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Growing Up in Australia:
The Longitudinal Study of Australian Children (LSAC)

LSAC Technical Paper No. 17

Using Australian Childhood Immunisation Register data in the Longitudinal Study of Australian Children

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Contents

List of Tables

List of Shortened Forms

ACIR	Australian Childhood Immunisation Register
AIFS	Australian Institute of Family Studies
DHS DSS	Department of Human Services Department of Social Services
HIC	Health Insurance Commission
LSAC	Longitudinal Study of Australian Children
MBS	Medicare Benefits Schedule
PBS	Pharmaceutical Benefits Scheme
FaCSIA	Department of Families and Community Services and Indigenous Affairs
NHMRC	National Health and Medical Research Council
NCIRS	National Centre for Immunisation Research and Surveillance
CDI	Communicable Diseases Intelligence
Hib	Haemophilus influenzae type b
MMR	Combination measles, mumps and rubella vaccine
HepB	Hepatitis B
DTPa	Combination diphtheria, tetanus and acellular pertussis vaccine

1 Introduction

Rates of childhood immunisation in Australia are high and have been maintained at a high level for the past decade. Although most children are fully immunised, even small lapses in coverage can increase the risk of highly contagious diseases like measles (Heywood et al., 2009). For these reasons, it is important to identify potentially modifiable factors that are related to incomplete immunisation.

Information about immunisation is available for children in *Growing up in Australia*: the Longitudinal Study of Australian Children (LSAC). These data were obtained from the Australian Childhood Immunisation Register (ACIR). This provides data users with opportunities to use the demographic, social and health information available in LSAC to examine many different issues relating to immunisation. This sort of research will continue to inform the development of best practice for the control of vaccine preventable diseases in Australia. This paper describes the linked data and provides guidance to data users on how to prepare it for analysis.

1.1 The Longitudinal Study of Australian Children

LSAC is a nationally representative study of over 10,000 children. The sample consists of two cohorts of children and their families: one cohort of 5,107 children aged 0 to 1 (the birth or "B" cohort) and another of 4,983 children aged 4 to 5 (the Kindergarten or "K" cohort). Beginning in 2004, information has been collected every two years on children's physical, emotional and cognitive wellbeing, as well as family, school and community circumstances. Information is collected from multiple sources, including resident and non-resident parents, teachers and carers, and by direct child assessment and self-report. The study is funded by the Australian Government Department of Social Services (DSS) and is conducted in partnership between DSS, the Australian Institute of Family Studies (AIFS) and the Australian Bureau of Statistics (ABS).

1.2 The Australian Childhood Immunisation Register

ACIR was established on 1 January 1996. It was the first purpose-built immunisation register established in the world. ACIR holds identification and immunisation details for all children up to 7 years old who are enrolled in Medicare, which is 99 per cent of children by 12 months of age. Initially, ACIR was administered by the Health Insurance Commission (HIC), and it is now administered by the Department of Human Services.

1.3 Outline of the report

ACIR data have great potential to develop further understanding of the health and social factors related to immunisation. However, ACIR data cannot be used 'as is' and need substantial reorganising to create useful variables for analysis. Moreover, a historical understanding of the immunisation schedules that were operating when the K and B cohort children were younger than 7 years old is essential for meaningful preparation, analysis and interpretation of LSAC–ACIR linked data.

In Sections 2 and 3 below, we firstly describe the process by which LSAC cases were matched to ACIR data. We also examine characteristics of cases that were not matched to ACIR, using a wide range of variables from Wave 1 of LSAC. This is important because, if cases not matched are systematically different to those that were matched, the cases available for research on immunisation may not be representative of the complete LSAC sample. We also describe how to handle LSAC cases that have no ACIR records.

Section 4 describes the immunisation schedules that regulated the K and B cohorts' immunisations up to ages 4 to 5. Since the 1990s, there have been a number of changes in the timing, doses and types of vaccinations that are funded for Australian children, and vaccinations recorded in the LSAC–ACIR data must be interpreted with reference to the relevant vaccination schedules.

Section 5 introduces milestone ages at which children's immunisation status is assessed in Australia. This section also outlines the criteria for full immunisation at each milestone age. Section 6 describes the variables included in the ACIR dataset. Section 7 describes in detail how to use these variables to determine which immunisations children have received by certain ages. It also highlights important issues of which all data users need to be aware.

Section 8 reports immunisation coverage rates for the LSAC sample, compared to immunisation coverage rates reported for the population. We find that the rates in the LSAC sample are a little higher than those in the population, and we describe several possible reasons for this difference.

Section 9 concludes, and Section 10 summarises, recommendations made from all sections of the report.

2 ACIR linkage process

2.1 Obtaining consent

ACIR data linkage was one component of a broader process of Medicare linkage. In the Wave 1 data collection, parents of LSAC children were asked to fill in a consent form for allowing access to their child's data stored in the following three Medicare databases:

- The Medicare Benefits Schedule (MBS)
- The Pharmaceutical Benefit Scheme (PBS)
- The ACIR

The consent form used is provided in Appendix A. For consent to be obtained, one of the parents or guardians had to complete the form and sign it in the presence of a witness. If the form was incomplete, it was considered that consent had not been given.

2.2 Data linkage process

The following procedure was used to link LSAC data with ACIR data:

1. The agency that collected the Wave 1 data (I-view) sent the identifiable information from the consent form (i.e., name, address, Medicare number) to HIC, which held the PBS, MBS and ACIR data. The identifiable data were sent with a dummy LSAC identifier, which was different from the LSAC *hicid*, the unique ID for a study child within LSAC.
2. HIC matched the identifiable data provided with the ACIR data.
3. HIC sent the Department of Families, Community Services and Indigenous Affairs (FaCSIA; now DSS) the Medicare data with the LSAC dummy identifier. The identifiable information was not sent.
4. FaCSIA sent the data to AIFS, where it was matched to the LSAC unique ID.

This procedure ensured that none of the agencies involved in the linkage (I-view, HIC, and FaCSIA) knew the LSAC ID, and they therefore could not match identifying information with LSAC data (in the case of HIC) or with Medicare data (in the case of FaCSIA). Moreover, AIFS did not know the identifiable information used in the matching and so could not match this to other LSAC datasets.

Across both cohorts, 93 per cent (9,385) of children were successfully matched to the Medicare, PBS and ACIR datasets. Matching was not possible for 705 children. It was not possible to determine whether non-matched cases were due to lack of consent or to matching failure.

2.3 Analysis examining characteristics of cases not matched

It is important to investigate whether children and their families who were not linked to the MBS, PBS or ACIR data are different from those who were linked. Any significant differences should be taken into account when interpreting results of analyses using the MBS, PBS, or ACIR data. For example, differences between matched and unmatched children should be considered when comparing immunisation coverage in LSAC with national estimates. We carried out a series of analyses to examine differences between matched and unmatched children. It should be noted that the findings apply to the MBS and PBS data as well as the ACIR data.

In the first step of the analysis, we assessed whether the percentage matched differed between the B cohort and the K cohort. Next, we used logistic regression to examine predictors of children being matched to Medicare data, separately for each cohort.[1] Only one predictor variable was in each model. In these models, the outcome was Medicare matching, which was coded 1 if a child was matched to Medicare data and 0 if the child was not matched. Predictor variables were all taken from Wave 1 LSAC data. The same predictor variables were used for both cohorts.

The full list of variables included as predictors in the models is summarised in Table B1 in Appendix B. The predictors included a wide range of demographic and socioeconomic variables. These variables were selected because they have been used to predict LSAC non-response and because many of them have been linked to incomplete immunisation in previous research (e.g., Haynes & Stone, 2004). Because the Medicare data may often be used to examine health outcomes, we also included a number of variables relating to study child health and to health services used for the study child. We also examined parent attitudes towards immunisation and parent self-report of the study child's immunisation status. Information was mostly derived from the child's primary carer, Parent 1 (P1), who in 98 per cent of cases was the child's mother.

Results

Difference in matching between cohorts

Table 1 shows the percentage of participants matched to Medicare in each cohort. The percentage of matched participants was 1.2 per cent higher in the B than the K cohort. Although this difference was statistically significant, in practice, it is very small. Therefore, while interpretation of analyses utilising both cohorts should consider that there are slightly fewer matched data for participants in the K cohort, this difference is unlikely to bias results in any way.

Table 1: Percentage of matched Medicare data in the B and K cohorts

Cohort	Not matched (%)	Matched (%)	Total (%)	χ^2 *(df)*
B	328 (6.4)	4,779 (93.6)	5,107 (100)	5.07 (1)*
K	377 (7.6)	4,606 (92.4)	4,983 (100)	
Total	**705 (7.0)**	**9,385 (93.0)**	**10,090 (100)**	

*$p < 0.05$

Predictors of matching in the B cohort

The results of the logistic regression model examining non-matching in the B cohort are shown in Table B2 in Appendix B. Overall, results showed that families where children were not matched had lower incomes and experienced slightly more disadvantage than families where children were matched. Children were less likely to be matched if:

- parental income was in the lower quintiles (compared to the highest quintile)
- the family's main source of income was government benefits
- the family lived in a postcode with higher levels of disadvantage
- the family lived in a postcode with a higher proportion of residents aged 4 years old and younger
- the family lived in a remote or very remote area
- the child's primary caregiver spoke a language other than English at home.

[1] There were missing cases on 15 of the predictor variables in the B cohort and 17 of the predictor variables in the K cohort. The number of missing cases ranged from fewer than 10 for parent reports of their child's health and immunisation status, own education and attitudes towards immunisation, to more than 800 for parent reports of the child's health service use. Service use data were missing because the parent did not return the survey portion at Wave 1. Multiple imputation with chained equations was used to account for missing data, assuming data were missing at random. The imputation model included all the predictor variables and the dependent variable. Ten datasets were imputed. Coefficients were combined using Rubin's Rules (Sterne et al., 2009), which adjust standard errors to account for variation between and across imputed datasets.

Male children were also less likely to be matched, although it is not clear what would account for this. Finally, matching was significantly associated with the primary caregiver's attitudes to child immunisation. Compared to parents who agreed quite strongly or very strongly with immunisation (93.6 per cent of parents), those who were neutral (4.6 per cent) were less likely to be matched. Those who very strongly or quite strongly disagreed were also less likely to be matched, although this did not reach statistical significance because of the very small number of parents who disagreed (1.8 per cent of parents). This suggests that, in the B cohort, the ACIR data may slightly underrepresent children whose parents were opposed to immunisation.

Predictors of matching in the K cohort

The results of the logistic regression model examining non-matching in the K cohort are shown in Table B3 in Appendix B. Income and disadvantage-related measures continued to differ between matched and non-matched children. Children were less likely to be matched if:

parental income was in the lowest quintile (compared to the 2nd, 3rd, and 4th quintiles)[2]

- the family's main source of income was government benefits
- the family did not have private hospital insurance
- the family lived in a postcode with a lower proportion of households earning more than $1,000 a week
- the family lived in a remote or very remote area
- the child's primary caregiver spoke a language other than English at home
- the child's primary caregiver was born outside Australia or New Zealand
- the family was a lone mother household.

In addition, children living in public housing and with mothers who were less than 20 years old when the child was born were less likely to be matched, although these factors did not reach statistical significance.

Conclusion

Taken together, the analyses suggest that LSAC children not linked to Medicare, PBS or ACIR data were in families that earned less, lived in more remote areas, lived in lower-earning areas or were dependent on government payments. Language and cultural background was also clearly an issue, with children of parents who did not speak English at home significantly less likely to be matched. Thus, disadvantaged, non-English-speaking families are slightly underrepresented in the LSAC–ACIR dataset. One likely consequence of this is that rates of full immunisation are higher in the LSAC sample than in the population. We discuss this issue in more detail in Section 8.

[2] In Table B3, the reference category for income is the highest quintile. The comparisons between the highest quintile and lower quintiles were not statistically significant; however, in reference to the lowest quintile, the 2nd, 3rd and 4th quintiles were significantly more likely to be matched.

3 Matched cases with no records on the ACIR

There are 151 children across both cohorts who were matched but who do not appear in the ACIR data file. Table 2 shows the percentage of these cases in both cohorts.

