

IMMUNISATION COVERAGE ANNUAL REPORT, 2014

Brynley P Hull, Alexandra J Hendry, Aditi Dey, Frank H Beard, Julia M Brotherton, Peter B McIntyre

Abstract

This 8th annual immunisation coverage report shows data for 2014 derived from the Australian Childhood Immunisation Register and the National Human Papillomavirus Vaccination Program Register. This report includes coverage data for 'fully immunised' and by individual vaccines at standard age milestones and timeliness of receipt at earlier ages according to Indigenous status. Overall, 'fully immunised' coverage has been mostly stable at the 12- and 24-month age milestones since late 2003, but at 60 months of age, it has increased by more than 10 percentage points since 2009. As in previous years, coverage for 'fully immunised' at 12 months of age among Indigenous children was 3.7% lower than for non-Indigenous children overall, varying from 6.9 percentage points in Western Australia to 0.3 of a percentage point in the Australian Capital Territory. In 2014, 73.4% of Australian females aged 15 years had 3 documented doses of human papillomavirus vaccine (jurisdictional range 67.7% to 77.4%), and 82.7% had at least 1 dose, compared with 71.4% and 81.5%, respectively, in 2013. The disparity in on-time vaccination between Indigenous and non-Indigenous children in 2014 diminished progressively from 20.2% for vaccines due by 12 months to 11.5% for those due by 24 months and 3.0% at 60 months of age. *Commun Dis Intell* 2017;41(1):E68–E90.

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

Introduction

This is the 8th annual immunisation coverage report, with the first report having focused on 2007 data.^{1–6} This report complements other reports providing data on immunisation coverage in Australia⁷ and highlights important trends and significant issues. It follows the format of previous reports, providing a detailed summary for 2014 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 vaccine objection. 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 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 at key milestone ages to measure coverage against national targets and to track trends over time. Table 1 shows the Australian National Immunisation Program (NIP) Schedule for 2014.

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.

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.⁹ 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.⁹ Children not enrolled in Medicare can also be added to the ACIR via a supplementary number. Since 2001, vaccinations 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 vaccination. This could occur automatically from medical practice software or through the Internet using the Medicare Australia web site or by submitting paper encounter forms. The existence of medical contraindications and conscientious objection to immunisation is also recorded on the ACIR. From 2016, conscientious objection is no longer a valid exemption to immunisation linked to family payments and therefore will no longer be recorded on the ACIR.¹⁰ All vaccination records for a child remain on the register indefinitely, but no new vaccination records are added after the 7th birthday. However, from 2016 this will change to allow the recording of vaccinations given up to 19 years of age.¹⁰

Vaccinations recorded on the ACIR must be rendered in accordance with the guidelines issued

Table 1: Australian National Immunisation Program Schedule for children, adolescents and adults, 2014

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-Men C†		MMR		Hep A‡	13vPCV§		
18 months						MMRV¶	Hep A‡	13vPCV§		
24 months							Hep A‡			
48 months		DTPa		Polio	MMR**				23vPPV††	
Adolescent vaccines										
12–15 years		dTpa				VZV				HPV‡‡
15–49 years								Flu§§		23vPPV¶¶
Adult vaccines										
≥50 years								Flu§§		23vPPV¶¶
65 years								Flu§§		23vPPV
Pregnant women (any age)								Flu***		

* 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 (Men C) vaccine, Menitorix®, was added to the NIP Schedule at 12 months of age. This combination vaccine replaces the single dose of monovalent meningococcal C conjugate vaccine (Men C) and booster dose of monovalent Hib vaccine previously scheduled at 12 months of age.

‡ Aboriginal and Torres Strait Islander children – doses at 12 months and 18 months of age in the Northern Territory and Western Australia and 18 and 24 months of age in Queensland and South Australia (schedule changed in July 2013 so doses administered at 12 months and 18 months of age in all four jurisdictions).

§ Booster dose for medically at risk children at 12 months of age and Aboriginal and Torres Strait Islander children in the Northern Territory, Western Australia, Queensland and South Australia at 12–18 months of age.

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

** To be given only if MMRV vaccine was not given at 18 months of age. The dose of measles-mumps-rubella vaccine at 4 years of age ceased on 1 January 2016.

†† Medically at-risk children

‡‡ From February 2013, males and females aged 12–13 years received the HPV 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.

§§ Annual vaccination, all aged ≥6 months with medical risk factors, Aboriginal and Torres Strait Islander people aged ≥15 years, non-Indigenous adults aged ≥65 years.

¶¶ Aboriginal and Torres Strait Islander people: aged ≥15 years with medical risk factors; all aged ≥50 years.

*** At any stage of pregnancy.

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 and 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 and 18 months), and 60 months of age (for vaccines due at 48 months). A minimum 3-month lag period is allowed for late notification of vaccinations to the ACIR, but only vaccinations 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 both 3-month wide and 12-month

Box: Significant changes in immunisation policy, immunisation incentives and coverage calculation algorithms, Australia, 2011 to 2014

July 2014 – Immunisation coverage assessment algorithm for the 24-month milestone amended to require a dose of meningococcal vaccine, a dose of varicella vaccine and a 2nd dose of measles-mumps-rubella (MMR) vaccine to be classified as fully immunised.

July 2013 – Immunisation coverage assessment algorithm for the 12-month milestone amended to include a 3rd dose of pneumococcal conjugate vaccine (PCV) in the assessment of fully immunised.

Combined *Haemophilus influenzae* type b (Hib) and meningococcal serogroup C (Men C) conjugate vaccine, Menitorix[®], added to the National Immunisation Program (NIP) Schedule at 12 months of age, replacing the single dose of monovalent Men C vaccine and booster dose of monovalent Hib vaccine previously scheduled at 12 months of age.

Combination measles-mumps-rubella-varicella (MMRV) vaccine added to the NIP at 18 months of age, replacing MMR dose previously scheduled at 4 years of age and varicella vaccine dose previously scheduled at 18 months of age. MMR vaccination at 4 years of age continued in parallel until first cohort eligible for MMRV vaccine reached 4 years of age.

Hepatitis A vaccination schedule for Indigenous children changed so that dose 1 administered at 12 months of age and dose 2 at 18 months of age in all four relevant jurisdictions (the Northern Territory, Western Australia, Queensland and South Australia).

February 2013 – Human papillomavirus vaccine funded under the NIP for males aged 12–13 years, delivered in school-based programs.

July 2012 – Eligibility for Family Tax Benefit Part A supplement required that children are assessed as fully immunised during the financial years that they turn 1, 2 and 5 years or have an approved exemption, replacing the Maternity Immunisation Allowance.

October 2011 – 13-valent PCV (13vPCV) replaced 23-valent pneumococcal polysaccharide vaccine as booster dose in Indigenous children living in the Northern Territory, Western Australia, Queensland and South Australia.

July 2011 – 13vPCV replaced 7-valent PCV on the NIP for children at 2, 4 and 6 months of age in all states and territories except the Northern Territory (adopts 13vPCV from 1 October 2011).

wide cohorts are used for all other analyses in this report. The 12-month wide cohorts used in this report are children born between 1 January and 31 December 2013 for the 12-month milestone age; children born between 1 January and 31 December 2012 for the 24-month milestone age; and children born between 1 January and 31 December 2009 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 is defined as a child having a record on the ACIR of 3 doses of a diphtheria (D), tetanus (T) and pertussis-containing (P) vaccine,

3 doses of polio vaccine, 2 or 3 doses of PRP-OMP containing *Haemophilus influenzae* type b (Hib) vaccine or 3 doses of any other Hib vaccine, 3 doses of hepatitis B vaccine, and 3 doses of 13-valent pneumococcal conjugate vaccine. ‘Fully immunised’ at 24 months of age is defined as a child having a record on the ACIR of 3 doses of a DTP-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of PRP-OMP Hib, Infanrix Hexa or Hiberix vaccine (3 doses only of Infanrix Hexa or Hiberix if given after 11.5 months of age), or 4 doses of any other Hib vaccine, 3 doses of hepatitis B vaccine, 2 doses of a measles-mumps-rubella-containing (MMR) vaccine, 1 dose of meningococcal C vaccine, and 1 dose of varicella vaccine. ‘Fully immunised’ at 60 months of age is defined as a child having a record on the ACIR of 4 doses of a DTP-containing vaccine, 4 doses of polio vaccine, and 2 doses of an MMR-containing vaccine.

Immunisation coverage estimates were also calculated for individual NIP vaccines, including the 3 NIP vaccines given in early childhood but not routinely reported in the quarterly coverage reports published in *Communicable Diseases Intelligence*¹⁵ and not part of 'fully immunised' calculations at 12, 24 and 60 months of age. These are: a 2nd or 3rd dose of rotavirus vaccine by 12 months of age; a 2nd dose of hepatitis A vaccine in Indigenous children by 30 months of age; and a booster dose of pneumococcal vaccine in Indigenous children by 30 months of age.

Changes to immunisation policy and changes to the 'fully immunised' coverage algorithms have had an impact on vaccination coverage presented in this report. From July 2012, eligibility for the Family Tax Benefit Part A supplement required that children needed to be assessed as fully immunised, replacing the Maternity Immunisation Allowance. To meet the immunisation requirements for the Family Tax Benefit Part A supplement, parents needed to have their children immunised during the financial years that each child turned 1, 2 and 5 years of age. Children needed to be up-to-date with immunisation or have an approved exemption.

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. From the December 2014 quarterly coverage report, a dose of meningococcal vaccine and a dose of varicella vaccine were included in the coverage requirements for 'fully immunised' at the 24-month milestone, along with the 2nd dose of MMR instead of the 1st dose as previously. The 2nd dose of MMR remained in the coverage assessment algorithm for the 60-month milestone age.

Timeliness

Age-appropriate timely vaccination 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 delay outcome measure for each dose as either delay of 1 to < 6 months or delay ≥ 6 months. Timeliness is measured in 12-month birth cohorts. Children included in the timeliness analysis were assessed at 1 to 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.

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 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 our 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. ARIA Accessibility/Remoteness categories were assigned for each child using their recorded postcode of residence on the ACIR.

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 two 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),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 15 of the MapInfo mapping software¹⁹ 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.²⁰

Objection to vaccination and incomplete immunisation

Until 2016, parents who registered vaccination objection were eligible for parental incentive payments even if their children were unvaccinated. However some parents who objected to vaccination did not register an objection. We calculated the proportions of children with registered vaccination objection status and no vaccines recorded on the

ACIR, registered vaccination objection status and at least 1 vaccine recorded on the ACIR, no registered vaccination objection status and no vaccines recorded on the ACIR, and no registered vaccination objection status and not 'fully immunised' by 24 months of age, from the cohort of children registered with Medicare and born between 1 October and 31 December 2012. Some of the children in the latter 2 groups may be incompletely immunised due to unregistered vaccination objection. We chose this cohort for calculation of proportions of these groups in 2014 so that children under the age of 12 months were excluded, to allow sufficient time for registration of objection.

