian Childhood Immunisation Register–A model for universal immunisation registers? *Vaccine* 2009;27(37):5054–5060.
9. Australian Government Department of Health. Frequently asked questions: Changes to national immunisation schedule and related payments. 2013. Accessed on 8 May 2015. Available from: http://www.humanservices.gov.au/customer/subjects/immunising-your-children#a5
10. 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.
11. Australian Technical Advisory Group on Immunisation (ATAGI). The Australian immunisation handbook. 10th edn. Canberra: Australian Government Department of Health and Ageing; 2013.
12. O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. *Commun Dis Intell* 1998;22(3):36–37.
13. Hull B, McIntyre P. 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.
14. 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.
15. Hull B. Australian childhood immunisation coverage, 1 October to 31 December cohort, assessed as at 31 March 2014. *Commun Dis Intell* 2013;38(3):E260–E261.
16. Australian Population and Migration Research Centre. ARIA and accessibility. Accessibility/Remoteness Index of Australia – ARIA+ (2011). 2011. Accessed on 17 November 2014. Available from: http://www.adelaide.edu.au/apmrc/research/projects/category/aria.html
17. 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.
18. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS). 2011. Accessed on 17 November 2014. Available from: http://www.abs.gov.au/websitedbs/d3310114.nsf/home/australian+statistical+geography+standard+%28asgs%29
19. MapInfo. MapInfo version 12.0. In. Stamford, Connecticut, USA: Pitney Bowes; 2013.
20. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS): Correspondences, July 2011. 2012. Accessed on 17 November 2014. Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/1270.0.55.006Main+Features1July%20 2011?OpenDocument
21. Australian Institute of Health and Welfare. 2009 Adult Vaccination Survey: summary results. 2011. Accessed on 2 December 2014. Available from: http://www.aihw.gov.au/publication-detail/?id=10737418409
22. Lawrence G. Coverage of the birth dose of hepatitis B vaccine among infants. In: National Centre for Immunisation Research and Surveillance; 2006. p. 19.
23. National, state, and local area vaccination coverage among children aged 19–35 months – United States, 2012. *MMWR Morb Mortal Wkly Rep* 2013;62(36):733–740.
24. Health and Social Care Information Centre. NHS immunisation statistics, England, 2012–13. 2013. Accessed on 2 December 2014. Available from: http://www.hscic.gov.uk/catalogue/PUB11665
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;30(1 Suppl):S25–S29.
26. Dey A, Wang H, Menzies R, Macartney K. Changes in hospitalisations for acute gastroenteritis in Australia after the national rotavirus vaccination program. *Med J Aust* 2012;197(8):453–457.
27. Brisson M, Edmunds WJ, Gay NJ, Law B, De Serres G. Modelling the impact of immunization on the epidemiology of varicella zoster virus. *Epidemiol Infect* 2000;125(3):651–669.
28. 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.
29. 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.
30. Plotkin S, Orenstein WA, Offit PA. Vaccines. 5th edn. Philadelphia, PA: Saunders Elsevier; 2008.
31. Hull BP, McIntyre P. Timeliness of childhood immunisation in Australia. *Vaccine* 2006;24:4403–4408.
32. Brotherton JM, Murray SL, Hall MA, Andrewartha LK, Banks CA, Meijer D, et al. Human papillomavirus vaccine coverage among female Australian adolescents: success of the school-based approach. *Med J Aust* 2013;199(9):614–617.
33. Brotherton J, Gertig D, Chappell G, Rowlands L, Saville M. Catching up with the catch-up: HPV vaccination coverage data for Australian women aged 18–26 years from the National HPV Vaccination Program Register. *Commun Dis Intell* 2011;35(2):197–201.

34. Brotherton JM, Liu B, Donovan B, Kaldor JM, Saville M. Human papillomavirus (HPV) vaccination coverage in young Australian women is higher than previously estimated: independent estimates from a nationally representative mobile phone survey. *Vaccine* 2014;32(5):592–597.

35. Tabrizi SN, Brotherton JM, Kaldor JM, Skinner SR, Liu B, Bateson D, et al. Assessment of herd immunity and cross-protection after a human papillomavirus vaccination programme in Australia: a repeat cross-sectional study. *Lancet Infect Dis* 2014;14(10):958–966.

36. Ali H, Donovan B, Wand H, Read TR, Regan DG, Grulich AE, et al. Genital warts in young Australians five years into national human papillomavirus vaccination programme: national surveillance data. *BMJ* 2013;346:f2032.

37. Gertig DM, Brotherton JM, Budd AC, Drennan K, Chappell G, Saville AM. Impact of a population-based HPV vaccination program on cervical abnormalities: a data linkage study. *BMC Med* 2013;11:227.

38. Australian Bureau of Statistics. 4715.0 – National Aboriginal and Torres Strait Islander Health Survey, 2004–05. 2006. Accessed on 2 December 2014. Available from: http://www.abs.gov.au/ausstats/abs@.nsf/mf/4715.0/

39. Australian Government Department of Health. Immunise Australia Program. 2014. Accessed on 2 December 2014. Available from: http://www.health.gov.au/internet/immunise/publishing.nsf/Content/home