Table 2: Percentage of LSAC children linked to Medicare but with no vaccines recorded on ACIR

Cohort	No vaccines recorded		Vaccines recorded		Total	
	Observations	(%)	Observations	(%)	Observations	(%)
B	85	(1.8)	4,694	(98.2)	4,779	(100)
K	66	(1.4)	4,540	(98.6)	4,606	(100)
Total	**151**	**(1.6)**	**9,234**	**(98.4)**	**9,385**	**(100)**

These children do not appear in the ACIR data because they do not have any vaccines recorded. There are five possible reasons for this, outlined below.

1. Some parents choose not to vaccinate their children

In Australia, from 1998 to 2016, parents whose child was registered with Medicare could choose to lodge an official objection to immunisation. These individuals were registered conscientious objectors. Children had to meet immunisation requirements for families to be eligible for some family payments. Until 2016, a registered conscientious objection was considered a valid exemption to these requirements, meaning that these families still received the payments (Homel & Edwards, forthcoming). However, parents could still object to immunisation and not lodge an official objection (Hull, Dey, Menzies, Brotherton, & McIntyre, 2014). Information about conscientious objection was not retrieved from ACIR for the matched LSAC participants. This means that it is not possible to know how many children with no vaccines recorded had a registered conscientious objection.

However, it is possible to examine how self-reported parental attitudes to immunisation differ between matched children who have records and matched children who do not have records. Table 3 shows that parents of children with no vaccines recorded are much more likely to disagree with childhood immunisation than parents of children with records. In the B cohort, 69 per cent of children with no vaccines recorded had a parent who disagreed with immunisation, compared to less than 1 per cent in children with vaccines recorded. In the K cohort, 42 per cent of children with no vaccines recorded had a parent who disagreed with immunisation, compared to 1 per cent in children with vaccines recorded.

Table 3: Parental attitude to childhood immunisation among matched children with and without ACIR records

Cohort		No vaccines recorded		Vaccines recorded	
	Parental attitude	Observations	(%)	Observations	(%)
B	Agree	16	(18.82)	4,468	(95.29)
	Neutral	10	(11.76)	181	(3.86)
	Disagree	59	(69.41)	40	(0.85)
	Total	**85**	**(100)**	**4,689**	**(100)**
K	Agree	32	(48.48)	4,285	(94.42)
	Neutral	6	(9.09)	203	(4.47)
	Disagree	28	(42.42)	50	(1.1)
	Total	**66**	**(100)**	**4,538**	**(100)**

2. Medical exemptions (contraindications) to vaccinations

A contraindication to vaccination is a rare condition in a recipient that increases the risk for a serious adverse reaction (World Health Organisation, http://vaccine-safety-training.org). Most contraindications are temporary. Contraindications applicable to all vaccines are extremely rare. For example, in 2012, the rate of adverse events in children under 7 years old following vaccinations (where a vaccine was suspected of involvement) was 23.5 per 100,000 (Mahajan et al,, 2015). In Australia, parents may register an Immunisation Exemption Medical Contraindication for some or all scheduled vaccines. Data on registered contraindications are not available in the ACIR matched data. Parents often delay vaccinations because of health concerns that are not contraindications, such as minor colds; however, this would be unlikely to account for complete lack of records. Therefore, we conclude that medical contraindications are not a major contributor to the number of children with no vaccines recorded.

3. Overseas vaccinations not transferred to the ACIR

Since 2001, vaccines received overseas can be submitted to the ACIR if proof of the vaccinations is provided and the application is endorsed by an Australian immunisation provider such as a GP (National Health Performance Authority, 2013). In the B cohort, only 17 matched children were born overseas, and all of these had vaccines recorded (Table 4). However, in the K cohort, 187 matched children were born overseas. Of the 66 K cohort children with no vaccines recorded, 11 (17 per cent) were born overseas. It is possible that these children received vaccines overseas but that these were not submitted to the ACIR. A study of children with no records in Western Australia (Gibbs, Hoskins, & Effler, 2015) found that the largest contributing factor to apparent non-immunisation was inaccurate records for children born overseas.

Table 4: Proportion of children born overseas with and without vaccines recorded

Cohort		No vaccines recorded		Vaccines recorded	
	Place of birth	**Observations**	**(%)**	**Observations**	**(%)**
B	Australia	85	(100)	4,677	(99.64)
	Overseas	0		17	(0.36)
	Total	**85**	**(100)**	**4,694**	**(100)**
K	Australia	55	(83.33)	4,364	(96.12)
	Overseas	11	(16.67)	176	(3.88)
	Total	**66**	**(100)**	**4,540**	**(100)**

4. Provider under-reporting of vaccinations

There were problems with provider under-reporting to the ACIR in the first few years after it was established in 1996. A study of children born in 1998 and 1999 (Hull, Lawrence, MacIntyre, & McIntyre, 2003b) concluded that provider under-reporting led to the ACIR underestimating immunisation coverage by about 5 per cent. However, provider notifications improved substantially after provider incentives were introduced in 1998 and have continued to improve as notifications are increasingly made online (Hull, Deeks, & McIntyre, 2009). Given this history, it is likely that the K cohort would be more affected by provider under-reporting than the B cohort. Under-reporting may account for a few of the instances in which children had no vaccines recorded in the K cohort.

5. Access issues

Parents may have difficulties accessing immunisations for a wide range of practical and logistic reasons. These could be the focus of research with the matched data.

Recommendation for data users #1

It is important to take into account the matched cases with no vaccinations recorded when carrying out analyses that involve assessing whether children are immunised or not. The missing cases should not be dropped, but included in the dataset. These cases should be included because they include some parents who, for one reason or another, have not immunised their children. This includes some who object to vaccination on principle, who may or may not be registered conscientious objectors. The group may also include families who had difficulty accessing immunisations. These are important topics for research. **Note that these cases have been included in the available dataset that includes LSAC-derived immunisation variables (see Section 6).**

4 Vaccination schedules for children in LSAC

The Immunise Australia program was introduced in 1997. Arising from the 1993 National Immunisation Strategy, the program was designed to improve immunisation coverage and to align vaccination funding and practice across states and territories (Ruff, Taylor, & Nolan, 2012). Under the program, children in Australia receive vaccinations according to schedules developed by the Australian Technical Advisory Group on Immunisation (ATAGI) and approved by the National Health and Medical Research Council (NHMRC). Schedules are updated at various times when new vaccines become recommended or funded, when recommendations for timing and number of doses change, or when recommendations for at-risk groups change. The schedules have been published in a series of Immunisation Handbooks (NHMRC 1997, 2000, 2003, 2008, 2013), which also include detailed clinical information about vaccines and guidelines for safe and effective procedures for practitioners. At the time of writing, the current Handbook was the 10th edition (July 2013, updated June 2015) and was available from the Immunise Australia website.

The vaccinations that children in LSAC K cohort should have received were published in the 1997 Handbook (6th edition). The vaccinations that children in the B cohort should have received were published in both the 2000 (7th edition) and 2003 (8th edition) Handbooks. We describe these schedules below. Because older handbooks are not readily accessible online, we present the 1997, 2000 and 2003 schedules in tables and note some changes that occurred prior to the 9th edition. Other very useful resources for information on the years when the LSAC cohorts were aged 7 or younger include the National Centre for Immunisation Research and Surveillance (NCIRS) National Surveillance Reports (2000a, 2002a, 2004a, 2007, 2010) jointly covering the period 1993–2007.

4.1 Vaccination schedule for the K cohort

Table 5 shows the schedule from the 1997 (6th edition) of the Immunisation Handbook. Points to note about this schedule include:

- Haemophilus influenzae type b (Hib) schedule
  - If Hib vaccine HbOC is used, doses are given at 2, 4, 6 and 18 months for a total of four doses.
  - If Hib vaccine PRP-OMP is used, doses are given at 2, 4 and 12 months for a total of three doses.
- In July 1998, a second dose of MMR (measles, mumps, rubella) at 10 to 14 years was rescheduled to 4 to 5 years old (NCIRS, 2010).
- In March 2000, the 5th dose of DTPa and 2nd dose of MMR at 4 to 5 years were rescheduled to 4 years of age (NCIRS, 2010).

Table 5: Australian Standard Vaccination Schedule for the K cohort (born March 1999 to February 2000) from birth to school entry

Age	Disease	Vaccine
2 months	Diphtheria, tetanus, pertussis Poliomyelitis Haemophilus influenzae type b (Hib)	DTPw[1] OPV-Sabin vaccine[2] HbOC[3] or PRP-OMP[4]
4 months	Diphtheria, tetanus, pertussis Poliomyelitis Haemophilus influenzae type b (Hib)	DTPw OPV-Sabin vaccine HbOC[3] or PRP-OMP[4]
6 months	Diphtheria, tetanus, pertussis Poliomyelitis Haemophilus influenzae type b (Hib) (HbOC schedule only)	DTPw OPV-Sabine vaccine HbOC
12 months	Measles, mumps, rubella Haemophilus influenzae type b (Hib) (PRP-OMP schedule only)	MMR[5] PRP-OMP
18 months	Diphtheria, tetanus, pertussis Haemophilus influenzae type b (Hib) (HbOC schedule only)	DTPw HbOC
Prior to school entry— 4 to 5 years[8]	Diphtheria, tetanus, pertussis Poliomyelitis Measles, mumps, rubella	DTPa[6] or DTPw OPV-Sabin vaccine MMR[7]

Notes: [1]Combination diphtheria-tetanus-whole-cell pertussis vaccine. [2]Live attenuated oral polio vaccine. [3]Hib vaccine 'HibTITER'. [4]Hib vaccine 'PedvaxHIB'. [5]Combination measles-mumps-rubella vaccine. [6]Combination diphtheria-tetanus-acellular pertussis vaccine. [7]From July 1998. [8]DTPa and MMR rescheduled to 4 years old from March 2000.

Source: National Health and Medical Research Council. (1997). *The Australian Immunisation Handbook* (6th edition). Canberra: NHMRC.

4.2 Vaccination schedule for the B cohort

The schedule is more complicated for the B cohort because a new edition of the Handbook was published during the year in which the cohort was born. For B cohort children born from March 2003 to August 2003, the relevant schedule is from the 7th edition of the Handbook, published in March 2000. For B cohort children born from September 2003 to February 2004, the schedule from the 8th edition of the Handbook, published in September 2003, is most applicable. The new schedule replaced the old schedule; however, it is likely that, during the transition period, some B cohort children born after September 2003 may have been vaccinated according to the previous schedule. Fortunately, the differences between schedules for core vaccinations are relatively small. Also, the criteria for full immunisation at milestone ages take the variations into account so that the same criteria can be applied to the entire B cohort. These criteria will be discussed in Section 5.

Table 6 shows the 2000 vaccination schedule for B cohort children born between March 2003 and August 2003. The distinctive feature of this schedule is the two different 'paths' for vaccinations due at 2, 4, 6 and 12 months. These state and territory-specific schedules actually differ only in the timing and doses for Hib and HepB components.

- Children in path 1 states or territories receive:
  - Hib vaccine PRP-OMP at 2, 4 and 12 months, for a total of three doses
  - HepB vaccine at birth and in combination with DTPa at 2, 4 and 6 months for a total of four doses.
- Children in path 2 states or territories receive:
  - combined Hib (PRP-OMP)-HepB vaccine at 2, 4 and 12 months for a total of three doses
  - HepB vaccine at birth and in combination with Hib at 2, 4 and 12 months for a total of four doses.

If necessary, the two Hib/HepB paths may be interchanged, for example, if a child moves interstate.