Human papillomavirus vaccine coverage

Human papillomavirus (HPV) vaccine is included on the NIP, with the vaccine delivered to females and, since 2013, males through an ongoing 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 HPV vaccination are provided by the National HPV Vaccination Program Register, which is operated by the Victorian Cytology Service. Data for males represent the vaccination coverage achieved during the catch-up program for males aged 14–15 years during 2013–2014. 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 to 2009 catch-up program. The World Health Organization recommends using 15 years as the reference age for HPV vaccination coverage for the purposes of international comparison.

Coverage in the elderly

While an Adult Vaccination Survey (AVS)²¹ has not been undertaken in Australia since 2009, data from a Newspoll Omnibus Survey in 2014 are presented.²² From September 2016 the ACIR will expand to become the Australian Immunisation Register. This Register will capture all vaccines administered throughout a person's life (birth to death) from that point forward, given through general practice and community clinics.

Indigenous adolescent and adult coverage

Indigenous adolescent and adult coverage estimates are obtained from the 2012–2013 Aboriginal and Torres Strait Islander Health Survey.

Results

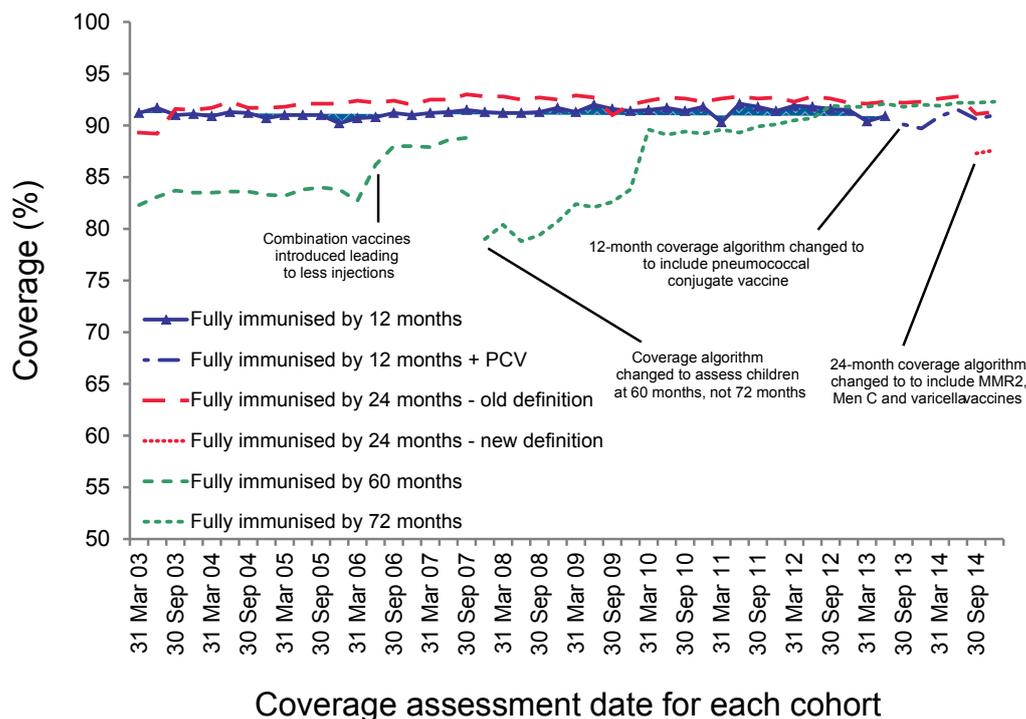
Coverage estimates

Fully immunised

Coverage estimates in 2014 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. The proportion of Australian children classified as 'fully immunised' was 91.5% at 12 months, 86.8% at 24 months and 92.0% at 60 months of age, compared with 2013 coverage at these milestones of 90.8%, 92.1% and 91.2%, respectively. Nationally and for almost all jurisdictions, 'fully immunised' coverage (except at the 24-month age milestone) and coverage for all individual vaccines (except rotavirus vaccine, varicella vaccine and dose 2 of MMR vaccine) at all 3 age milestones was above 90%, the target at that time.

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 1997 to 31 December 2013. Coverage has been largely stable at the 12- and 24-month age milestones since late 2003. However, during 2013, 'fully immunised' coverage at the 12-month age milestone for vaccines due at 6 months of age declined by 1.8 percentage points, partly due to the inclusion of 13-valent pneumococcal conjugate vaccine (PCV) in the coverage assessment algorithm, and then increased by 1.2% in 2014. In the latter half of 2014, 'fully immunised' coverage at the 24-month age milestone declined by 5.5 percentage points. The bulk of this decrease was due to the coverage assessment algorithm being amended in July 2014 to include a dose of meningococcal vaccine, a dose of varicella vaccine and a 2nd dose of MMR vaccine. This is demonstrated in Table 2, which shows 'fully immunised' coverage at the 24-month age milestone to have only dropped by 0.4 of a percentage point when calculated using the old algorithm. 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, but then rose substantially in 2009 and 2010 and kept increasing throughout 2011 to 2014 to a level higher than that for the 12-month and 24-month age milestones in 2014.

Figure 1: Trends in ‘fully immunised’ vaccination coverage estimates, Australia, 2003 to 2014*



* By 3-month birth cohorts born between 1 January 1999 and 31 December 2013. Coverage assessment date was 12 months after the last birth date of each cohort.

PCV = pneumococcal conjugate vaccine

Source: Australian Childhood Immunisation Register.

Table 2: Percentage of children as immunised by 12 months of age, Australia, assessed in 2014, by vaccine and state or territory*

Vaccine	State or territory								Aust.
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	
Total number of children	5,560	98,101	3,641	61,747	19,593	5,893	75,544	33,710	303,789
Diphtheria, tetanus, pertussis	95.1	92.4	91.3	92.8	92.2	92.0	92.7	92.7	92.6
Polio	95.1	92.3	91.3	92.8	92.1	92.0	92.6	92.7	92.5
<i>Haemophilus influenzae</i> type b	94.8	92.0	91.1	92.5	91.9	91.7	92.3	92.3	92.3
Hepatitis B	94.6	92.0	91.3	92.4	91.8	91.7	92.2	92.1	92.2
Pneumococcal conjugate	94.6	91.8	91.1	92.3	91.6	91.7	92.1	91.8	92.0
Fully immunised†	93.9	91.3	90.6	92.0	91.2	91.2	91.6	91.3	91.5
Rotavirus	90.4	87.4	86.4	82.2	83.5	86.1	83.3	80.0	84.3

* Cohort born 1 January 2013 – 31 December 2013.

† ‘Fully immunised’ – 3 doses of a diphtheria-tetanus-pertussis-containing 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, 3 doses of any hepatitis B vaccine or 2 doses of either Enderix-B (paediatric), Comvax or H-B-VAX II (paediatric), and 3 doses of pneumococcal conjugate vaccine.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 3: Percentage of children immunised by 24 months of age, Australia, assessed in 2014, by vaccine and state or territory*

Vaccine	State or territory								Aust.
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	
Total number of children	5,549	101,937	3,638	63,676	20,223	5,902	77,235	34,355	312,515
Diphtheria, tetanus, pertussis	96.3	95.1	95.4	95.1	94.7	95.2	95.5	94.6	95.2
Polio	96.3	95.1	95.4	95.1	94.7	95.1	95.5	94.5	95.1
<i>Haemophilus influenzae</i> type b	94.8	93.7	94.9	94.1	93.2	93.8	94.0	93.1	93.8
Hepatitis B	95.6	94.6	95.4	94.6	94.2	94.8	94.9	93.8	94.6
Measles, mumps, rubella	91.9	88.7	89.2	90.3	88.5	88.0	89.1	86.2	88.9
Varicella	92.3	89.6	90.1	90.4	88.9	88.6	89.8	87.7	89.6
Meningococcal C	94.6	93.5	94.7	94.1	93.2	94.0	93.7	92.7	93.6
Fully immunised – old definition†	93.3	91.5	93.4	92.7	91.5	91.8	92.1	91.1	91.9
Fully immunised‡	90.1	86.4	86.4	88.7	86.3	85.3	87.0	84.3	86.8

* Cohort born 1 January 2012 to 31 December 2012.

† 'Fully immunised – old definition' – 3 doses of a diphtheria-tetanus-pertussis-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of PRP-OMP-containing *Haemophilus influenzae* type b (Hib) vaccine or 4 doses of any other Hib vaccine, and 3 doses of hepatitis B vaccine.

‡ 'Fully immunised' – 3 doses of a diphtheria-tetanus-pertussis-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 doses of hepatitis B vaccine, 2 doses of a measles-mumps-rubella-containing vaccine, 1 dose of varicella vaccine, and 1 dose of meningococcal C vaccine.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 4: Percentage of children immunised by 60 months of age, Australia, assessed in 2014, by vaccine and state or territory*

Vaccine	State or territory								Aust.
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	
Total number of children	5,347	100,617	3,532	64,869	20,299	6,399	75,454	33,930	310,447
Diphtheria, tetanus, pertussis	93.9	92.9	92.6	92.6	91.4	92.9	92.9	91.1	92.6
Polio	93.9	92.9	92.6	92.6	91.3	92.9	92.9	91.0	92.6
Measles, mumps, rubella	93.7	92.9	93.0	92.6	91.3	92.8	92.9	91.0	92.5
Fully immunised†	93.3	92.4	92.0	92.2	90.7	92.1	92.4	90.4	92.0

* Cohort born 1 January 2009 to 31 December 2009.

† 'Fully immunised' – 4 or 5 doses of a diphtheria-tetanus-pertussis-containing vaccine, 4 doses of polio vaccine, and 2 doses of an measles-mumps-rubella-containing vaccine.

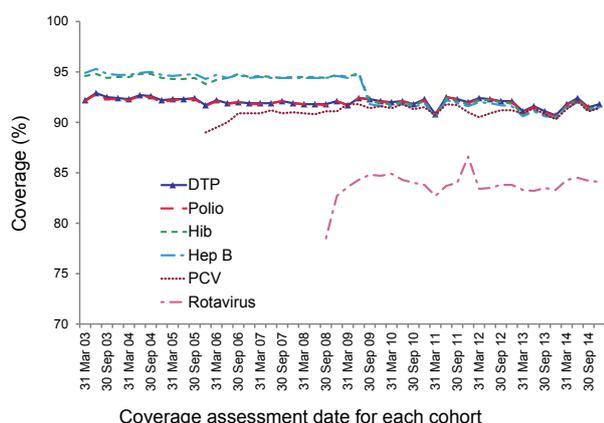
Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Individual vaccines

Coverage at 12 months of age for individual antigens in the relevant combination vaccine (DTPa-hepB-polio-Hib) increased in 2014 (Figure 2). Coverage for 3 doses of PCV by 12 months of age rose steadily from below 90% in mid-2007 to 91.4% in late 2014, just below the level for all other vaccines assessed at this age except for rotavirus vaccine. After being added to the NIP in July 2007, rotavirus vaccine coverage for 2 or 3 doses (depending on whether the vaccine in use is Rotarix® or

RotaTeq®) at 12 months of age rose steeply from about 75% in late 2008 to almost 84% in late 2011 and has remained largely stable since, with minor fluctuations. Rotavirus vaccine 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 2014 at 12 months of age varied from 90.4% in the Australian Capital Territory for 2 doses of Rotarix® vaccine, to 80.0% in Western Australia for 3 doses of RotaTeq® vaccine (Table 2).