Table 6: Australian Standard Vaccination Schedule for the B cohort (born March 2003 to August 2003) from birth to 4 years old

All States and Territories				
Age	**Disease**		**Vaccine**	
Birth	Hepatitis B		HepB[1]	
	Path 1 (QLD, NSW, SA, NT)		Path 2 (VIC, WA, TAS)	
	Disease	Vaccine	Disease	Vaccine
2 months	Diphtheria, tetanus, pertussis, hepatitis B	DTPa-HepB[2]	Diphtheria, tetanus, pertussis	DTPa[3]
	Haemophilus influenzae type b (Hib)	PRP-OMP[4]	Haemophilus influenzae type b, hepatitis B	Hib (PRP-OMP)-HepB[5]
	Poliomyelitis	OPV-Sabine vaccine[6]	Poliomyelitis	OPV-Sabine vaccine
4 months	Diphtheria, tetanus, pertussis, hepatitis B	DTPa-HepB	Diphtheria, tetanus, pertussis	DTPa
	Haemophilus influenzae type b (Hib)	PRP-OMP	Haemophilus influenzae type b, hepatitis B	Hib (PRP-OMP)-HepB
	Poliomyelitis	OPV-Sabine vaccine	Poliomyelitis	OPV-Sabine vaccine
6 months	Diphtheria, tetanus, pertussis, hepatitis B	DTPa-HepB	Diphtheria, tetanus, pertussis	DTPa
	Poliomyelitis	OPV-Sabine vaccine	Poliomyelitis	OPV-Sabine vaccine
12 months	Measles, mumps, rubella	MMR[7]	Measles, mumps, rubella	MMR
	Haemophilus influenzae type b (Hib)	PRP-OMP	Haemophilus influenzae type b, hepatitis B	Hib (PRP-OMP)-HepB
All States and Territories				
	Disease		**Vaccine**	
18 months	Diphtheria, tetanus, pertussis		DTPa	
48 months (4 years)	Diphtheria, tetanus, pertussis		DTPa	
	Measles, mumps, rubella		MMR	
	Poliomyelitis		OPV-Sabine vaccine	

Notes: [1]Monovalent HepB vaccine. [2]Combination diphtheria-tetanus-acellular pertussis-HepB vaccine. [3]Combination diphtheria-tetanus-acellular pertussis vaccine. [4]Hib vaccine 'PedvaxHIB'. [5]Combination Hib-HepB vaccine. [6]Live attenuated oral polio vaccine. [7]Combination measles-mumps-rubella vaccine.

Source: National Health and Medical Research Council. (2000). *The Australian Immunisation Handbook* (7th edition). Canberra: NHMRC.

Table 7 shows the schedule introduced in September 2003, most relevant for B cohort children born between September 2003 and February 2004. This schedule also features a varying Hib/HepB schedule, now somewhat complicated by different recommendations for Aboriginal and Torres Strait Islander children:

- Aboriginal and Torres Strait Islander children receive Hib vaccine PRP-OMP at 2, 4 and 12 months for a total of three doses.
- Non-Indigenous children can receive either:
  - Hib vaccine PRP-OMP at 2, 4 and 12 months for a total of three doses; or
  - Hib PRP-T or HbOC vaccines at 2, 4, 6 and 12 months for a total of four doses.

Mixing Hib schedules is not recommended, and infants who started with PRP-OMP should continue with it.

Other features of this schedule to note:

- Pneumococcal schedule:
  - In 2003, pneumococcal vaccine was only funded (accessible for free) for Aboriginal and Torres Strait Islander children up to 2 years, Aboriginal children in central Australia up to 5 years, non-Indigenous children in central Australia aged up to 2 years, and all children under 5 years with medical risk factors that predisposed them to high rates or high severity of pneumococcal infection.
  - Since January 2005, pneumococcal vaccine (7vPCV) has been funded for all infants, with a catch-up program for children aged less than 2 years (NCIRS, 2010).
- Meningococcal C schedule:
  - In January 2003, the meningococcal C conjugate vaccine (MenCCV) was funded for all children at 12 months of age.
  - A catch-up program for all children aged 1 to 19 years commenced in January 2003 and ceased in June 2008 (NCIRS, 2010).
- Varicella-Zoster (chickenpox-shingles) schedule:
  - In 2003, the varicella vaccine was recommended, but not funded, at 18 months.
  - In November 2005, varicella vaccination was funded for all children with a single dose at 18 months. All of the B cohort children were 18 months old before November 2005; therefore, no B cohort children were eligible to receive this vaccination, although some may have received it late or outside the regular schedule.

Table 7: Australian Standard Vaccination Schedule for the B cohort (born September 2003 to February 2004) from birth to 4 years old

Age	Disease	Vaccine
Birth	Hepatitis B	HepB[1]
2 months	Diphtheria, tetanus, pertussis	DTPa[2]
	Haemophilus influenzae type b (Hib)	PRP-T[3] or HbOC[4] or PRP-OMP[5]
	Poliomyelitis	IPV[6]
	Hepatitis B	HepB[1] or DTPa-HepB[7] or Hib (PRP-OMP)-HepB[8]
	Pneumococcal disease	7cPCV[9]
4 months	Diphtheria, tetanus, pertussis	DTPa
	Haemophilus influenzae type b (Hib)	PRP-T or HbOC or PRP-OMP
	Poliomyelitis	IPV
	Hepatitis B	HepB or DTPa-HepB or Hib (PRP-OMP)-HepB
	Pneumococcal disease	7cPCV
6 months	Diphtheria, tetanus, pertussis	DTPa
	Haemophilus influenzae type b (Hib)	PRP-T or HbOC
	Poliomyelitis	IPV
	Hepatitis B	HepB or DTPa-HepB
	Pneumococcal disease	7cPCV
12 months	Measles, mumps, rubella	MMR
	Haemophilus influenzae type b (Hib)	PRP-T or HbOC or PRP-OMP
	Hepatitis B	Hib (PRP-OMP)-HepB
	Meningococcal C	MenCCV[10]
18 months	Varicella-zoster virus	VZV[11]
	Pneumococcal disease	23vPPV[12]
48 months (4 years)	Diphtheria, tetanus, pertussis	DTPa
	Poliomyelitis	IPV
	Measles, mumps, rubella	MMR

Notes: [1]Monovalent HepB vaccine. [2]Combination diphtheria-tetanus-acellular pertussis vaccine. [3]Hib vaccines 'ActHIB' or 'Hiberix'. [4]Hib vaccine 'HibTITER'. [5]Hib vaccine 'PedvaxHIB'. [6]Inactivated poliomyelitis vaccine. [7]Combination DTPa and HepB vaccine. [8]Combination HepB and Hib vaccine. [9]7-valent pneumococcal conjugate vaccine (Indigenous children only). [10]Meningococcal C conjugate vaccine. [11]Varicella-zoster vaccine. None of the B cohort children were eligible to receive this vaccine. [12]23-valent pneumococcal polysaccharide vaccine (Indigenous children only).

Source: National Health and Medical Research Council. (2003). *The Australian Immunisation Handbook* (8th edition). Canberra: NHMRC.

5 Assessing immunisation status at each milestone age in LSAC–ACIR data.

In Australia, the immunisation status of all children on the ACIR is reported at three **milestone ages,** including 12 months, 24 months and 60 or 72 months (O'Brien, Sam, & Mead, 1998; Hull, McIntyre, Heath, & Sayer, 1999). The oldest reporting age dropped from 72 months to 60 months in 2008, affecting all children born from 1 January 2003. This means that all the K cohort children were assessed at the milestone age of 72 months, and all the B cohort children at the milestone age of 60 months. A child is considered to be fully immunised at each milestone age if he or she has completed all the types and doses of vaccines recommended on the schedule that are assessed at that milestone.

The following points are important to understanding how immunisation status is assessed at milestone ages:

1. **There is a distinction between *scheduled age* and *milestone age*.** The **scheduled age** is the age at which a specific vaccine dose is due on the relevant schedule. The **milestone age** is the age at which these are assessed. For example, vaccines scheduled at 2, 4 and 6 months are assessed at the milestone age of 12 months.
2. **A child is considered to have received a scheduled vaccine if the final dose is recorded on or before his or her birthday at the relevant milestone age. Importantly, if full immunisation at that age requires a sequence of doses, a child is assumed to have received all of them, as long as the last vaccine due in the sequence is recorded on the ACIR.** This is true even if the earlier doses are not recorded. For example, there are three doses of DTPa due at 2, 4, and 6 months. A child born on 1 April 2003 would be considered to have received the DTPa vaccine for the 12 month milestone age if the third dose was recorded in the ACIR on or before 1 April 2004. This 'third dose' assumption has been shown to be valid (Hull & McIntyre, 2000b; Hull, Lawrence, MacIntyre, & McIntyre, 2003a).
3. **Immunisation status at each milestone age is independent from other milestone ages.** This means that each milestone is assessed as its own event, without taking into account the status of the child at the previous milestone. For example, as long as a K cohort child has received the doses that are assessed at 72 months (see Table 8), he or she is fully immunised even if he or she was not fully immunised at 24 months.

In the K cohort, the milestone ages were:

- 12 months (for vaccinations scheduled at 2, 4 and 6 months)
- 24 months (for vaccinations scheduled at 12 and 18 months, and some at 6 months)
- 72 months (for vaccinations scheduled at 48 months).

Table 8 shows the vaccines and dose numbers required for full immunisation at each of these milestone ages in the K cohort.

Table 8: Criteria for full immunisation at 12, 24 and 72 months in the K cohort

Milestone age	Vaccine	Assessed doses	Scheduled age
12 months	DTPa	3rd dose	6 months
	Polio	3rd dose	6 months
	Hib	Either (3rd dose of HbOC or PRP-T or PRPD or IFHX or PDCL[1] or PLCL[1]) or (2nd or 3rd dose of PRP-OMP or CMX or GNHIB)	6 months
24 months	DTPa	4th dose	18 months
	Polio	3rd dose	6 months
	Hib	Either (4th dose of HbOC or PRP-T or PRPD or HBX or PDCL[1] or PLCL[1]) or (3rd or 4th dose of PRP-OMP or CMX or IFHX or GNHIB)	12 or 18 months
	MMR	1st dose	12 months
72 months	DTPa	5th dose	48 months
	Polio	4th dose	48 months
	MMR	2nd dose	48 months

Note: [1]PDCL and PLCL do not appear in the LSAC–ACIR linked data

Source: O'Brien et al. (1998); NCIRS (2000b—first coverage report for 12-month milestone in K cohort); NCIRS (2001c—first coverage report for 24-month milestone in K cohort); NCIRS (2005c—first coverage report for 72-month milestone in K cohort); Chin, Crawford, Rowles, & Buttery (2012). Hib algorithms courtesy of Brynley Hull (NCIRS).

- In the B cohort, the milestone ages were:
  - 12 months (for vaccinations scheduled at 2, 4 and 6 months)
  - 24 months (for vaccinations scheduled at 12 months, and some at 6 months)
  - 60 months (for vaccinations due at 48 months).

Table 9 shows the vaccines and dose numbers required for full immunisation at each of these milestone ages in the B cohort. Note:

- Although the B cohort schedule included Meningococcal C vaccines, these were not included in the coverage estimates for the period that the B cohort were reported nationally.
- The birth dose of HepB is not included in coverage estimates.

Table 9: Criteria for full immunisation at 12, 24 and 60 months in the B cohort

Milestone age	Vaccine	Assessed doses	Scheduled age
12 months	DTPa	3rd dose	6 months
	Polio	3rd dose	6 months
	Hib	Either (3rd dose of HbOC or PRP-T or PRPD or IFHX or PDCL[1] or PLCL[1]) or (2nd or 3rd dose of PRP-OMP or CMX or GNHIB)	6 months
	HepB	Either (3rd dose of IFXB or HBV or IFHX or GNHEP or IFPA[2]) or (2nd or 3rd dose of ENGP or CMX or HBVP)	6 months
24 months	DTPa	3rd dose	6 months
	Polio	3rd dose	6 months
	Hib	Either (4th dose of HbOC or PRP-T or PRPD or HBX or PDCL[1] or PLCL[1]) or (3rd or 4th dose of PRP-OMP or CMX or IFHX or GNHIB)	6 or 12 months
	HepB	3rd dose of IFXB or ENGP or CMX or HBV or IFHX or GNHEP or IFPA[2]	12 months
	MMR	1st dose	12 months
60 months	DTPa	4th dose	48 months
	Polio	4th dose	48 months
	MMR	2nd dose	48 months

Notes: [1]PDCL and PLCL do not appear in the LSAC–ACIR linked data. [2]IFPA does not appear in the LSAC–ACIR linked data.