Figure 2: Trends in vaccination coverage estimates for individual vaccines* at 12 months of age, Australia, 2003 to 2014



* 3rd dose of DTPa, polio and pneumococcal conjugate vaccines, 2nd or 3rd dose of Hib and rotavirus vaccines, and 3rd dose of hepatitis B vaccine.

By 3-month birth cohorts born between 1 January 1999 and 31 December 2013. Coverage assessment date was 12 months after the last birth date of each cohort.

DTPa = diphtheria-tetanus-acellular pertussis

Hib = *Haemophilus influenzae* type b

Hep B = Hepatitis B

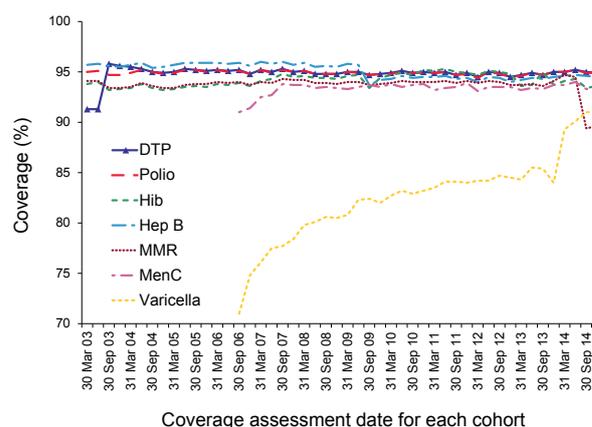
PCV = Pneumococcal conjugate vaccine

Source: Australian Childhood Immunisation Register.

In 2014, coverage at 24 months of age was around 93% to 95% for all vaccines (except varicella and the 2nd dose of MMR) (Figure 3). In the latter half of 2014, coverage for MMR declined by 5.1 percentage points. This was due to the 2nd dose of MMR, now due at 18 months of age, being assessed at 24 months of age for the first time, instead of the 1st dose as previously. Varicella coverage at 24 months of age increased sharply in mid-2013, following replacement of monovalent varicella vaccine with measles-mumps-rubella-varicella (MMRV) vaccine as the vaccine due at 18 months of age (a comparison between varicella coverage before and after introduction of MMRV vaccine is discussed in a separate section). As the 18-month schedule point has historically been associated with lower coverage when assessed at the 24-month age milestone, given that there is only a 6-month time period for catch-up, we compared varicella coverage assessed at 36 months and 60 months of age to that assessed at 24 months, by jurisdiction (Figure 4). Coverage by jurisdiction was 6.0 to 10.4 percentage points higher at 60 months, with all jurisdictions reaching over 90% varicella coverage when assessed at 60 months.

For vaccines due at 48 months of age, trends in individual vaccine coverage were similar to

Figure 3: Trends in vaccination coverage estimates for individual vaccines* at 24 months of age, Australia, 2003 to 2014



* 3rd dose of DTPa, 3rd dose of polio, 3rd or 4th dose of Hib, 3rd dose of hepatitis B, 2nd dose of MMR (from September 2014), 1st dose of meningococcal C and varicella.

By 3-month birth cohorts born between 1 January 1998 and 31 December 2012. Coverage assessment date was 24 months after the last birth date of each cohort.

DTPa = Diphtheria-tetanus-acellular pertussis

Hib = *Haemophilus influenzae* type b

Hep B = Hepatitis B

MMR = Measles-mumps-rubella

MenC = Meningococcal C

MMRV = Measles-mumps-rubella-varicella

Source: Australian Childhood Immunisation Register.

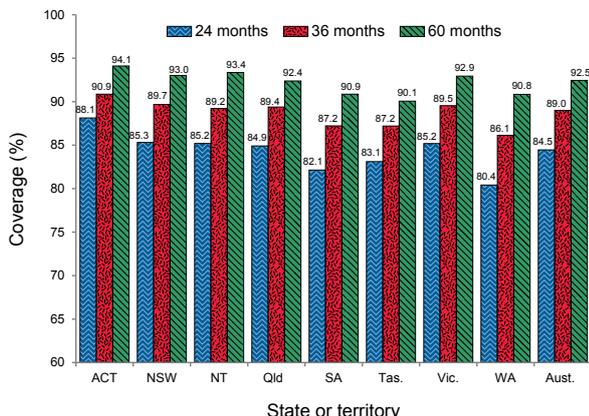
that seen for ‘fully immunised’ coverage, that is, a marked drop in January 2008 following the change in assessment age from 72 months to 60 months, followed by a marked increase in 2009 and 2010 and ongoing increase to a level higher than when coverage was assessed at 72 months of age (Figure 5). Coverage for both vaccines due at 48 months (DTPa and MMR) was greater than 92% in 2014.

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

In July 2013, MMRV was introduced at the 18 months of age schedule point, replacing the single dose of varicella vaccine previously scheduled at this age point and the 2nd dose of MMR previously scheduled at 48 months of age.

Table 5 provides varicella coverage for two 3-month wide birth cohorts 2 years apart, allowing comparison of coverage before and after introduction of MMRV vaccine. For Australia as a whole, varicella coverage increased by 3.7 percentage points from pre- to post-introduction of MMRV. Increases occurred in

Figure 4: Comparison of 1-dose varicella vaccine coverage at 24 months of age versus 36 months of age and 60 months of age, Australia, assessed in December 2014, by state or territory



Cohort born 1 October to 31 December 2009.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

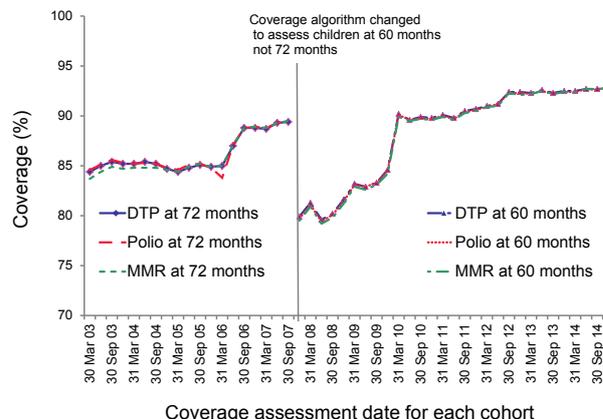
all jurisdictions except the Northern Territory and Tasmania, ranging up to a 5.2 percentage point increase in South Australia and Victoria.

Indigenous coverage estimates

Individual vaccines

Immunisation coverage estimates in 2014 for the 3 age milestones by Indigenous status, vaccine and jurisdiction are provided in Tables 6 and 7. As in previous years, ‘fully immunised’ coverage at 12 months of age among Indigenous children was lower than for non-Indigenous children in all jurisdictions, with the differential varying from 6.9 percentage points in Western Australia to 0.3 percentage points in the Australian Capital Territory, and 3.7% overall. ‘Fully immunised’ coverage at 24 months of age among Indigenous children in 2014 was 3.3 percentage points lower, with the differential varying from 6.4 percentage

Figure 5: Trends in vaccination coverage estimates for individual vaccines* at 60 months of age (assessed at 72 months prior to December 2007), Australia, 2003 to 2014



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

By 3-month birth cohorts born between 1 January 1996 and 31 December 2009. 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.

DTPa = Diphtheria-tetanus-acellular pertussis

MMR = Measles-mumps-rubella

Source: Australian Childhood Immunisation Register.

points in Victoria to 0.5 of a percentage point in New South Wales. The lower coverage gap for New South Wales may reflect the NSW Aboriginal Immunisation Health Care Worker Program that began as a 3-year pilot program in 2012. ‘Fully immunised’ coverage at 60 months of age in 2014 was 1.6 percentage points higher among Indigenous children compared with non-Indigenous children, with coverage in Indigenous children at this age milestone higher in all jurisdictions except Victoria, South Australia and Tasmania.

The coverage differential between Indigenous and non-Indigenous children for individual vaccines varied in 2014, with coverage lower for Indigenous

Table 5: Comparison of varicella coverage (%) before and after introduction of measles-mumps-rubella-varicella vaccine, Australia, 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†	91.8	89.2	84.1	89.5	88.9	87.1	90.1	88.5	89.3

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

† Cohort born 1 April – 30 June 2013, assessed at 24 months.

MMRV = measles-mumps-rubella-varicella

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 6: Vaccination coverage estimates (%), Australia, assessed in 2014, by age, vaccine and Indigenous status

Vaccine	Milestone age	Indigenous	Non-Indigenous
Diphtheria, tetanus, acellular pertussis	12 months*	88.3	92.8
	24 months†	95.3	95.1
	60 months‡	94.0	92.5
Polio	12 months*	88.2	92.8
	24 months†	95.3	95.1
	60 months‡	94.0	92.5
<i>Haemophilus influenzae</i> type b	12 months*	88.2	92.5
	24 months†	94.7	93.7
	60 months‡	N/I	N/I
Hepatitis B	12 months*	88.2	92.3
	24 months†	95.2	94.6
	60 months‡	N/I	N/I
Measles-mumps-rubella	12 months*	N/I	N/I
	24 months†	86.1	89.0
	60 months‡	94.3	92.4
Varicella	12 months*	N/I	N/I
	24 months†	86.3	89.7
	60 months‡	N/I	N/I
Meningococcal C conjugate	12 months*	N/I	N/I
	24 months†	94.5	93.6
	60 months‡	N/I	N/I
Pneumococcal conjugate	12 months*	86.4	91.2
	24 months†	N/I	N/I
	60 months‡	N/I	N/I
Rotavirus	12 months*	73.9	84.8
	24 months†	N/I	N/I
	60 months‡	N/I	N/I

* Cohort born 1 January 2013 – 31 December 2013.

† Cohort born 1 January 2012 – 31 December 2012.

‡ Cohort born 1 January 2009 – 31 December 2009.

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

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 7: Percentage of children fully immunised by 12 months, 24 months and 60 months of age, Australia, assessed in 2014, by Indigenous status and state or territory

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aus.
12 months – fully immunised*									
Indigenous	93.6	90.5	88.3	86.8	87.5	87.4	87.5	84.8	88.0
Non-Indigenous	93.9	91.3	92.0	92.4	91.4	91.5	91.6	91.7	91.7
24 months – fully immunised†									
Indigenous	88.2	85.9	85.4	84.2	80.8	80.8	80.7	79.2	83.7
Non-Indigenous	90.2	86.4	87.0	89.1	86.5	85.6	87.1	84.6	87.0
60 months – fully immunised‡									
Indigenous	97.4	95.2	95.4	93.4	89.3	91.4	91.1	92.7	93.6
Non-Indigenous	93.2	92.3	89.9	92.1	90.7	92.2	92.4	90.3	92.0

* 'Fully immunised' – 3 doses of a diphtheria-tetanus-pertussis-containing 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, 3 doses of hepatitis B vaccine, and 3 doses of pneumococcal conjugate vaccine. Cohort born 1 January 2013 – 31 December 2013

† 'Fully immunised' – 3 doses of a diphtheria-tetanus-pertussis-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 doses of hepatitis B vaccine, 2 doses of a measles-mumps-rubella-containing vaccine, 1 dose of meningococcal C vaccine, and 1 dose of varicella vaccine. Cohort born 1 January 2012 – 31 December 2012

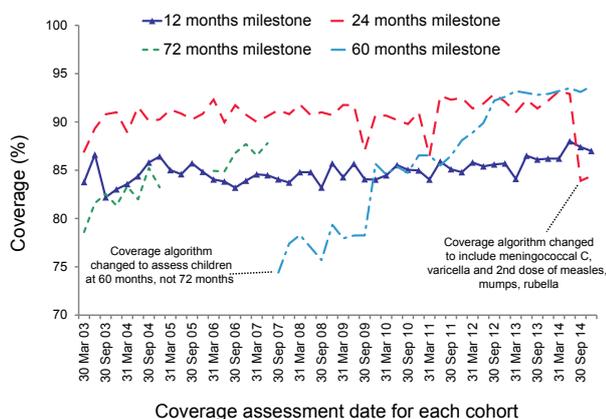
‡ 'Fully immunised' – 4 doses of a DTPa-containing vaccine, 4 doses of polio vaccine, and 2 doses of a measles-mumps-rubella-containing vaccine. Cohort born 1 January 2009 – 31 December 2009

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

children for all vaccines at 12 months of age, but higher at 24 months of age for DTPa, polio, hepatitis B, Hib and meningococcal C vaccines, and at 60 months of age for DTPa, polio and MMR.

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 to that at 24 months (Figure 6). During the latter half of 2014, the proportion of Indigenous children 'fully immunised' by 24 months of age decreased from 92.9% to 84.4%, due to the changes to the 'fully immunised' coverage algorithm, as noted above.

Figure 6: Trends in 'fully immunised' vaccination coverage estimates for Indigenous children in Australia, 2003 to 2014, by age milestones



MMR = measles, mumps, rubella

Source: Australian Childhood Immunisation Register.

Adolescents and adults

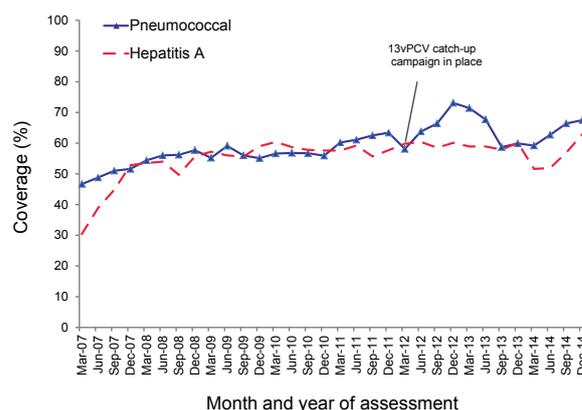
For Indigenous adults and adolescents, according to the 2012/13 Aboriginal and Torres Strait Islander Health Survey, 13% of Indigenous Australians aged 15 years and over had a pneumococcal vaccination in the previous 5 years and 34% of Indigenous Australians aged 15 and over had an influenza vaccination in the previous 12 months.

Pneumococcal booster and hepatitis A vaccine for Indigenous children in some jurisdictions

Hepatitis A vaccine 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 vac-

cine 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 had increased from 30.5% to 60.1% in December 2013 (Figure 7). By the latter half of 2014, coverage had increased to its highest recorded level of 62.9% with all 4 jurisdictions assessing 2 doses at 30 months of age from July 2013. An additional 17% of children had received 1 dose of hepatitis A vaccine by 18 months of age, putting national coverage in 2014 for Indigenous children (the Northern Territory, Queensland, South Australia and Western Australia only) for at least 1 dose of hepatitis A vaccine at 79.8% (Table 8). There was variation in reported hepatitis A vaccine coverage by jurisdiction, from a low of 37.5% in South Australia to a high of 86.2% in the Northern Territory for 2-dose coverage (Table 8).

Figure 7: Trends in coverage estimates for hepatitis A* and pneumococcal† vaccines for Indigenous children, Australia,‡ 2007 to 2014



* 18-month dose assessed at 30 months of age in all 4 jurisdictions from July 2013.

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

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

13vPCV = 13-valent pneumococcal conjugate vaccine

Source: Australian Childhood Immunisation Register.

A pneumococcal booster dose at 18–24 months of age has been recommended and funded for Indigenous children in the same 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 (13vPCV), from July 2013 in Queensland, South Australia and Western Australia, and from October 2013 in the Northern Territory. Coverage gradually increased from 47.0% in March 2007 to 63.4% in December 2011 (Figure 7). In 2012

coverage increased by 15 percentage points following the 13vPCV catch-up campaign that took place that year. Coverage then fell 14 percentage points during 2013 but increased by 9 percentage points in 2014 to 67.5%. There was a large variation between jurisdictions in coverage for the booster dose of pneumococcal conjugate vaccine, from a low of 41.2% in South Australia to a high of 85.4% in the Northern Territory (Table 8).

Table 8: Vaccination coverage* (%) for Indigenous children for hepatitis A and pneumococcal, Australia, 2014, by state or territory

State or territory	Vaccine type	
	Hepatitis A† 2 dose (1 dose)	13vPCV‡
NT	86.2 (92.1)	85.4
Qld	59.2 (77.4)	68.2
SA	37.5 (65.6)	41.2
WA	65.5 (82.1)	60.1
Australia§	63.0 (79.8)	66.9

* Cohort born 1 April 2012 – 30 June 2012.

† Indigenous only: 2 doses by 30 months of age.

‡ Indigenous only: 4th dose of 13-valent pneumococcal conjugate vaccine (13vPCV) by 30 months of age.

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

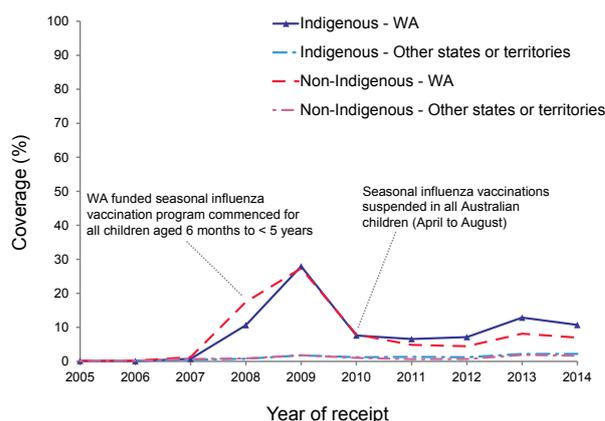
Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Seasonal influenza vaccine coverage

Seasonal influenza vaccine has been recommended and funded for children with underlying medical conditions for many years. In 2008 a funded seasonal influenza vaccination program for all children aged from 6 months to less than 5 years was introduced in Western Australia. In 2013 seasonal influenza vaccine was recommended (but not funded) for all Australian children aged from 6 months to less than 5 years, and in 2015 it was included on the NIP for all Aboriginal and Torres Strait Islander children aged 6 months to less than 5 years. This report provides baseline coverage data up to 2014 to inform future monitoring of coverage under this program, although these data should be interpreted with caution due to the potential for under-reporting, possibly due to influenza vaccine notifications by immunisation providers not resulting in any notification payments unlike other vaccines on the NIP. Influenza vaccine coverage recorded in the ACIR in this age group was less than 2.5% in both Indigenous and non-Indigenous Australian children (excluding Western Australia) from 2005 through to 2014 (Figure 8). Coverage in Western Australian children rose to around 28% in 2009 following introduction of their universal funded program, but has been substantially lower since, following the much publicised issues of increased incidence of high fevers and febrile convulsions post-vaccination with one particular vaccine brand in 2010. The percentage of influenza vaccinated children aged 6 months to less than 5 years recorded in the ACIR as having received 2 doses in their first year of influenza vaccination, as recommended, ranged from 32% to 61% between 2007 and 2014 for both Indigenous and non-Indigenous children, apart from a sharp decline to less than 10% in 2010 following suspension of influenza vaccine use in this age group in that year (data not shown).

digenous Australian children (excluding Western Australia) from 2005 through to 2014 (Figure 8). Coverage in Western Australian children rose to around 28% in 2009 following introduction of their universal funded program, but has been substantially lower since, following the much publicised issues of increased incidence of high fevers and febrile convulsions post-vaccination with one particular vaccine brand in 2010. The percentage of influenza vaccinated children aged 6 months to less than 5 years recorded in the ACIR as having received 2 doses in their first year of influenza vaccination, as recommended, ranged from 32% to 61% between 2007 and 2014 for both Indigenous and non-Indigenous children, apart from a sharp decline to less than 10% in 2010 following suspension of influenza vaccine use in this age group in that year (data not shown).

Figure 8: Trends in coverage estimates* for seasonal influenza vaccine in children aged 6 months to less than 5 years, Australia, 2005 to 2014, by Indigenous status and state or territory



* Coverage definition = any influenza vaccination in 2014, so at least 1 influenza vaccination. If a child received 2 vaccinations in 2014 they weren't counted twice.

Source: Australian Childhood Immunisation Register.

Timeliness of immunisation

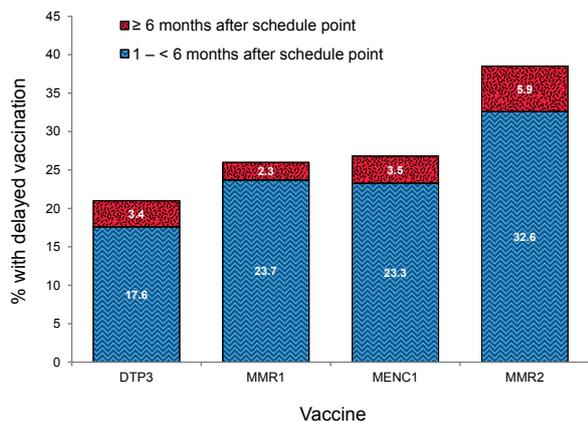
We examined timeliness of immunisation in 2014 for vaccines requiring multiple doses (DTPa, PCV and MMR) or a single dose (meningococcal C) at 12 and 24 months of age.