Source: O'Brien et al. (1998); NCIRS (2004b—first coverage report for 12-month milestone in B cohort); NCIRS (2005c—first coverage report for 24-month milestone in B cohort); NCIRS (2009a—first correct coverage report for 60-month milestone in B cohort); Chin et al. (2012). Hib and HepB algorithms courtesy of Brynley Hull (NCIRS).

From these tables, it is clear that the ages at which vaccines are scheduled are much earlier than the milestone age at which they are assessed. Specifically:

- All the vaccines that are required to be fully immunised at 12 months are due by 6 months.
- All the vaccines that are required to be fully immunised at 24 months are due by 12 months.
- All the vaccines that are required to be fully immunised at 60 or 72 months are due by 48 months.

A child would still be considered immunised for a particular antigen if he or she had received the final dose by the milestone age, even if that date was after the scheduled age. This means that even children who are several months delayed in receiving scheduled vaccinations have usually received them by the milestone age.

6 The LSAC–ACIR data file

As for other linked data, ACIR data are provided in a separate file to the LSAC data collected directly from respondents. The data consist of 142,461 rows. Each row contains information about an ACIR episode (single vaccination) for one LSAC child. Each column contains one variable. The linked data contain four ACIR-provided variables and 28 LSAC-derived variables. The ACIR-provided variables are summarised in Table 10, and the LSAC-derived variables in Table 11. We describe all the variables in greater detail below.

Users should note that the data are in 'long' format. Each vaccination episode is recorded in a new row of data, so each child (*hicid*) has multiple rows. The data are sorted by *hicid*. Records (rows) within each child are sorted by immunisation date (*dateimm*), beginning with the earliest date.

Table 10: ACIR-provided variables in the LSAC–ACIR dataset

Variable name	Description	Format	Unique values
ACIR-provided variables			
hicid	This is the child id used in all LSAC data files.	Numeric	9,324
daterec	The date that the vaccination encounter was added to the ACIR.	Date, e.g., 21 May 2010	3,128
vacccode	ACIR vaccination code.	String, e.g., PRP-OMP3	198
dateimm	The date that the vaccination was received.	Date, e.g., 21 May 2010	3,397
provid	An unique id for the provider who administered the vaccine	Numeric	10,297

Further details for ACIR-provided variables

daterec: The date that vaccinations were recorded on the ACIR was usually shortly after the episode, but, in some cases, the lag between episode and recording was much longer. In the K cohort, the average lag is 51 days (standard deviation = 194 days). The lag ranges from 0 days to 4,427 days (about 12 years), with 94 per cent of episodes added to the ACIR within 90 days. In the B cohort, the average lag is 31 days (standard deviation = 110 days). The lag ranges from 0 days to 3,259 days (about 9 years), with 95 per cent of episodes added to the ACIR within 90 days. Lags are probably longer in the K cohort because these participants were registered only a couple of years after the ACIR was established, and early problems with the transmission of data to the ACIR have been documented (Hull et al., 1999; Hull & McIntyre, 2000a; O'Brien et al., 1998).

vacccode: Each vaccination encounter is reported to the ACIR with a single code to identify the type of vaccine and the dose received. The first part of a code is letters, identifying the vaccine, and the last part is usually a number, indicating the dose. For example, the code 'IPV3' means that the vaccine received was the 3rd dose of the inactivated polio vaccine. The 'vacccode' variable contains all this information, but it is time consuming to code these into antigen-dose indicators. This has already been done, and the derived variables are available as described in Table 11. For users who require extra detail, the vaccine codes are described in detail in Appendix C.

provid: Medicare maintains a database that identifies health providers. The variable 'provid' in the ACIR data is a scrambled, or de-identified, version of this provider ID for the provider where a vaccination episode was administered. The scrambled provider code is dataset wide, meaning that different children have had vaccines administered by the same provider. It is not possible to derive any information about the location or type of provider from the code. For users of the LSAC–ACIR linked data, provider code may be used to establish how many vaccines a child received from a particular provider, or how many LSAC children received vaccines from a particular provider.

Table 11: LSAC-derived variables in the LSAC–ACIR dataset

Variable name	Description	
	Immunisation status indicators	
fi12m	Fully immunised at 12 months	
fi24m	Fully immunised at 24 months	
fi60m	Fully immunised at 60 months	
fi72m	Fully immunised at 72 months	
	Antigen-dose indicators	
	Antigen	**Dose numbers (*n*)[1]**
dtpa*n*[1]	DTPa (diphtheria, tetanus, acellular pertussis)	1–5
ifxb*n*	IFXB (HepB)	1–5
gnhep*n*	GNHEP (HepB)	1–3
engp*n*	ENGP (HepB)	1–4
cmx*n*	CMX (HepB)	1–4
hbvp*n*	HBVP (HepB)	1–4
hbv*n*	HBV (HepB)	1–4
ifhx*n*	IFHX (HepB)	1–4
hboc*n*	HbOC (Hib)	1–5
prpomp*n*	PRP-OMP (Hib)	1–5
prpt*n*	PRP-T (Hib)	1–4
hbx*n*	HBX (Hib)	1–4
gnhib*n*	GNHIB (Hib)	1–4
prpd*n*	PRPD (Hib)	2, 4
pol*n*	Polio	1–5
mmr*n*	MMR (measles, mumps, rubella)	1–3
mnc*n*	Meningococcal C	1–4
pn7v*n*	Pneumococcal 7vPCV	1–5
pn23v*n*	Pneumococcal 23vPPV	1–2
hepa*n*	Hepatitis A	1–3
var*n*	Varicella-zoster	1–2
flu*n*	Influenza	1–7
je*n*	Japanese encephalitis	1–2
tb*	Tuberculosis	1–2

Note: [1]*n* denotes the dose number for each antigen.

Further details for LSAC-derived variables

All the LSAC-derived variables take values of 0 and 1 only. There are no missing values.

Immunisation status indicators: fi12m, fi24m, fi60m and fi72m

These variables indicate whether a child was fully immunised according to the relevant schedule at the milestone ages of 12 months, 24 months, 60 months and 72 months. The criteria for defining full immunisation status were described in detail in Section 5. To be comparable to previously reported national estimates, the 72-month indicator should be used for the K cohort and the 60-month indicator for the B cohort.

Antigen-dose indicators

The antigen-dose indicators were derived from the 'vacccode' variable, which contains vaccinations codes identifying the type of vaccine and the dose received. There are many different types of vaccine that have been scheduled at different times between 1999 and 2008, the years during which the K and B cohorts were receiving childhood immunisations. Sometimes the same antigen is contained in vaccines with different codes. Sometimes vaccines are multivalent, meaning that they contain more than one antigen. Refer to Table C1 in Appendix C for details. Often, however, data users may be interested in antigens, not individual vaccines. For example, a researcher might want to know if children have received a polio vaccination by a particular age.

Therefore, we have derived variables that, for each vaccination episode, are coded 1 if that antigen was received in the episode, and 0 otherwise. Because most vaccines have multiple doses, the first part of the variable identifies the antigen, and the numeric suffix indicates the dose number. For example, if an episode was a vaccine that contained the first dose of polio, then the variable 'pol1' would = 1, and most of the other antigen-dose indicators in Table 7 would = 0.

When using the derived antigen-indicators, the following points should be noted:

1. DTPa is actually three antigens (diphtheria, tetanus and acellular pertussis). The derived variables 'dtpa*n*' are coded 0 if only a dose of CDT (diphtheria-tetanus) or a monovalent component of DTPa has been received. For more information on coding DTPa, refer to Section 7.1.
2. MMR is also three antigens (measles, mumps and rubella). The derived variables 'mmr*n*' are coded 0 if only a monovalent dose of a component of MMR has been received. For more information on coding MMR, refer to Section 7.1.
3. Vaccines containing Hib and HepB are not aggregated to the level of antigen because of complexities in scheduling for these vaccines. In Section 7.1 and 7.3, we describe how to determine whether children are fully immunised for Hib and HepB.

7 Using ACIR data to assess immunisation status and vaccine timing

The criteria for determining full immunisation involve assessing whether the required number of doses for particular vaccines have been received by a cut-off age. Getting the data to the point where this is possible involves substantial reorganisation of the ACIR-provided variables. If data users are mostly interested in the 12, 24 and 60/72-month milestones described above, the derived variables *fi12m*, *fi24m*, *fi60m* and *fi72m* can be used with little further reorganisation. However, if there is a need to examine individual vaccines, individual doses, or aspects of vaccine timing, the guidelines in this section are relevant.

While the focus in this section is on immunisation coverage at the three milestone ages, these issues and recommendations are general. They are relevant whenever a researcher is interested in which vaccines a child has received, and when.

Defining full immunisation involves the following four broad steps:

1. Create variables that identify the required vaccine types as they are listed in the relevant vaccination schedule (Tables 7, 8 and 9).
2. Calculate the timing of doses—determine the date that each dose of each vaccine type was received and calculate a cut-off date for each child at each of the milestone ages.
3. Determine whether the final dose of the required number for each vaccine type was received by the relevant cut-off date.
4. Apply the full-immunisation criteria (which differ for the B and K cohorts) at each milestone age.

There are some considerations to each of these steps, discussed in detail below.

7.1 Creating variables that identify vaccine types

Comparison of the vaccination schedules shown in Tables 7, 8 and 9 with the vaccine codes shown in the Appendix will reveal, firstly, that immunisation against one disease may be contained in several different vaccines, which have different vaccine codes. For example, Hib antigens are contained in vaccines with the codes CMX, GNHIB, HbOC, HBX, IFHX, PRPD, PRP-OMP and PRP-T . Secondly, many vaccines are multivalent, meaning that they contain more than one vaccine. For example, Infanrix Hexa (IFHX) contains vaccines for diphtheria, tetanus, acellular pertussis, inactivated polio, hib and hepatitis B.

Therefore, it is necessary to create variables that indicate whether a child has been immunised against a particular disease by considering information from multiple different vaccine codes. **These variables have been derived for the LSAC–ACIR data and are listed in Table 11.** For example, the variable called '*pol1*' is coded 1 if any of the vaccination codes that include a first dose of polio were present in the episode (i.e., GNPOL1, IFHX1, IFIP1, IPV1, OPV1, QDCL1) and coded 0 otherwise.

If data users wish to derive their own or additional vaccine-dose indicators, the information needed to match vaccine code to diseases can be derived from the information in Appendix C. In addition, however, the following recommendations must be considered.

Recommendation for data users #2

DTPa and MMR should be assessed as single episodes, even though they contain multiple antigens. This is clear from the schedules presented in Tables 3, 4 and 5. Although monovalent vaccines do exist for these diseases (e.g., generic measles, GNMEA), the monovalent versions are generally not available in Australia (NHMRC, 2013). There are a very few observations in the LSAC–ACIR data where monovalent vaccines are recorded (e.g., generic diphtheria, GNDIP) and a few instances of CDT. In order for these children to be immunised according to the schedule, however, they must have received all the doses of the all the components of DTPa and MMR. **We recommend that data users carefully assess whether this is the case for children who have received monovalent components of DTPa or MMR.**

Recommendation for data users #3

Hib and HepB: Determining immunisation against Hib is complicated, because there have been distinct eras of implementation of the vaccines for this disease for Australian children (Wang, Deeks, Glasswell, & McIntyre, 2008). At times, the recommendations for timing and the required number of doses have differed, depending on region of Australia and the type of Hib vaccine used (i.e., PRP-OMP, PRP-T, HbOC or PRP-D; refer to Tables 3, 4 and 5). HepB is complex by association because it may often be administered in a multivalent vaccine with Hib. Therefore, in preparing data, **we recommend coding information about receipt of Hib and HepB vaccines at the level of the vaccine name, and not aggregating to the disease level until later in the analysis.** This is particularly important if full immunisation at milestone ages must be defined, as we discuss in Section 7.3.

7.2 Calculating the timing of doses

Data users may wish to determine the precise ages at which children received vaccines, to calculate the time elapsed between doses or to examine seasonal variations in the timing of vaccines. The information needed for all these questions can be derived from the variable '*dateimm*', which is the date of a vaccination episode.