As demonstrated in previous reports, the proportion with vaccination delay increased with older age (Figure 9). The greatest proportion with any delay was seen with the 2nd dose of MMR vaccine due at 48 months, with 38.5% of doses given late

and 5.9% given very late at ≥ 6 months (Figure 9). These figures are an improvement from the 2013 report (50.7% and 6.9%, respectively).

For the 3rd dose of DTPa vaccine, there was greater

Figure 9: Vaccination delay for cohorts born in 2012 (DTPa3, MMR1, MENC1) and 2008 (MMR2), Australia, assessed in 2014



DTPa3 = 3rd dose of a diphtheria-tetanus-acellular pertussis-containing vaccine (due at 6 months of age)

MMR1 = 1st dose of a measles-mumps-rubella vaccine (due at 12 months of age)

MENC1 = 1st dose of a meningococcal C vaccine (due at 12 months of age)

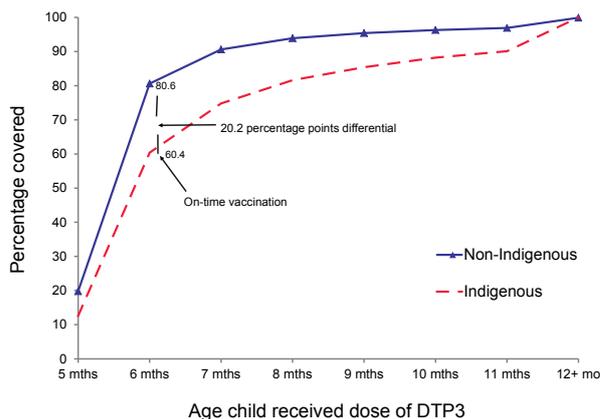
MMR2 = 2nd dose of a measles-mumps-rubella vaccine (due at 48 months of age)

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

delay for Indigenous children than for non-Indigenous children, with a 20.2% differential in on-time vaccination by 7 months of age (Figure 10). The same pattern was found for timeliness of the 1st dose of MMR vaccine by 13 months of age, but with a smaller differential of 11.5% (Figure 11). This differential in on-time vaccination between Indigenous and non-Indigenous children was slightly improved from the 2013 report, where the corresponding differentials for the 3rd dose of DTPa and 1st dose of MMR were 21.6% and 12.9%, 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 between Indigenous and non-Indigenous children, of 3% by 49 months of age (Figure 12a). We also examined the timeliness of immunisation for the 2nd dose of MMR as the coverage algorithm for the 24-month age group changed in July 2014 to include this dose at 18 months of age. Timeliness of the 2nd dose of MMR improved for non-Indigenous

children from 58.0% (when due at 48 months) to 68.0% (when due at 18 months) but decreased for Indigenous children (from 55.0% to 52.7%, respectively) (Figure 12b). As a consequence, there was a greater differential in on-time vaccination between Indigenous and non-Indigenous children in 2014 (15.3 percentage points).

Figure 10: Timeliness* of the 3rd dose of diphtheria-tetanus-acellular pertussis vaccine (DTPa3), Australia, by Indigenous status

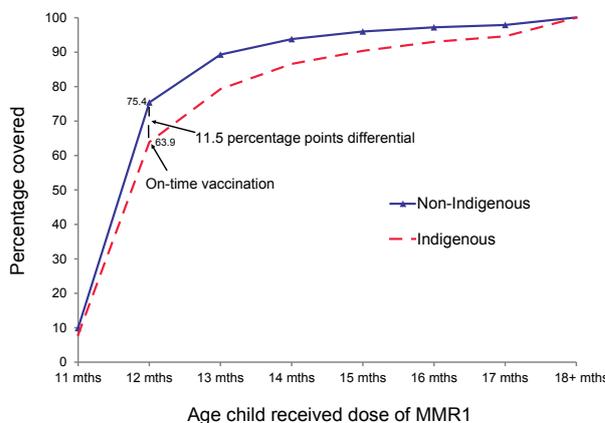


* Percentage covered = number of children who received vaccine dose at particular ages / the total number of children who received the vaccine dose, expressed as a percentage.

Cohort born in 2012.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Figure 11: Timeliness* of the 1st dose of measles-mumps-rubella vaccine (MMR1), 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.

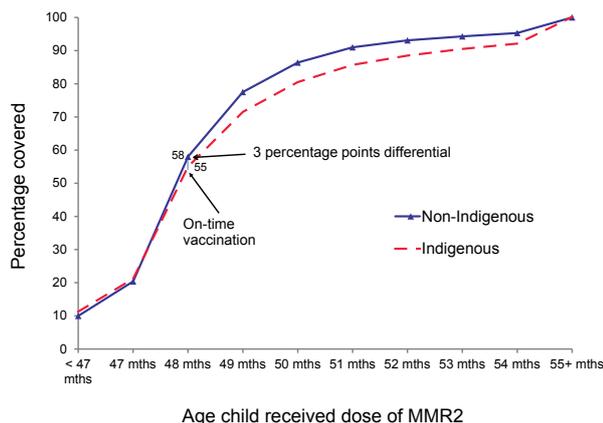
Cohort born in 2012.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Delayed receipt of the 3rd dose of DTPa and the 1st dose of MMR by 1 to <6 months was found in 28% to 38% of Indigenous children and 17% to 24% of non-Indigenous children in 2014, 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 the highest proportions experiencing delays of 1 to <6 months in Western Australia (34.5%) and the Northern Territory (33.6%), and delays of ≥6 months in South Australia (12.6%) and Western Australia (11.5%) (Figure 13).

Figure 12a: Timeliness* of the 2nd dose of measles-mumps-rubella vaccine (MMR2) due at 48 months, Australia, by Indigenous status

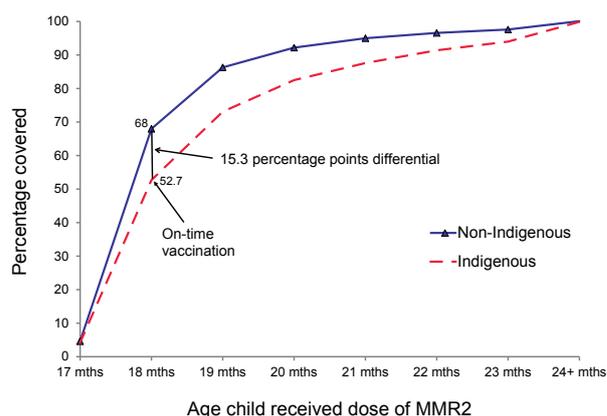


* Percentage covered = number of children who received vaccine dose at particular ages / the total number of children who received the vaccine dose, expressed as a percentage.

Cohort born in 2008.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Figure 12b: Timeliness* of the 2nd dose of measles-mumps-rubella vaccine (MMR2) due at 18 months, 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 2012.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 9: Vaccination delay for children 2 year of age,* Australia, 2014, by Indigenous and remoteness status

Vaccine dose	Indigenous status	Remoteness category	1-<6 months after schedule point %	≥6 months after schedule point %
DTPa3	Indigenous	Major cities	27.7	9.6
		Inner and Outer regional	29.4	10.5
		Remote and Very remote	37.5	8.8
	Non-Indigenous	Major cities	16.5	2.9
		Inner and Outer regional	18.1	3.2
		Remote and Very remote	18.3	2.4
MMR1	Indigenous	Major cities	31.5	5.5
		Inner and Outer regional	31.3	5.8
		Remote and Very remote	33.0	3.7
	Non-Indigenous	Major cities	23.2	2.2
		Inner and Outer regional	23.3	2.1
		Remote and Very remote	23.5	2.0

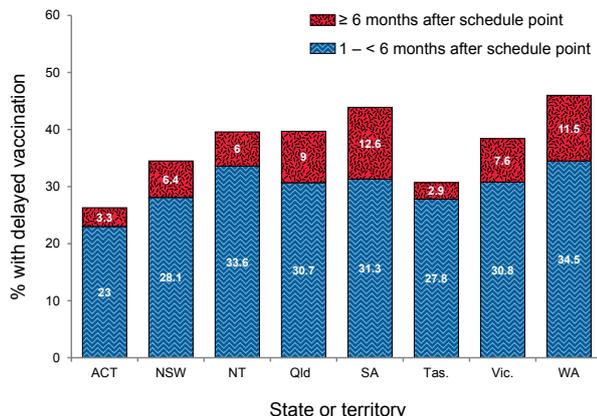
* The cohort of children born in 2012 and assessed in 2014.

DTPa3 = 3rd dose of diphtheria-tetanus-acellular pertussis vaccine

MMR1 = 1st dose of measles-mumps-rubella vaccine

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Figure 13: Vaccination delay for Indigenous children for the 3rd dose of pneumococcal conjugate vaccine, Australia, 2014, by state or territory



Cohort born in 2012.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Trends in timeliness of the 3rd dose of PCV and the 1st dose of MMR vaccine by Indigenous status are provided in Figures 14 and 15. Timeliness for the 3rd dose of PCV improved marginally over time for non-Indigenous children, from 78% in the 2007 birth cohort to 80% in the 2012 birth cohort; however, no improvements were seen for Indigenous children (Figure 14). Timeliness for the 1st dose of MMR vaccine improved over time for non-Indigenous children, from 70.0% in the 2007 birth cohort to 75.0% in the 2012 birth cohort. Timeliness also improved marginally over time for Indigenous children, from 61.0% in the 2007 birth cohort to 63.0% in the 2012 birth cohort (Figure 15).

Figure 14: Timeliness of the 3rd dose of pneumococcal vaccine, Australia, 2007 to 2012, assessed in 2014, by Indigenous status and year of birth

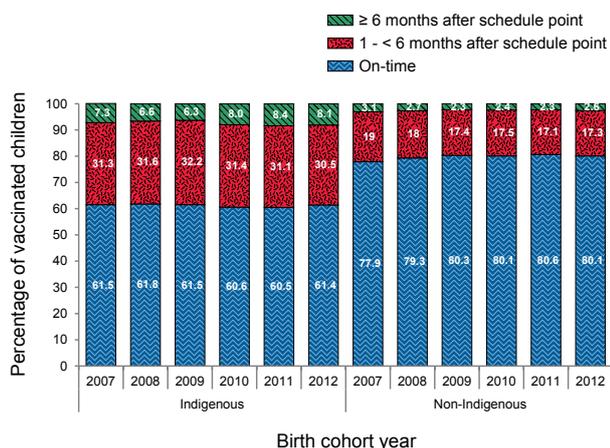
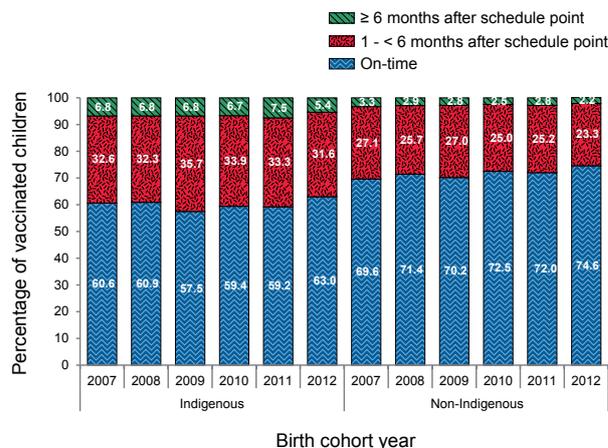


Figure 15: Timeliness of the 1st dose of measles-mumps-rubella vaccine, Australia, 2007 to 2012, assessed in 2014, by Indigenous status and year of birth



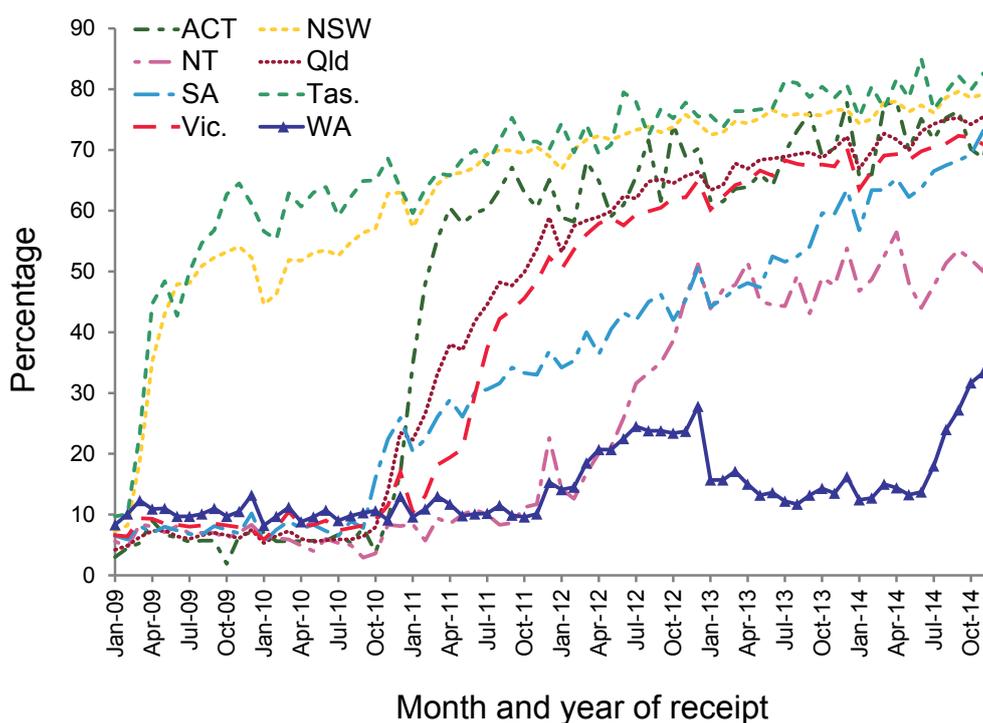
Source: Australian Childhood Immunisation Register.

Recommendation to give 1st dose of DTPa from 6 weeks of age and the 4th dose of DTPa from 3.5 years of age

In response to a pertussis epidemic, and to provide early protection to young infants, the Australian Technical Advisory Group on Immunisation (ATAGI) recommended in March 2009 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. Over the next few years the percentage rose and by late 2014 it was greater than 70% in all jurisdictions except Western Australia and the Northern Territory (Figure 16).

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 17). As at December 2014, more than 35% of children in three jurisdictions (the Australian Capital Territory, the Northern Territory and South Australia) were receiving the dose at 3.5 to 4 years of age (Figure 17).

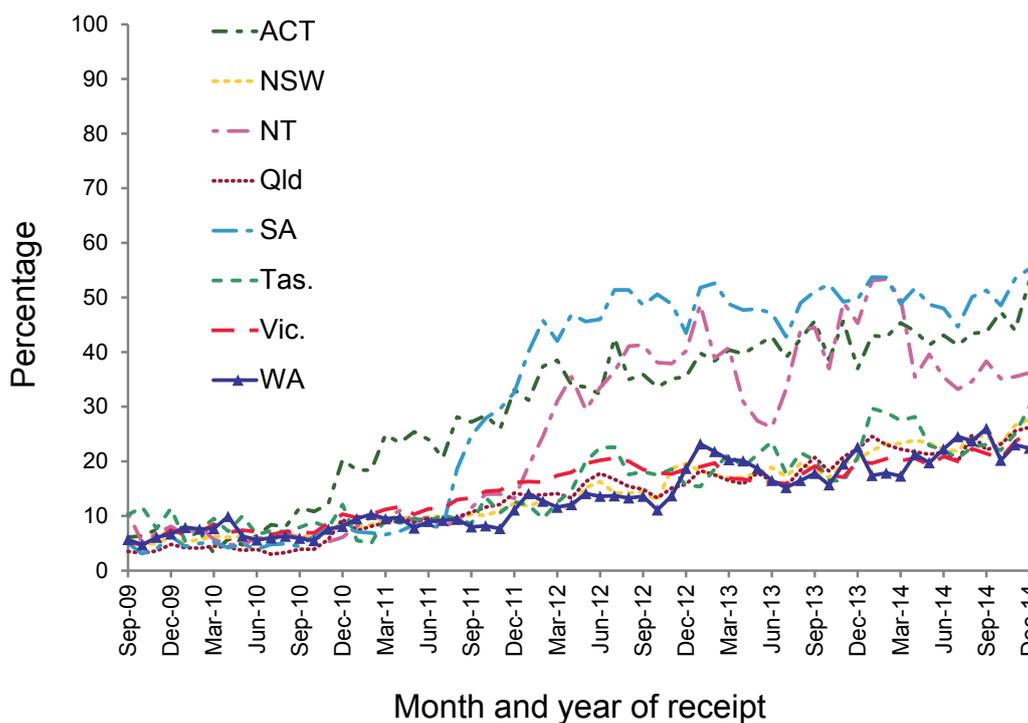
Figure 16: Percentage of children who received their 1st dose of DTPa/Hexa vaccine at age 6 to < 8 weeks, Australia, 2009 to 2014, by state or territory and month of receipt



* DTPa/Hexa = combined diphtheria-tetanus-acellular pertussis (DTPa), polio, *Haemophilus influenzae* type b and hepatitis B vaccine.

Source: Australian Childhood Immunisation Register.

Figure 17: Percentage of children who received their 4th dose of DTPa/Hexa vaccine at age 3.5 years to < 4 years, Australia, 2009 to 2014, by state or territory and month of receipt



* DTPa/Hexa = combined DTPa-IPV-Hib-Hep B vaccine

Source: Australian Childhood Immunisation Register.

Objection to vaccination and incomplete immunisation

Registered objection

The proportions of children with registered vaccination objection status and no vaccines recorded on the ACIR, registered vaccination objection status and at least 1 vaccine recorded on the ACIR, no registered vaccination objection status and no vaccines recorded on the ACIR, and no registered vaccination objection status and not 'fully immunised' by 24 months of age (partially immunised), for all jurisdictions and Australia, is shown in Table 10. Some of the children in the latter 2 groups may be incompletely immunised due to unregistered vaccine objection. Of the 4 groups, the largest is those without a registered objection and partially immunised.

The rate of registered objection in 2014 for Australia was 1.8%. This varied by jurisdiction with a high of 2.4% in Queensland and a low of 1.1% in Tasmania.

The proportions of children with a registered objection to vaccination are presented by Statistical Area 3 (SA3) in Figure 18. The map shows pockets of high levels of registered objection in 2014,

particularly in coastal areas of northern and south-east Queensland, northern New South Wales, the Adelaide Hills and the Margaret River/Busselton region. These areas have had consistently high levels of registered objection over many years.

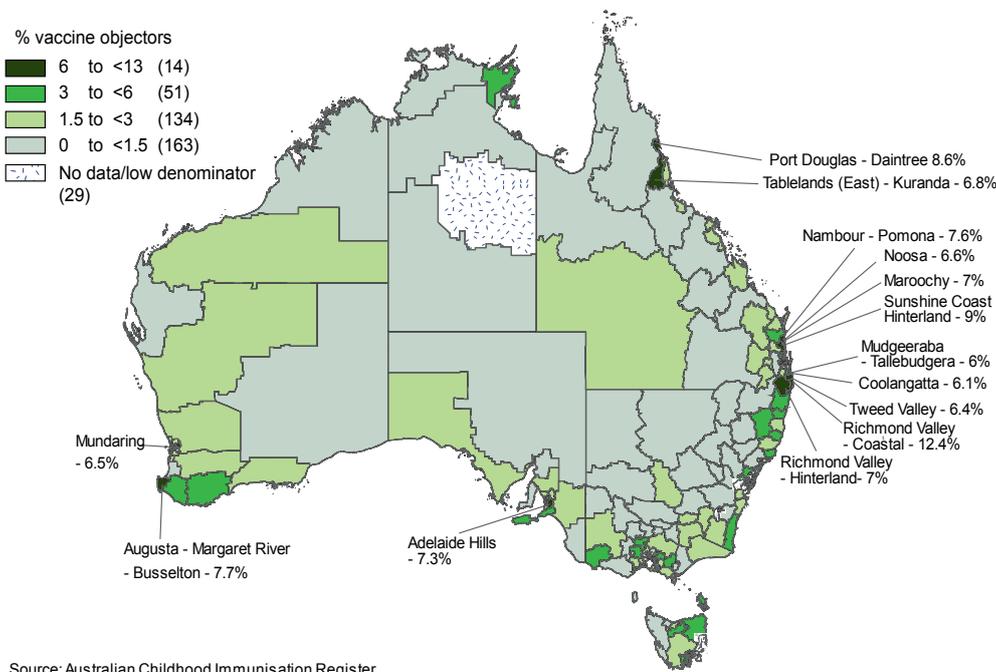
Partially immunised children

The percentage of partially immunised children (excluding those with a registered vaccination objection) who were up-to-date in 2014 for specific vaccines due by 24 months of age is shown in Table 1, by jurisdiction. The vaccines that partially immunised children were most commonly missing by 24 months of age were the 2nd dose of MMR and the dose of varicella (Table 11).