Sometimes it will be necessary to use the study child's date of birth, for example, to calculate whether a certain dose was received by a cut-off age. There are two issues to consider when preparing data using dates of birth and dates of vaccination:

Date of birth versus month of birth

Dates of birth are provided in the main LSAC data files. However, in the general release data, for confidentiality reasons, date of birth is provided as month of birth. All dates in the month were changed to the first of that month. For instance, the date of birth for a child born on 13 July 2003 would be 1 July 2003. This leads to some loss of accuracy for variables that assess whether a vaccination dose was received by a particular age. Consider the hypothetical child born on 13 July 2003. The 12-month cut-off date for receiving the 3rd dose of DTPa is 13 July 2004. The dose was actually received on 6 July 2004. Therefore, this child did receive the dose before the cut-off date. However, when the confidentialised month of birth is used, date of birth becomes 1 July, 2003 and the 12-month cut-off becomes 1 July 2004. Now, the child would not be calculated as having received the dose before the cut-off date.

This loss of accuracy is fairly small when defining cut-off dates of 12 months, 24 months, and 60 or 72 months. This is because most of the immunisations assessed at these cut-offs are actually due sometime earlier, and most children have already received them. Overall, using month of birth underestimates coverage at the milestone ages by 0.5 per cent to 1.0 per cent; for example:

- In the B cohort, 24 children (0.5 per cent) were fully immunised at 12 months using date of birth, but were not fully immunised at 12 months using month of birth. This means that month of birth underestimates full immunisation by 0.5 per cent.
- At 24 months, there were 28 children who were fully immunised at 12 months using date of birth, but not fully immunised using month of birth, again accounting for an underestimation of 0.5 per cent in full immunisation using month of birth.
- At 60 months, there were 48 children who were fully immunised using date of birth, but not fully immunised using month of birth, leading to a 1.0 per cent underestimation of full immunisation using month of birth.

These differences in coverage at the milestone ages are quite small and may not be important for some data users. **However, the loss of accuracy might be a bigger problem for data users interested in assessing whether doses were received at scheduled ages**, for example, whether the third dose of DTPa was received on or before the 6-month age. In the B cohort, allowing one month for normal variation in timing, 891 children had received the third dose of DTPa by 7 months using date of birth, but had not received the dose by 7 months using month of birth. This is an underestimation of 18.6 per cent in the timeliness of the 3rd dose of DTPa when using month of birth to calculate.

Recommendation for data users #4

Data users should consider how much accurate estimates of children's age when they received vaccines matter for their research question. One way of getting around the problem might be to also code the dates of immunisation episodes in '*dateimm*' to be the first day of the month. This would avoid misclassifying children who received immunisations in the same month as their cut-off date.

Leap years

When calculating cut-off dates and assessing timing of immunisations, **data users should remember that both 2000 (K cohort) and 2004 (B cohort) were leap years**. The youngest children in both cohorts were born on 29 February. For others, the date for, say '7 months old', is 29 February in one of these years.

7.3 Determine whether final doses were received by each child's milestone date

As described in Section 5, full immunisation at each milestone requires that the final dose of each scheduled vaccine be received by each child's milestone date. The required doses were outlined in Tables 8 (K cohort) and 9 (B cohort). When there is a sequence of doses on the schedule (for example, DTPa at 2, 4 and 6 months), a child is considered fully immunised if the final dose has been recorded by the milestone age, even if earlier doses are not recorded.

To determine whether the final dose of Hib and HepB were received, use the criteria outlined in Tables 8 and 9. For example, to determine whether K cohort children were immunised against Hib by 12 months, use the LSAC-derived variables and apply the following algorithm:

A child is immunised for Hib if, by 12 months, he or she has received = (hboc3 or prpt3 or prpd3 or ifhx3 or pdcl3 or plcl3) OR ((prpomp2 or prpomp3) or (cmx2 or cmx3) or (gnhib2 or gnhib3)).

Apply the full immunisation criteria for each milestone age

Use the criteria in Tables 8 and 9 to determine whether or not each child received all the final doses.

8 Immunisation coverage in LSAC compared to national estimates

Since 1998, coverage estimates have been reported about quarterly in *Communicable Diseases Intelligence* (CDI), published by the Office of Health Protection, Department of Health. The 24-month milestone age was reported from October 1998 (NCIRS, 1998). The 72-month milestone age was reported from late 2002 (NCIRS, 2002b), but was shifted down to 60 months from the beginning of 2008 (NCIRS, 2008). Thus, vaccines scheduled at 4 years old were reported at 72 months for the entire K cohort, and at 60 months for the entire B cohort.

For children in the B and K cohorts, coverage was reported for full immunisation according to the criteria outlined in Tables 9 and 10, as well as for the dose of each individual immunisation that is part of the full immunisation criteria.

National immunisation coverage has been reported from national ACIR data using the cohort method, which is widely used internationally. 'Cohorts' are three-month birth groups. The first report of this methodology using the ACIR was reported by O'Brien et al. (1998) for the cohort born 1 January 1996 to 31 March 1996. For the national estimates, children's immunisation status was assessed three months after the relevant milestone age of the youngest children in the cohort. This was to allow some time for late reporting of episodes to ACIR. For example, children born 1 January to 31 March 2003 were 12 months old 1 January to 31 March 2004. The assessment date for the 12-month coverage for this cohort was 30 June 2004. Only immunisations recorded up to or on the child's first birthday were considered. The 3-month period was to allow records to be transmitted to ACIR.

For children in the K cohort, national coverage estimates were published in *CDI* issues:

- Coverage at 12 months: 2000 (volume 24, issues 7 and 10), 2001 (volume 25 issues 1 and 2)
- Coverage at 24 months: 2001 (volume 25, issue 4), 2002 (volume 26, issues 1, 2 and 3)
- Coverage at 72 months: 2005 (volume 29, issues 3 and 4), 2006 (volume 30, issues 1, 2 and 3).

For children in the B cohort, national coverage estimates were published in *CDI* issues:

- Coverage at 12 months: 2004 (volume 28, issues 3 and 4), 2005 (volume 29 issues 1, 2 and 3)
- Coverage at 24 months: 2005 (volume 29, issues 3 and 4), 2006 (volume 30 issues 1, 2 and 3)
- Coverage at 60 months: 2009 (volume 33, issues 2 and 3)[3]
  - For the birth cohorts January to March 2003, April to June 2003 and July to September 2003, 60 month estimates were incorrectly made at 66 months instead of 60 months. Correct estimates for these quarters were published in an erratum in CDI 33, issue 2 (2009a).

8.1 LSAC–ACIR and national ACIR coverage estimates

In this section, we compare immunisation coverage calculated from the LSAC cohorts to the national estimates previously reported for children of these ages.

LSAC estimates are calculated using population weights that take account of the survey design and produce valid estimates for the population. Coverage percentages should be interpreted with the 95 per cent confidence intervals.

The LSAC cohorts were born in 12-month periods between March 1999 and February 2000 (K cohort) and March 2003 and February 2004 (B cohort). National estimates, however, were reported in 3-month cohorts starting from January. We present national estimates averaged across cohorts born between January in the first year and March in the following year. For instance, LSAC estimates for the B cohort born in the

[3] In 2008, coverage reports changed from 72 months to 60 months for children born from 1 January 2003. The 60 month coverage estimates for the first of these cohorts (born 1 January to 30 March 2003), were reported in *Communicable Diseases Intelligence*, 32(3), 2008. These children were assessed at 30 June 2008. In the first year after this change, coverage rates were lower at 60 months than they had been at 72 months, reflecting delays in adapting to the new milestone age. However, coverage estimates improved throughout 2009 (Hull, Dey, Mahajan, Menzies, & McIntyre, 2011).

12-month period between March 2003 and February 2004 are compared with national estimates for cohorts born in the 15-month period between January 2003 and March 2004.

Tables 12, 13 and 14 show LSAC–ACIR and national ACIR estimates for the K cohort at 12, 24 and 72 months respectively. Tables 15, 16 and 17 show LSAC–ACIR and national ACIR estimates for the B cohort at 12, 24 and 60 months respectively. Note that for the B cohort, the 60-month estimates are lower than those at 12 and 24 months because the reporting age changed from 72 months to 60 months from 1 January 2003 (see Footnote 3).

Table 12: LSAC–ACIR and national ACIR coverage estimates at 12 months for the K cohort

	LSAC K cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000[1]	
Vaccinations assessed at 12 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—3rd dose	92.7	91.8–93.5	91.2	89.8–91.8
Polio—3rd dose	92.7	91.8–93.5	91.3	89.8–91.8
Hib—2nd or 3rd dose	92.6	91.7–93.5	92.9	89.3–94.6
Fully immunised	**92.1**	**91.2–93.0**	**90.8**	**88.4–91.5**

Note: [1]12-month data for the cohort born January to March 2000 were not published in CDI; coverage estimates provided by Brynley Hull, NCIRS.

Source: Quarterly national estimates for the period can be found in NCIRS (2000b, 2000c, 2001a, 2001b).

Table 13: LSAC–ACIR and national ACIR coverage estimates at 24 months for the K cohort

	LSAC K cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000[1]	
Vaccinations assessed at 24 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—4th dose	92.3	91.4–93.1	90.0	89.5–90.3
Polio—3rd dose	95.3	94.6–96.0	94.1	93.9–94.4
Hib—3rd or 4th dose	92.1	91.2–93.0	95.2	95.0–95.4
MMR—1st dose	94.9	94.1–95.6	93.1	92.8–93.4
Fully immunised	**89.9**	**88.9–90.9**	**87.5**	**86.6–88.1**

Note: [1]24-month data for the cohort born January to March 1999 were not published in CDI; coverage estimates provided by Brynley Hull, NCIRS.

Source: Quarterly national estimates for the period can be found in NCIRS (2001c, 2002b, 2002c, 2002d).

Table 14: LSAC–ACIR and national ACIR coverage estimates at 72 months for the K cohort

	LSAC K cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000	
Vaccinations assessed at 72 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—5th dose	89.5	88.4–90.4	84.8	84.4–85.1
Polio—4th dose	89.6	88.5–90.6	84.7	83.8–85.2
MMR—2nd dose	89.5	88.5–90.5	84.9	84.4–85.2
Fully immunised	**88.6**	**87.6–89.6**	**83.5**	**82.7–84.0**

Source: Quarterly national estimates for the period can be found in NCIRS (2005a, 2005b, 2006a, 2006b, 2006c).

Table 15: LSAC–ACIR and national ACIR coverage estimates at 12 months for the B cohort

	LSAC B cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000	
Vaccinations assessed at 12 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—3rd dose	94.6	93.8–95.2	92.4	92.2–92.7
Polio—3rd dose	94.6	93.8–95.3	92.3	92.0–92.6
Hib—2nd or 3rd dose	96.4	95.8–96.9	94.6	94.3–94.8
HepB—2nd or 3rd dose	95.1	94.4–95.5	94.8	94.6–95.0
Fully immunised	**93.5**	**92.7–94.3**	**91.0**	**90.7–91.3**

Source: Quarterly national estimates for the period can be found in NCIRS (2004b, 2004c, 2005a, 2005b, 2005c).

Table 16: LSAC–ACIR and national ACIR coverage estimates at 24 months for the B cohort

	LSAC B cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000	
Vaccinations assessed at 24 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—3rd dose	96.8	96.2–97.3	95.2	95.0–95.3
Polio—3rd dose	96.8	96.2–97.3	95.1	94.9–95.2
Hib—3rd or 4th dose	96.1	95.4–96.6	93.5	93.3–93.8
HepB—2nd or 3rd dose	96.3	95.7–96.9	93.7	93.4–94.0
MMR—1st dose	96.2	95.6–96.8	95.9	95.7–95.9
Fully immunised	**95.4**	**94.7–96.0**	**92.1**	**91.8–92.4**

Source: Quarterly national estimates for the period can be found in NCIRS (2005c, 2005d, 2006a, 2006b, 2006c).

Table 17: LSAC–ACIR and national ACIR coverage estimates at 60 months for the B cohort

	LSAC B cohort, born Mar 1999–Feb 2000		Children in ACIR, born Jan 1999–Mar 2000	
Vaccinations assessed at 60 months	**%**	**95% CI**	**Average % across birth cohorts**	**Range in % across birth cohorts**
DTPa—4th or 5th dose	81.8	80.5–83.0	81.2	79.6–83.2
Polio—4th dose	81.7	80.4–82.9	81.0	79.4–83.1
MMR—2nd dose	81.6	80.3–82.9	80.8	79.2–82.9
Fully immunised	**81.4**	**80.1–82.6**	**80.3**	**78.8–82.4**

Source: Quarterly national estimates for the period can be found in NCIRS (2009a, 2009b).

Overall, it can be seen that the LSAC–ACIR estimates are slightly higher than the national ACIR estimates. Across ages, the B cohort estimates are 1.5 percentage points higher than the national estimates, and the K cohort estimates are 2.2 percentage points higher. There are a number of reasons, outlined below, why the LSAC estimates might be higher than the national estimates.

Issues relating to characteristics of children not matched:

1. Factors that decreased the likelihood of LSAC cases being matched included lower parental income, a family being dependent on government benefits, families living in more disadvantaged areas and families living in remote areas. These indicators of disadvantage have often been linked with incomplete immunisation in the literature (Haynes & Stone, 2004; Falagas & Zarkadoulia, 2008), suggesting that coverage may have been lower in those not included in our sample.
2. In the B cohort, children of parents with more negative attitudes towards childhood immunisation were less likely to be matched, suggesting that these children may have had lower rates of full immunisation.
3. In both cohorts, children of parents who did not speak English at home were less likely to be matched. Non-English-speaking background has been associated with incomplete immunisation in some studies (Falagas & Zarkadoulia, 2008), and, in Australia, some ethnic groups are at elevated risk of incomplete immunisation (Najjar et al., 2014). Also, some children of non-English-speaking parents may have moved from overseas, and previous immunisations may not have been added to the ACIR.

Therefore, the characteristics of the 7 per cent of the LSAC children not matched suggest that rates of full immunisation may have been lower in this group. The LSAC survey weights cannot correct for this, because they are designed to compensate for differences between the final sample and the national population (Soloff, Lawrence, Mission, & Johnstone, 2006), and the matched sample is different from the final (full) LSAC sample.

Issues relating to the LSAC sample:

4. The LSAC sample excluded temporary residents, who may be new arrivals to Australia (Soloff, Millward & Sanson et al., 2003). Children from some developing countries, or who are refugees, may arrive without adequate immunisation. Also, as described, immunisation received overseas may not be recorded on the ACIR. Moreover, some children living in remote or very remote locations were excluded from the LSAC sample.
5. In the design of LSAC, an initial sample of 9,259 children aged 0 to 1 years (infant cohort) and 10,275 children aged 4 to 5 years was selected from the Medicare enrolments database. Of these, 5,107 infants and 4,983 children were recruited to the study. The design weights were adjusted for this non-response based on two variables: mother's level of schooling and whether the mother spoke a language other than English at home (Soloff et al., 2006). However, Australian research suggests that incomplete immunisation is related to a wider range of sociodemographic variables, including family size, family structure, financial stress, residential mobility, and parents' attitudes towards childhood

immunisation (Haynes & Stone, 2004; Homel & Edwards, forthcoming). Possibly the design weights cannot adequately correct for all the differences between the final sample and non-respondents that might be related to differing rates of full immunisation.

6. Children are automatically added to the ACIR when they are assigned a Medicare number. Therefore, the number of children in a birth cohort on the ACIR will increase over time because of migration into Australia. As described, new arrivals may be incompletely immunised, and this may pull down coverage estimates for the population. The composition of the LSAC cohorts, on the other hand, does not change.

Taken together, these factors mean that, firstly, the LSAC sample as a whole may under-represent groups with lower coverage and less complete immunisation records, such as new arrivals to Australia, families of non-English-speaking background and those living in very remote locations. Secondly, the LSAC sample matched to ACIR may further underrepresent characteristics associated with incomplete and delayed immunisation.

Recommendation for data users #5

When interpreting results of analysis with the LSAC–ACIR matched data, data users should be aware that the LSAC matched sample over-represents full immunisation and characteristics of families, children and communities that are associated with full immunisation.

A final issue to consider when comparing the LSAC–ACIR and national estimates is the lag-time between the date a vaccine was received and the date it was recorded on the ACIR. The description of the variable 'daterec' in Section 6 showed that, in some cases, the lag between vaccination and recording was years. As described in Section 8, the nationally reported estimates were assessed three months after the milestone age. Therefore, some children who had received required immunisations by the cut-off age might have been assessed as not immunised because the episode had not been recorded on the ACIR. As the youngest of the B cohort children were 60 months old in early 2009, it is possible that the LSAC coverage estimates capture these very delayed records more completely than the reported national estimates. To examine this, we identified immunisations that been received by the age cut-off but had not been uploaded by the reported assessment date, and changed their status to 'not immunised.' The number of observations affected was very small and the coverage estimates were altered only beyond the second decimal place. Therefore, we do not consider that the long lags for some observations cause LSAC–ACIR estimates to be higher than the national estimates.

9 Conclusions

The linkage of LSAC and ACIR data provides researchers from several different disciplines with opportunities to examine patterns and predictors of immunisation using a rich, nationally representative dataset. In this report, we have provided a detailed introduction to ACIR data, highlighting issues that data users should be aware of when managing, analysing and interpreting these data. It is hoped that this introduction will make ACIR data accessible to many users and further enhance the value of LSAC to researchers and policymakers.

10 Recommendations

As discussed, we have provided derived variables for all the individual antigens, contained in Appendix C, and also for full immunisation at the three milestone ages. However, there are many different ways that these data could be coded and analysed, depending on a researcher's interests. Regardless of research topic or method, however, data users should keep the following recommendations in mind.

1. **Matched cases with no vaccines recorded:** LSAC cases matched to the ACIR but which have no vaccines recorded should not be dropped from the analysis if issues relating to incomplete immunisation are being investigated. These cases may include parents who object to vaccination and parents who had difficulty accessing vaccination.
2. **Assessing DTPa and MMR:** Remember that DTPa and MMR are assessed as single episodes, even though they contain multiple antigens. Further, monovalent components are not considered complete immunisation unless children have received all the doses of the all the components of DTPa and MMR. Data users should therefore carefully assess whether this is the case for children who have received monovalent components of DTPa or MMR.
3. **Assessing Hib and HepB:** Hib and HepB vaccines have a complex scheduling history. Information about receipt of Hib and HepB vaccines should be coded at the level of the vaccine name, and not be aggregated to the disease level until later in the analysis. Variables indicating whether each of the individual vaccines for Hib and HepB have been derived and are provided with the dataset.
4. **Date of birth or month of birth:** Data users who are interested in examining the timing of immunisations should think carefully about whether basing timing variables on month of birth will provide sufficient accuracy for their analysis. This will be important if timing needs to be examined in greater detail than the 'fully immunised' variables at milestone ages that have been provided with the data.
5. **Representativeness of the matched sample:** Children from lower-income families, from non-English-speaking families, and from families living in more disadvantaged areas were less likely to be matched. In the B cohort, children of parents who had more negative attitudes towards childhood immunisation were less likely to be matched. The LSAC sampling frame also under-represents children living in very remote areas and those who are new arrivals to Australia who may have incomplete immunisation records. Overall, the matched sample slightly over-represents completely immunised children at milestone ages. This should be borne in mind when interpreting results of analyses.

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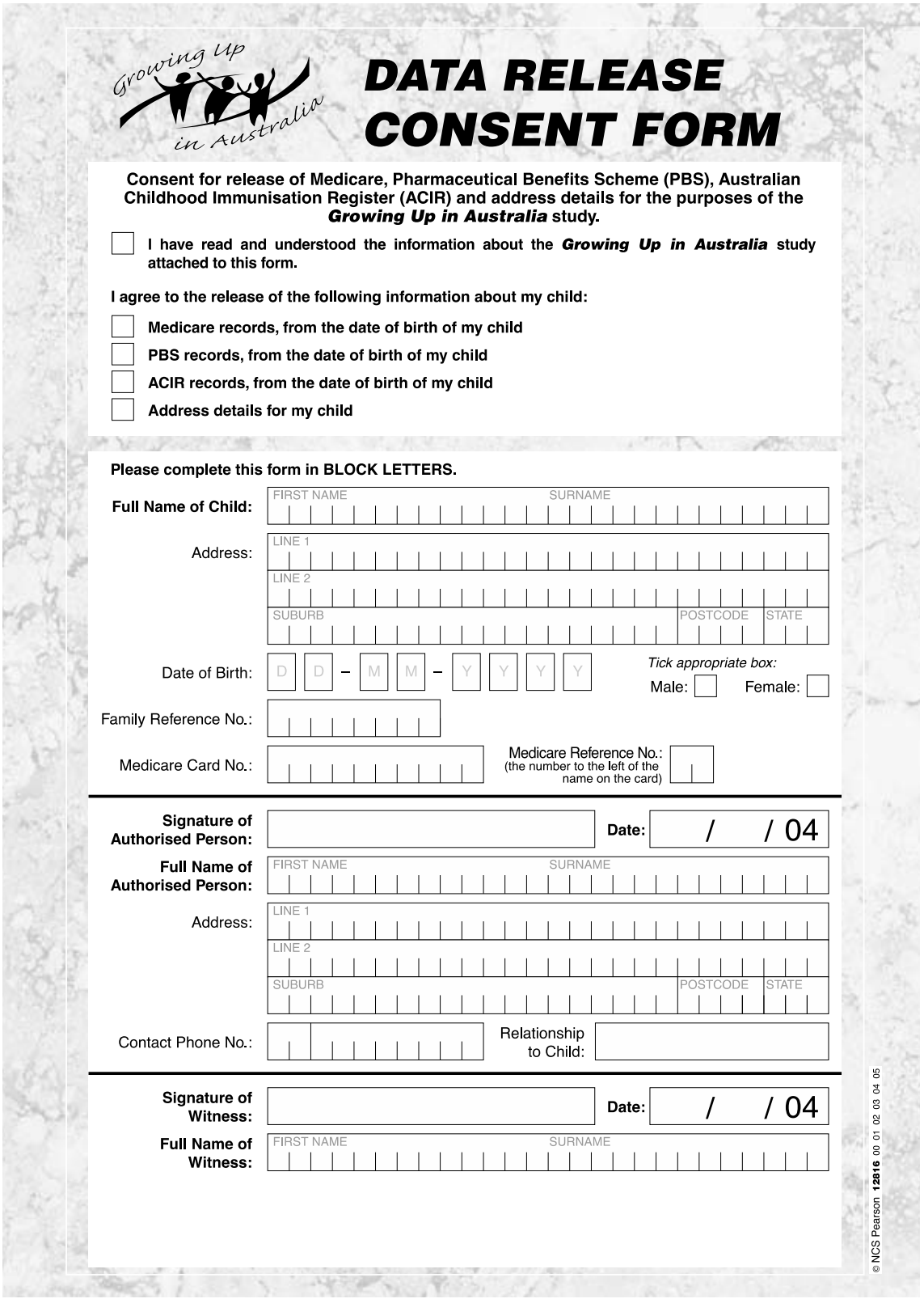
Appendix A: Consent form for data linkage



Growing Up in Australia

DATA RELEASE CONSENT FORM

Consent for release of Medicare, Pharmaceutical Benefits Scheme (PBS), Australian Childhood Immunisation Register (ACIR) and address details for the purposes of the *Growing Up in Australia* study.

☐ **I have read and understood the information about the *Growing Up in Australia* study attached to this form.**

I agree to the release of the following information about my child:

☐ **Medicare records, from the date of birth of my child**

☐ **PBS records, from the date of birth of my child**

☐ **ACIR records, from the date of birth of my child**

☐ **Address details for my child**

Please complete this form in BLOCK LETTERS.