Human papillomavirus vaccine coverage

Vaccination coverage, as notified to the HPV Register, for dose 3 of the HPV vaccine for females and males aged 15 years in 2014 is shown in Table 12. For females in Australia, 73.4% completed a full course of the vaccine, up from 71.4% in 2013. Coverage varied by jurisdiction from a low of 67.7% in Tasmania to a high of 77.4% in Victoria in 2014. Coverage in all age groups was higher for earlier doses, as high as 87.0% for the 1st dose in females aged 12–13 years (Figure 19).

Figure 18: Proportion of children with recorded vaccination objection, Australia, 2014, by Statistical Area 3



Cohort born January 2012 – December 2012, assessed in 2014.

* Number of SA3s in each category in parentheses.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 10: Percentage of children aged 2 years* with registered vaccination objection and whether no/some vaccines recorded on the Australian Childhood Immunisation Register, Australia, assessed in 2014, by state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aus.
Total number of children	1,273	22,002	737	13,716	4,383	1,270	17,280	7,334	67,995
Objection† and no vaccines recorded	1.0	1.0	0.6	1.7	1.4	0.7	1.0	1.3	1.2
Objection† and at least 1 vaccine recorded	0.6	0.4	0.6	0.7	0.7	0.4	0.6	0.8	0.6
No objection and no vaccines recorded	1.5	1.7	2.6	1.7	1.6	0.9	1.6	1.8	1.7
No objection and partially immunised‡	6.9	9.9	9.2	7.4	9.8	12.5	9.2	9.7	9.2

* Cohort born 1 October – 31 December 2012 and assessed in 2014.

† Vaccination objection recorded on the Australian Childhood Immunisation Register.

‡ Record of at least 1 vaccine recorded on the Australian Childhood Immunisation Register, no recorded vaccination objection, and not 'fully immunised' by 24 months of age. 'Fully immunised' – 3 doses of a diphtheria-tetanus-acellular pertussis-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of PRP-OMP-containing *Haemophilus influenzae* type b vaccine or 4 doses of any other *Haemophilus influenzae* type b vaccine, 3 doses of hepatitis B vaccine, 2 doses of a measles-mumps-rubella-containing vaccine, 1 dose of varicella vaccine, and 1 dose of meningococcal C vaccine.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Table 11: Percentage of partially immunised* children aged 2 years† who have received individual vaccines, Australia, 2014, by state or territory

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
Total number of children	100	2,597	84	1,202	526	194	1,930	865	7,498
3 doses of diphtheria, tetanus, acellular pertussis vaccine	88.0	77.9	83.3	79.2	80.6	75.3	81.6	79.5	79.6
3 doses of polio vaccine	88.0	77.2	83.3	79.0	80.4	75.3	81.3	78.5	79.1
4 doses of <i>Haemophilus influenzae</i> type b vaccine	59.0	58.5	61.9	61.7	60.1	60.3	56.6	59.4	58.8
3 doses of hepatitis B vaccine	82.0	74.0	83.3	76.0	76.6	74.7	78.2	74.3	75.8
1 dose of meningococcal C conjugate vaccine	62.0	63.5	73.8	69.6	68.6	68.0	65.3	66.1	65.8
2 doses of measles, mumps, rubella vaccine	23.0	27.2	34.5	28.0	28.5	29.4	28.7	23.7	27.5
1 dose of varicella vaccine	25.0	27.1	21.4	21.3	25.3	26.8	26.3	23.0	25.3

* Record of at least 1 vaccine recorded on the Australian Childhood Immunisation Register, no recorded vaccination objection, and not 'fully immunised' by 24 months of age. 'Fully immunised' – 3 doses of a diphtheria-tetanus-acellular pertussis-containing vaccine, 3 doses of polio vaccine, 3 or 4 doses of PRP-OMP-containing *Haemophilus influenzae* type b vaccine or 4 doses of any other *Haemophilus influenzae* type b vaccine, 3 doses of hepatitis B vaccine, 2 doses of a measles-mumps-rubella-containing vaccine, 1 dose of varicella vaccine, and 1 dose of meningococcal C vaccine.

† Cohort born 1 October – 31 December 2012 and assessed in 2014.

Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Coverage was higher in the younger age groups than the older age groups, with only 52.0% of females aged 20–26 years fully vaccinated. For males in Australia, 61.4% completed a full course of the vaccine. Coverage varied by jurisdiction from a low of 55.1% in Tasmania to a high of 67.8% in Victoria in 2014 (Table 12). As with data for females, coverage in all age groups was higher for earlier doses, as high as 75.0% for the 1st dose in males aged 14–15 years (data not shown). HPV coverage by Indigenous status is not available due to limitations in Indigenous status reporting on the HPV Register.

Coverage in the elderly

According to a Newspoll Omnibus Survey, 73% of Australian adults aged 65 years or over had received an influenza vaccination in 2014 as at mid-June.

Provider type

GPs administer the large majority of immunisations in Australia (Figure 20); the proportion given by GPs has increased over the past 12 years by almost 5% (data not shown). Regional differ-

Table 12: Coverage (%) for 3 doses of human papillomavirus vaccine for girls 15 years of age in 2011, 2012, 2013 and 2014, and males age 15 years in 2014, by state or territory, Australia

	State or territory								
	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
2011	74.2	74.5	87.0	72.4	68.0	66.5	76.5	64.6	72.9
2012	74.4	71.0	84.5	69.4	71.0	64.7	74.2	70.1	71.4
2013	74.0	68.6	81.4	71.0	72.4	64.1	75.2	71.2	71.4
2014	70.0	69.8	77.3	73.5	73.1	67.7	77.4	76.0	73.4
2014 males*	64.2	56.9	55.4	61.1	63.3	55.1	67.8	61.0	61.4

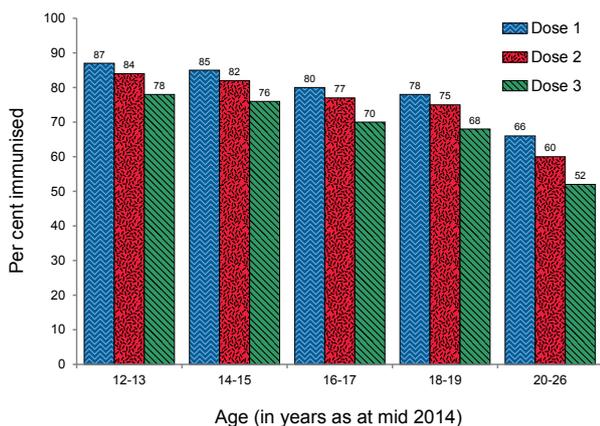
* Reflects male catch-up vaccination program 2013–2014. Routine immunisation ongoing at age 12–13 years.

Includes doses that comply with the recommended vaccine dosage and administration as per *The Australian Immunisation Handbook* (up to 3 doses administered at prescribed intervals).

Denominator data used is Australian Bureau of Statistics Estimated Resident Population on 2012 boundaries (final) as at 30 June in the relevant year.

Earlier coverage reports utilised interim Australian Bureau of Statistics Estimated Resident Population data. As a result, small changes in coverage rates may be apparent if compared with earlier reports.

Source: National Human Papillomavirus Vaccination Program Register, January 2016.

Figure 19: Human papillomavirus vaccination coverage for females, Australia, mid-2014, by dose number and age group

Technical notes:

Data extracted from the National Human Papillomavirus Vaccination Program Register (HPV Register) as at 19 January 2016.

Includes doses that comply with the recommended vaccine dosage and administration as per *The Australian Immunisation Handbook* (up to 3 doses administered at prescribed intervals).

Population is Estimated Resident Population 2014 (as at 30/06/2014) from the Australian Bureau of Statistics Cat 3101.0 Australian Demographic Statistics, Tables 51 to 58: Estimated resident population by single year of age by state and territory. Interim data published December 2014.

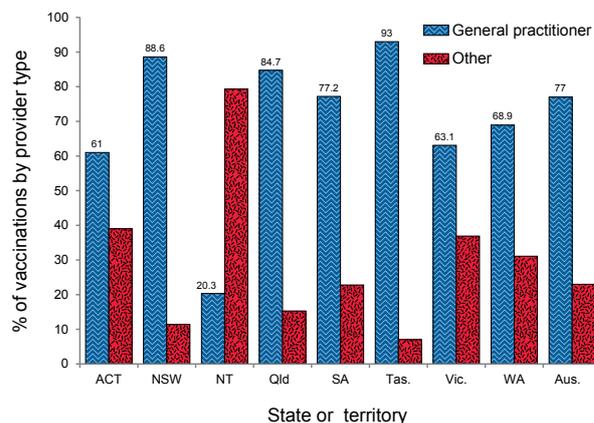
Age is age as at date of Estimated Resident Population estimate (30 June 2014).

Coverage is calculated as doses administered and reported to the HPV Register / Estimated Resident Population expressed as a percentage.

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

Source: National HPV Vaccination Program Register, June 2016.

ences are marked, with over 80% of immunisations administered by GPs in New South Wales, Queensland and Tasmania, and the majority of immunisations given by GPs in all other jurisdictions except for the Northern Territory.

Figure 20: Proportion of vaccinations on the Australian Childhood Immunisation Register given by provider type, January to December 2014, by state or territory, Australia

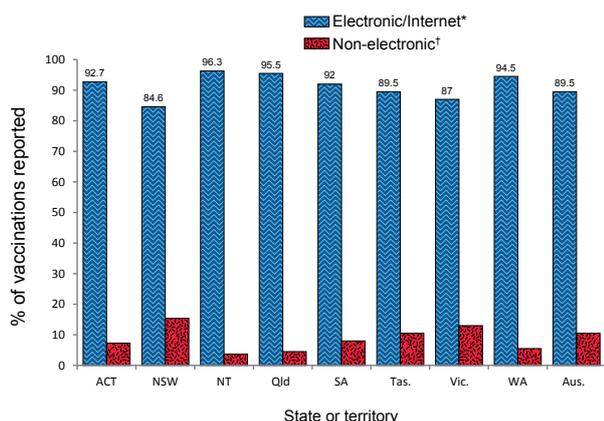
Source: Australian Childhood Immunisation Register, data as at 31 March 2015.

Mechanisms of reporting to the Australian Childhood Immunisation Register

The proportions of vaccinations on the ACIR lodged by electronic/online mechanisms versus non-electronic mechanisms by jurisdiction are shown in Figure 21. Most reporting in 2014

occurred through electronic/online mechanisms, for all jurisdictions, with the proportion reported through this method varying from 96.3% in the Northern Territory to 84.6% in New South Wales.

Figure 21: Proportion of immunisations on the Australian Childhood Immunisation Register lodged by type of reporting mechanism, January to December 2014, by state or territory, Australia



* 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 where approved immunisation providers can send immunisation details using the Internet Data Interchange upload facility through the ACIR secure area within Medicare Australia’s web site, or Health Professionals Online Services, where approved immunisation providers can submit immunisation encounters which are records of immunisations, view immunisation history, request reports and update provider contact details.