Full Name of Child: FIRST NAME SURNAME

Address: LINE 1 / LINE 2 / SUBURB POSTCODE STATE

Date of Birth: D D – M M – Y Y Y Y

Tick appropriate box: Male: ☐ Female: ☐

Family Reference No.:

Medicare Card No.: Medicare Reference No.: (the number to the left of the name on the card)

Signature of Authorised Person: **Date:** / / 04

Full Name of Authorised Person: FIRST NAME SURNAME

Address: LINE 1 / LINE 2 / SUBURB POSTCODE STATE

Contact Phone No.: Relationship to Child:

Signature of Witness: **Date:** / / 04

Full Name of Witness: FIRST NAME SURNAME

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Appendix B: Results of models predicting matching

Table B1: Description of variables used to predict non-matched Medicare cases

Variable	Categories	Description
Study child sex	0=female 1=male	Study child sex
Young mother	0=younger than 20, 1=20–24, 2=25 and older	Age of the mother at the time of the study child's birth
Lone mother household	1=Yes, 0=No	A family was defined as lone mother if the father was not present in the household at Wave 1
P1 of Aboriginal or Torres Strait Islander origin	1=Yes, 0=No	The study child's primary carer was of Aboriginal or Torres Strait Islander origin
P1's country of birth	0=Australia and New Zealand, 1=elsewhere	The study child's primary carer was born outside Australia or New Zealand
P1 speaks a language other than English at home	1=Yes, 0=No	The main language spoken at home by the study child's primary carer is English
Number of siblings in household	0=none, 1=1 sibling, 2=2 siblings, 3=3 or more siblings	The number of siblings of the study child in the household
P1 education	0=Bachelor degree and above, 1=Advanced diploma, 2=Certificate, 3=Completed year 12, 4=Year 11 and below	The primary caregiver's highest educational qualification
P1's working hours	0=35 hours and more, 1=less than 35 hours, 2=no hours	The average number of weekly hours worked by the primary caregiver in all jobs
Parental warmth		Weighted average of six items (e.g., How often do you express affection by hugging, kissing and holding this child?). Higher scores indicate warmer parenting
P1 approval of childhood immunisation	1=very strongly/quite strongly agree, 2=neither agree nor disagree, 3=quite strongly/very strongly disagree	Primary caregiver's answer to the question "Overall, how much do you agree with children being immunised, that is having their needles or injections?"
P1 report of study child's immunisation status at Wave 1	1=completely up to date, 2=not up to date	Primary caregiver's answer to the question: "Is [your child] up to date with his/her immunisations, that is needles or injections?"
Parental income	Quintiles, ranging from 1 (lowest quintile) to 5 (highest quintile)	Parental income is the sum of the usual weekly income for both P1 and P2 (if present)
Family's main income is government benefits	0=no, 1=yes	The main source of income for both P1 and P2 (when present) is government benefits
Financial stress	0=no stressful events, 1=1 event, 2=2 and more events	Experience of financially stressful events in the last 12 months as indicated by six items (e.g., Parent has not been able to pay gas, electricity or telephone bills on time due to a shortage of money)
Difficulty affording medical care	1=Yes, 0=No	The study child's primary caregiver has had difficulty affording medical care or medicines needed by the study child in the last 12 months
Family does not have private hospital insurance	1=no insurance, 0=has insurance	

Table B1: Description of variables used to predict non-matched Medicare cases

Variable	Categories	Description
Household lives in public housing	1=Yes 0=No	The study child's household lives in housing provided by a state or territory housing authority, government housing, or a housing co-operative
Study child has a medical condition or disability	0 = no, 1 = yes	The study child has a medical condition or disability that is expected to last 6 months or longer
P1 global rating of study child's health	0=very good or excellent 1=poor, fair, or good	Primary caregiver's rating of study child's general health
Study child birth weight	0 = 2,500g and more, 1= less than 2,500g	The weight of the study child in grams at birth
Study child was multiple birth	0 = singleton birth 1 = multiple birth	The study child was a twin or triplet
Health services accessed for study child in last 12 months		
Maternal/child health services	0 = no, 1 = yes	
GP	0 = no, 1 = yes	
Hospital emergency	0 = no, 1 = yes	
SEIFA Index of Disadvantage	0=High (Bottom 25%), 1=Medium-High(25–50%), 2=Medium-Low (50–75%), 3=Low (Top 25%)	Higher scores on the SEIFA index of disadvantage indicate less disadvantage in the local area
Proportion of residents of postcode aged 0 to 4		Census linked data for family's postcode
Proportion of residents of postcode in families with incomes of >$1,000/week		Census linked data for family's postcode
Remote residence	1=Remote or very remote area, 0=Moderate to highly accessible area	Household is located in an area classified as remote or very remote in terms of road distance from the local service centre

Table B2: Logistic regression models predicting non-matching to Medicare, PBS, or ACIR data in the B cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
Family and parent characteristics			
Study child gender			
Female	-	2,641 (94.29)	2,610
Male	0.78 (0.63–0.98)*	2,318 (92.83)	2,497
Maternal age			
25 and older	-	4,023 (93.56)	4,300
20–24 years old	1.01 (0.72–1.41)	600 (93.60)	641
20 and younger	1.07 (0.56–2.06)	156 (93.98)	166
Lone parent or coupled			
Coupled	-	4,344 (93.76)	4,633
Lone parent	0.74 (0.52–1.05)	435 (91.77)	474
P1 Aboriginal or not			
Not Aboriginal	-	4,626 (93.59)	4,943
Aboriginal	0.95 (0.51–1.78)	153 (93.29)	164
P1 country of birth			
P1 born in Australia/NZ		3,896 (93.77)	4,155
P1 born outside Australia/NZ	0.85 (0.65–1.12)	883 (92.75)	952
P1 language spoken at home			
English	-	4,114 (94.14)	4,370
Language other than English	0.57 (0.44–0.76)***	665 (90.23)	737
Number of siblings of study child in household			
None	-	1,855 (93.36)	2,019
One	1.18 (0.90–1.53)	1,769 (94.30)	1,876
Two	0.94 (0.68–1.29)	766 (92.96)	824
Three or more	0.88 (0.58–1.34)	359 (92.53)	388
P1 education			
Bachelor and above	-	1,572 (93.73)	1,677
Advanced diploma	1.16 (0.75–1.79)	471 (94.54)	498
Certificate	0.90 (0.67–1.21)	1,182 (93.12)	1,269
Year 12	1.07 (0.75–1.54)	750 (94.14)	797
Year 11 or less	0.87 (0.63–1.21)	804 (92.87)	866
P1 working hours			
35 hours	-	647 (93.90)	689
Less than 35 hours	1.12 (0.77–1.63)	1,727 (94.53)	1,827
No hours	0.84 (0.59–1.19)	2,405 (92.82)	2,591
Parenting warmth	0.90 (0.67–1.20)		-
P1 approval of child immunisation			
Quite strongly or very strongly agree	-	4,488 (93.91)	4,779
Neither agree nor disagree	0.43 (0.28–0.64)***	192 (86.86)	221
Quite strongly or very strongly disagree	0.80 (0.39–1.67)	99 (92.54)	107

Table B2: Logistic regression models predicting non-matching to Medicare, PBS, or ACIR data in the B cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
P1 report of study child immunisation status at Wave 1			
Not up to date	-	450 (94.48)	476
Up to date	0.84 (0.56–1.27)	4,329 (93.49)	4,631
Income and hardship			
Parental weekly income (ref = highest quintile)			
1st quintile	0.68 (0.46–0.99)*	954 (93.35)	1,022
2nd quintile	0.65 (0.44–0.94)*	950 (93.05)	1,021
3rd quintile	0.59 (0.41–0.86)**	972 (92.48)	1,051
4th quintile	0.71 (0.48–1.05)	929 (93.65)	992
5th quintile	-	974 (95.40)	1,021
Family's main source of income			
Not government benefits	-	4,664 (93.72)	4,976
Government benefits	0.50 (0.29–0.86)*	115 (88.16)	131
Financial stress			
No stressful events	-	3,320 (93.55)	3,549
1 event	1.00 (0.74–1.35)	825 (93.54)	882
2 and more events	1.04 (0.74–1.46)	634 (93.79)	676
Difficulty affording medical care last 12 months			
No difficulty	-	4,434 (93.60)	4,737
Has had difficulty	0.94 (0.62–1.44)	345 (93.25)	370
Private hospital insurance			
Family has insurance	-	2,212 (94.12)	2,349
Family does not have insurance	0.83 (0.66–1.04)	2,567 (93.06)	2,758
Public housing			
Family does not live in public housing	-	4,544 (93.60)	4,855
Family lives in public housing	0.93 (0.56–1.55)	235 (93.17)	252
Study child health and service use			
Study child: medical condition or disability expected to last at least 12 months			
Does not have a condition or disability	-	4,514 (93.57)	4,824
Has a condition or disability	1.01 (0.62–1.65)	265 (93.64)	283
P1 global rating of study child's health			
Very good or excellent health	-	4,177 (93.72)	4,457
Poor, fair or good health	0.84 (0.61–1.16)	602 (92.62)	650
Study child birth weight			
2,500g and more	-	4,524 (93.64)	4,832
less than 2,500g	0.85 (0.53–1.36)	255 (92.59)	275
Study child: type of birth			
Single birth	-	4,327 (93.63)	4,942
Multiple birth	0.80 (0.45–1.42)	152 (92.14)	165

Table B2: Logistic regression models predicting non-matching to Medicare, PBS, or ACIR data in the B cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
Services used for study child in the last 12 months			
Maternal/child health services			
Has used	0.87 (0.59–1.26)	3,934 (93.43)	4,211
Has not used	-	845 (94.25)	896
GP			
Has used	1.22 (0.91–1.63)	3,855 (93.82)	4,109
Has not used	-	924 (92.57)	998
Hospital emergency			
Has used	1.28 (0.93–1.77)	1,036 (94.67)	1,094
Has not used	-	3,743 (93.28)	4,013
Community characteristics			
SEIFA index of area disadvantage			
1st quartile (most disadvantaged)	0.68 (0.49–0.94)*	1,290 (92.27)	1,398
2nd quartile	0.93 (0.65–1.32)	1,158 (94.22)	1,229
3rd quartile	0.81 (0.58–1.13)	1,240 (93.44)	1,327
4th quartile (least disadvantaged)	-	1,091 (94.62)	1,153
Proportion of residents of postcode aged 0 to 4	0.87 (0.81–0.94)***	-	-
Proportion of residents of postcode in families with incomes of >$1,000/week	1.00 (1.00–1.01)	-	-
Remoteness			
Household is in a highly accessible, accessible, or moderately accessible area	-	4,576 (93.79)	4,879
Household is in a remote area	0.53 (0.35–0.82)**	203 (88.97)	228

Notes: Statistically significant differences are noted: * $p < .05$; ** $p < .01$; *** $p < .001$. [1]In the B cohort, all children with a birthweight of <1,500g were matched, producing an empty cell in the analysis. Therefore children of less than 2,500g were compared with those 2,500g and over.

Source: B Cohort, Wave 1. N = 5,107 for all analyses.