† Manual voucher: by completing an immunisation encounter form and sending it to Medicare Australia, or an immunisation 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, data as at 31 March 2015.

Discussion

In 2014, ‘fully immunised’ coverage was higher than in 2013 nationally for children at 12 and 60 months of age (91.5% and 92.0% versus 90.8% and 91.2%, respectively) but lower for children at 24 months of age (86.8% versus 92.1%). However, this decline in coverage at the 24-month age milestone was predominantly a measurement artefact due to the immunisation coverage assessment algorithm for ‘fully immunised’ at the 24-month milestone being amended in July 2014 to include a dose of meningococcal vaccine, a dose of varicella vaccine and a 2nd dose of MMR vaccine.

Aside from minor fluctuations and the impact of changes to assessment algorithms, ‘fully immunised’ coverage has been largely stable at the 12- and 24-month age milestones since late 2003. The more than 10 percentage points increase in coverage at 60 months of age 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.

Coverage estimates for varicella vaccine and the 2nd dose of MMR were substantially lower than for other vaccines included in the algorithm for ‘fully immunised’ at the 24-month milestone. 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 lower 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 60 months of age instead of 24 months, we observed much higher estimates across all jurisdictions, ranging from 6.0 to 10.4 percentage points higher. We also found that national varicella vaccine coverage increased by 3.7 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, are likely to explain lower coverage when compared to 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.^{23,24} In contrast, modelling studies suggest that low coverage (70%–90%) with varicella vaccine may result in a shift of disease to older age groups with higher disease severity.²⁵

Coverage for vaccines recommended for Indigenous children only (i.e. hepatitis A and a booster dose of pneumococcal vaccine) remained suboptimal in 2014. 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 children²⁶ 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 likely to be important contributing factors. While coverage for 2 doses of hepatitis A vaccine was only 63%, an additional 17% of Indigenous children received a single dose, which provides a protective antibody response in most children.²⁸

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 for vaccines assessed at 12 and 24 months of age in 2014 increased for Indigenous children but decreased for non-Indigenous children. However, while the differential in on-time vaccination between Indigenous and non-Indigenous children in 2014 did improve marginally from 2013, timeliness is still a significant problem for Indigenous children in Australia. Poorer timeliness in Indigenous children aged 2 years of age has been noted previously.²⁹ Timeliness 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. In 2014 more than 70% of children in all jurisdictions except Western Australia and the Northern Territory received the 1st dose of DTPa vaccine prior to 8 weeks of age, in line with recommendations encouraging early protection of young infants from pertussis infection.

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 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 has led to an improvement in the timeliness of this dose but in non-Indigenous children only.

Analysis of ACIR data has demonstrated the rapid uptake by the population of new vaccines in the Australian setting, unlike some other developed countries.^{30,31} Only 1.8% of children are registered as having parental vaccination objection 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 about incompletely immunised children will be the subject of an upcoming National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases report. Further vaccination coverage estimates in small areas have been provided by the National Health Performance Authority for children in 2013 to 2015.³²

Coverage data for the HPV vaccine from the National HPV Vaccination Program Register

reflect a successful school-based program with lower but still substantial coverage for the catch-up program in older females.^{33,34} The coverage achieved in the program has resulted in demonstrable decreases in HPV prevalence in young women,³⁶ and in genital warts³⁷ and cervical abnormalities.³⁸ Coverage achieved during the catch-up program for males aged 14–15 years in 2013 to 2014 indicates that the vaccine is acceptable to most parents of boys but that further work may be needed to normalise HPV vaccination for males and raise coverage to the same level as achieved in females. Ongoing routine HPV vaccination of both sexes, and a possible change to a 2-dose schedule for adolescents aged under 15 years at 1st dose in future, as endorsed by the World Health Organization in 2014,³⁹ will hopefully facilitate further increases in HPV vaccine coverage.

Data provided in this report reflect continuing successful delivery of the NIP in Australia, while identifying some areas for improvement. Coverage for rotavirus vaccine, varicella vaccine and the 2nd dose of MMR vaccine is below that for other vaccines. Timeliness of vaccination could be improved, particularly for Indigenous children, and coverage for vaccines recommended only for Indigenous children is lower than for other vaccines.

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Author details

Brynley Hull¹
Alexandra Hendry¹
Aditi Dey¹
Frank Beard¹
Julia Brotherton²
Peter McIntyre¹

1. National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, The Children's Hospital at Westmead and University of Sydney, Locked Bag 4001, Westmead, NSW 2145
2. National HPV Vaccination Program Register, Victorian Cytology Service, PO Box 310, East Melbourne, Victoria

Corresponding author: Mr Brynley Hull, National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, The Children's Hospital at Westmead and University of Sydney, Locked Bag 4001, WESTMEAD NSW 2145. Telephone: +61 2 9845 1435. Facsimile: +61 2 9845 1418. Email: brynley.hull@health.nsw.gov.au

List of vaccine abbreviations

13vPCV	13-valent pneumococcal conjugate vaccine
23vPPV	23-valent pneumococcal polysaccharide vaccine
Comvax	<i>Haemophilus influenzae</i> 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-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	<i>Haemophilus influenzae</i> type b
HPV	human papillomavirus
MMR	measles-mumps-rubella
MMRV	measles-mumps-rubella-varicella
PCV	pneumococcal conjugate vaccine
PRP-OMP	<i>Haemophilus influenzae</i> type b conjugate vaccine
VZV	varicella-zoster virus

References

- Hull B, Deeks S, Menzies R, McIntyre P. Immunisation coverage annual report, 2007. *Commun Dis Intell* 2009;33(2):170–187.
- Hull BP, Mahajan D, Dey A, Menzies RI, McIntyre PB. Immunisation coverage annual report, 2008. *Commun Dis Intell* 2010;34(3):241–258.
- Hull B, Dey A, Mahajan D, Menzies R, McIntyre PB. Immunisation coverage annual report, 2009. *Commun Dis Intell* 2011;35(2):132–148.
- Hull B, Dey A, Menzies R, McIntyre PB. Annual immunisation coverage report, 2010. *Commun Dis Intell* 2013;37(1):E21–E39.
- Hull BP, Dey A, Menzies RI, Brotherton JM, McIntyre PB. Immunisation coverage annual report, 2011. *Commun Dis Intell* 2013;37(4):E291–E312.
- Hull BP, Dey A, Menzies RI, Brotherton JM, McIntyre PB. Immunisation coverage annual report, 2012. *Commun Dis Intell* 2014;38(3):E208–E231.
- National Health Performance Authority. Healthy communities: Immunisation rates for children in 2012–13. 2014. Available from: <http://www.nhpa.gov.au/internet/nhpa/publishing.nsf/Content/Our-reports> Accessed on 2 December 2014.
- Hull BP, Deeks SL, McIntyre PB. The Australian Childhood Immunisation Register – a model for universal immunisation registers? *Vaccine* 2009;27(37):5054–5060.
- 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.
- Australian Government Department of Health. Update: No Jab No Pay – Immunisation catch-up arrangements. 2015. Available from: [http://www.immunise.health.gov.au/internet/immunise/publishing.nsf/Content/clinical-updates-and-news/\\$File/Update-No-Jab-No-Pay-Immunisation-Catch-Up-Arrangements\(D15-1126865\).pdf](http://www.immunise.health.gov.au/internet/immunise/publishing.nsf/Content/clinical-updates-and-news/$File/Update-No-Jab-No-Pay-Immunisation-Catch-Up-Arrangements(D15-1126865).pdf) Accessed on 30 November 2015.
- Australian Technical Advisory Group on Immunisation. *The Australian Immunisation Handbook*. 10th edn. Canberra: Australian Government Department of Health; 2013.
- O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. *Commun Dis Intell* 1998;22(3):36–37.
- 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.
- Hull BP, Lawrence GL, McIntyre CR, McIntyre PB. Estimating immunisation coverage: is the 'third dose assumption' still valid? *Commun Dis Intell* 2003;27(3):357–361.
- Hull B. Australian childhood immunisation coverage, 1 October to 31 December cohort, assessed as at 31 March 2014. *Commun Dis Intell* 2014;38(3):E260–E261.

16. Australian Population and Migration Research Centre. ARIA and accessibility. Accessibility/Remoteness Index of Australia – ARIA+ (2011). 2011. Available from: <http://www.adelaide.edu.au/apmrc/research/projects/category/aria.html> Accessed on 17 November 2014.
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. Available from: <http://www.abs.gov.au/websitedbs/d3310114.nsf/home/australian+statistical+geography+standard+%28asgs%29> Accessed on 17 November 2014.
19. MapInfo Pro version 15.0. Stamford, Connecticut, USA. 2015.
20. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS): Correspondences, July 2011. 2012. Available from: <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/1270.0.55.006Main+Features1July%202011?OpenDocument> Accessed on 17 November 2014.
21. Australian Institute of Health and Welfare. 2009 Adult Vaccination Survey: summary results. 2011. Available from: <http://www.aihw.gov.au/publication-detail/?id=10737418409> Accessed on 2 December 2014.
22. Newspoll. Newspoll Omnibus Survey June 2014 – Summary Report Flu Vaccinations. 2014. Available from: [http://www.immunise.health.gov.au/internet/immunise/publishing.nsf/Content/762A8FB9101D1759CA257D49002227B6/\\$File/summ-report-flu-vaccinations-survey2014.pdf](http://www.immunise.health.gov.au/internet/immunise/publishing.nsf/Content/762A8FB9101D1759CA257D49002227B6/$File/summ-report-flu-vaccinations-survey2014.pdf) Accessed on 30 November 2015.
23. 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.
24. 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.
25. 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.
26. 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.
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. Philadelphia, PA: Saunders Elsevier; 2008.
29. Hull BP, McIntyre PB. Timeliness of childhood immunisation in Australia. *Vaccine* 2006;24(20):4403–4408.
30. Centers for Disease Control and Prevention. 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.
31. Health and Social Care Information Centre. NHS immunisation statistics, England, 2012–13. 2013. Available from: <http://www.hscic.gov.uk/catalogue/PUB11665> Accessed on 2 December 2014.
32. National Health Performance Authority. Healthy communities: Immunisation rates for children in 2013–15. 2016. Accessed on 20 February 2016. Available from: <http://www.nhpa.gov.au/internet/nhpa/publishing.nsf/Content/Our-reports>
33. 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.
34. 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.
35. 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.
36. 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.
37. 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.
38. 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.
39. World Health Organization. Meeting of the Strategic Advisory Group of Experts on immunization, April 2014 – conclusions and recommendations. *Wkly Epidemiol Rec* 2014 May 23;89(21):221–236.