Table B3: Logistic regression models predicting non-matching to Medicare, PBS or ACIR data in the K cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
Family and parent characteristics			
Study child gender			
Female	-	2,357 (92.91)	2,537
Male	0.87 (0.71–1.08)	2,249 (91.95)	2,446
Maternal age			
25 and older	-	3,887 (92.66)	4,195
20–24 years old	0.90 (0.66–1.22)	586 (91.88)	638
20 and younger	0.60 (0.36–1.01)	133 (88.37)	150
Lone parent or coupled			
Coupled	-	4,009 (92.74)	4,323
Lone parent	0.74 (0.56–0.99)*	597 (90.45)	660
P1 Aboriginal or not			
Not Aboriginal	-	4,476 (92.46)	4,841
Aboriginal	0.88 (0.48–1.61)	130 (91.55)	142
P1 country of birth			
P1 born in Australia/NZ		3,604 (93.03)	3,874
P1 born outside Australia/NZ	0.70 (0.55–0.89)**	1,002 (90.35)	1,109
P1 language spoken at home			
English	-	3,908 (92.91)	4,206
Language other than English	0.67 (0.52–0.87)**	698 (89.83)	777
Number of siblings of study child in household			
None	-	525 (92.11)	570
One	1.05 (0.75–1.48)	2,231 (92.46)	2,413
Two	1.16 (0.80–1.67)	1,240 (93.09)	1,332
Three or more	0.90 (0.60–1.35)	610 (91.32)	668
P1 education			
Bachelor and above	-	1,301 (92.79)	1,402
Advanced diploma	1.01 (0.67–1.53)	418 (92.87)	450
Certificate	1.0 (0.75–1.35)	1,169 (92.82)	1,260
Year 12	1.04 (0.74–1.46)	727 (93.03)	781
Year 11 or less	0.78 (0.58–1.04)	991 (90.93)	1,090
P1 working hours			
35 hours	-	721 (92.79)	777
Less than 35 hours	1.05 (0.76–1.45)	1,922 (93.12)	2,064
No hours	0.85 (0.62–1.16)	1,963 (91.64)	2,142
Parenting warmth	0.85 (0.66–1.10)		-
P1 approval of child immunisation			
Quite strongly or very strongly agree	-	4,319 (92.57)	4,666
Neither agree nor disagree	0.84 (0.52–1.35)	209 (91.27)	229
Quite strongly or very strongly disagree	0.62 (0.32–1.21)	78 (88.64)	88

Table B3: Logistic regression models predicting non-matching to Medicare, PBS or ACIR data in the K cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
P1 report of study child immunisation status at Wave 1			
Not up to date	-	320 (92.45)	346
Up to date	1.0 (0.66–1.51)	4,286 (92.43)	4,637
Income and hardship			
Parental weekly income (ref = highest quintile)			
1st quintile	0.84 (0.61–1.14)	922 (90.48)	1,019
2nd quintile	1.39 (0.98–1.97)	917 (94.05)	975
3rd quintile	1.13 (0.81–1.57)	925 (92.78)	997
4th quintile	1.17 (0.84–1.63)	932 (93.01)	1,002
5th quintile	-	910 (91.92)	990
Family's main source of income			
Not government benefits	-	4,484 (92.64)	4,840
Government benefits	0.47 (0.29–0.77)**	122 (85.61)	143
Financial stress			
No stressful events	-	3,214 (92.86)	3,461
1 event	0.89 (0.67–1.18)	761 (92.02)	827
2 or more events	0.76 (0.57–1.01)	631 (90.79)	695
Difficulty affording medical care last 12 months			
No difficulty	-	4,160 (92.55)	4,495
Has had difficulty	0.86 (0.61–1.20)	446 (91.40)	488
Private hospital insurance			
Family has insurance	-	2,139 (93.29)	2,293
Family does not have insurance	0.80 (0.64–0.99)*	2,467 (91.71)	2,690
Public housing			
Family does not live in public housing	-	0 (92.62)	4,683
Family lives in public housing	0.68 (0.46–1.00)	0 (89.53)	300
Study child health and service use			
Study child: medical condition or disability expected to last at least 12 months			
Does not have a condition or disability	-	3,657 (92.19)	3,967
Has a condition or disability	1.20 (0.91–1.58)	949 (93.41)	1,016
P1 global rating of study child's health			
Very good or excellent health	-	4,035 (92.46)	4,364
Poor, fair or good health	0.97 (0.71–1.33)	571 (92.25)	619
Study child birth weight			
2,500g and more	-	4,303 (92.39)	4,657
less than 2,500g	1.11 (0.70–1.74)	303 (93.07)	326
Study child: type of birth			
Single birth	-	4,475 (92.40)	4,843
Multiple birth	1.20 (0.60–2.37)	131 (93.57)	140

Table B3: Logistic regression models predicting non-matching to Medicare, PBS or ACIR data in the K cohort

	Unadjusted odds ratio (95% CI)	Number of children	
		Matched (%)	Total (100%)
Services used for study child in the last 12 months			
Maternal/child health services			
Has used	1.20 (0.88–1.62)	3,471 (92.14)	3,767
Has not used	-	1,135 (93.34)	1,216
GP			
Has used	1.29 (0.98–1.70)	1,184 (91.04)	1,301
Has not used	-	3,422 (92.93)	3,682
Hospital emergency			
Has used	0.87 (0.61–1.23)	3,706 (92.65)	4,000
Has not used	-	900 (91.58)	983
Community characteristics			
SEIFA index of area disadvantage			
1st quartile (most disadvantaged)	1.0 (0.75–1.34)	1,218 (92.06)	1,323
2nd quartile	1.33 (0.98–1.79)	1,350 (93.88)	1,438
3rd quartile	0.91 (0.68–1.24)	962 (91.36)	1,053
4th quartile (least disadvantaged)	-	1,076 (92.04)	1,169
Proportion of residents of postcode aged 0 to 4	0.99 (0.92–1.07)	-	-
Proportion of residents of postcode in families with incomes of >$1,000/week	1.01 (1.00–1.02)**	-	-
Remoteness			
Household is in a highly accessible, accessible, or moderately accessible area	-	4,409 (92.61)	4,759
Household is in a remote area	0.58 (0.38–0.88)*	197 (87.96)	224

Notes: Statistically significant differences are noted: * $p < .05$; ** $p < .01$; *** $p < .001$.

Source: K Cohort, Wave 1. N = 4,983 for all analyses.

Appendix C: Vaccine codes

A list of the vaccine codes currently in use can be found on the Department of Human Services (DHS) website http://www.humanservices.gov.au/health-professionals/services/australian-childhood-immunisation-register/acir-vaccine-code-formats, but this list provides only sparse information about the diseases that each vaccine targets. Additional sources include the abbreviation lists provided in appendices to the *Communicable Diseases Intelligence* Supplements (2000a, 2002a, 2004a, 2007, 2010) authored by the NCIRS and in the NCIRS Biennial reports (2010, 2012). The current Handbook (10th edition, 2013) and the CDI Supplements are also very useful for providing details about diseases and associated vaccine names, brands and histories of use in Australia.

Table C1 lists all the vaccine codes that appear in the LSAC–ACIR data in alphabetical order, as well as vaccine brand name, the antigen/s, and the doses that appear in the LSAC–ACIR data. Note:

- Not all codes found in the list provided on the DHS website appear in the LSAC–ACIR data.
- At the time of writing, most of the codes that appear in the dataset were listed as 'standard' vaccines on the DHS website, but about a third were listed as 'non-standard' vaccines and one (PNEUMO) was listed as a sub-population vaccine (for Aboriginal and Torres Strait Islander children, for children in at-risk areas, and for some children medically at risk, see Table 7 and the current (2013) Australian Immunisation Handbook).
- The column labelled 'dose numbers in the LSAC–ACIR data' lists the dose numbers that appear in the data, not the total number of doses received or required. For some vaccines with a very low rate of use, only one or two doses of all possible doses appear in the dataset. For example, the only episode recorded as generic diphtheria (GNDIP) was recorded as dose 4 (GNDIP4).

Table C1: Vaccine codes appearing in the LSAC–ACIR data

Vacccode (vaccine code)	Brand name / Vaccine	Antigen/s	Dose numbers in the LSAC–ACIR data
AVAXM	Avaxim	Hepatitis A	1–2
BCG	BCG—Bacille-Calmette-Guérin	Tuberculosis	1–2
CDT	CDT—Child diphtheria-tetanus	Diphtheria, tetanus	1–5
CMX	COMVAX—Hib(PRP-OMP)-HepB	Hib, hepatitis B	1–4
DTP	Generic DTPa	Diphtheria, tetanus, acellular pertussis	1–5
DTPa	Triple Antigen	Diphtheria, tetanus, acellular pertussis	1–5
ENGP	Engerix-B—paediatric	Hepatitis B	1–4
ENGPB[1]	Engerix-B—paediatric	Hepatitis B	1 (birth)
FLRIX	Fluarix	Influenza	1–3
FLUVAX	Fluvax	Influenza	1–6
FLVRN	Fluvirin	Influenza	1
GNDIP	Generic diphtheria	Diphtheria	4
GNFLU	Generic influenza	Influenza	1–4
GNHEP	Generic hepatitis B	Hepatitis B	1–3
GNHEPB[1]	Generic hepatitis B	Hepatitis B	1 (birth)
GNHIB	Generic hib	Hib	1–4
GNHPA	Generic hepatitis A	Hepatitis A	1–2

Table C1: Vaccine codes appearing in the LSAC–ACIR data

Vacccode (vaccine code)	Brand name / Vaccine	Antigen/s	Dose numbers in the LSAC–ACIR data
GNJEN	Generic Japanese encephalitis	Japanese encephalitis	1–3
GNMEA	Generic measles	Measles	1–2
GNMEN	Generic meningoccal C	Meningococcal C	1–3
GNPNE	Generic pneumococcal	Pneumococcal disease	1–3
GNPOL	Generic polio	Polio	1–5
GNRUB	Generic rubella	Rubella	1
GNTET	Generic tetanus	Tetanus	2, 4
GNVAR	Generic varicella-zoster	Varicella-zoster virus	1
HATWNJ	Twinrix Junior	Hepatitis A & Hepatitis B	1–3
HAVAQ	Vaqta—paediatric adolescent	Hepatitis A	1–3
HAVJ	Havrix Junior	Hepatitis A	1–2
HBOC	HibTITER (HbOC)	Hib	1–5
HBV	Generic hepatitis B	Hepatitis B	1–4
HBVB[1]	Generic hepatitis B	Hepatitis B	1 (birth)
HBVP	HBVAX II—paediatric	Hepatitis B	1–4
HBVPB[1]	HBVAX II—paediatric	Hepatitis B	1 (birth)
HBX	Hiberix (PRP-T)	Hib	1–4
IFHX	Infanrix Hexa	Diphtheria, tetanus, acellular pertussis, inactivated polio, Hib (PRP-T), hepatitis B	1–4
IFIP	Infanrix IPV	Diphtheria, tetanus, acellular pertussis, inactivated polio	1–5
IFX	Infanrix	Diphtheria, tetanus, acellular pertussis	1–5
IFXB	Infanrix-Hep B	Diphtheria, tetanus, acellular pertussis, hepatitis B	1–5
INFLUV	Influvac	Influenza	1–2, 4
IPV	IPOL	Inactivated polio	1–5
JEVAX	JE-VAX	Japanese encephalitis	1–3
MENJUG	Menjugate—conjugate vaccine (MenCCV)	Meningococcal C	1–3
MENTEC	Meningitec—conjugate vaccine (MenCCV)	Meningococcal C	1–4
MENUME	Menomune—polysaccharide vaccine (4vMenPV)	Meningococcal A,C,W-135 & Y	1
MENVAX	Mencevax ACWY—polysaccharide vaccine (4vMenPV)	Meningococcal A,C,W-135 & Y	1
MMR	Generic MMR	Measles, mumps, rubella	1–3

Table C1: Vaccine codes appearing in the LSAC–ACIR data

Vacccode (vaccine code)	Brand name / Vaccine	Antigen/s	Dose numbers in the LSAC–ACIR data
MMRCSL	MMR II	Measles, mumps, rubella	1–3
MMRSKB	Priorix	Measles, mumps, rubella	1–3
NEISVC	NeisVac-C—conjugate vaccine (MenCCV)	Meningococcal C	1–3
OPV	Polio Sabin (Oral)	Polio	1–5
PANVAX	PANVAX	H1N1 Influenza	1–5
PNEUMO	Pneumovax 23—23-valent pneumococcal polysaccharide (23vPPV)	Pneumococcal disease	1–2
PRPD	ProHIBit (PRPD)	Hib	1–2
PRPOMP	PedvaxHIB (PRP-OMP)	Hib	1–5
PRPT	ActHib (PRP-T)	Hib	1–4
PRVNR	Prevenar 7—7-valent pneumococcal conjugate vaccine (7vPCV)	Pneumococcal	1–5
QDCL	Quadracel	Diphtheria, tetanus, acellular pertussis, inactivated polio	2–5
TCL	Tripacel	Diphtheria, tetanus, acellular pertussis	1–5
VAXGRP	Vaxigrip	Influenza	1–7
VLRIX	Varilrix	Varicella-zoster	1–2
VRVAX	Varivax	Varicella-zoster	1–2

Notes: [1]Birth doses of HepB vaccine do not have a numeric suffix, but are identified with the suffix 'B'

Source: DHS (http://www.humanservices.gov.au/health-professionals/services/australian-childhood-immunisation-register/acir-vaccine-code-formats), NCIRS (2010; 2012); NHMRC (2013).