

Immunisation coverage in Australian children: a systematic review 1990-1998

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Abstract

The Australian Childhood Immunisation Register (ACIR) commenced operation in January 1996 and provides a comprehensive database of children's immunisations in Australia. The ACIR enables implementation of an immunisation recall and reminder system and improved surveillance and reporting of immunisation coverage. Before the introduction of the ACIR, the methods used in assessing coverage varied widely in design and quality, with few studies measuring coverage at national or statewide level. This is a systematic review of the scope and reliability of estimates of immunisation coverage available in Australia from 1990 to 1998. A total of 108 studies were identified of which 51 were classified as higher quality based on a range of criteria including whether they had a response rate of 50% or better. *Commun Dis Intell* 1999;23:145-170.

Summary

Introduction

Accurate information on the proportion of children immunised in Australia is essential for the planning of effective immunisation programs. Before the introduction of the Australian Childhood Immunisation Register (ACIR) in

January 1996, the methods used in assessing coverage varied widely in design and quality, with few studies measuring coverage at national or statewide level.

This systematic review of the scope and reliability of estimates of immunisation coverage from 1990 to 1998 was initiated by the National Centre for Immunisation Research and Surveillance of

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Vaccine Preventable Diseases (NCIRS) to evaluate the available Australian estimates of immunisation status against data from the ACIR.

Methods

Studies were identified and included in the review, using all available sources, if they examined Australian data and were published or produced between January 1990 and June 1998. Eligible studies were abstracted with a standard proforma including type of publication, sample characteristics, validation and outcome measures. Studies were classified as higher quality using a range of criteria, including if they had response rates of 50% or higher. The term 'fully immunised' was defined as coverage of the full course of vaccines scheduled at the time of each study. Data were also tabulated by individual vaccine and age strata (12-23 months, 24-35 months and 4-6 years) where available.

Results

A total of 108 eligible studies were identified and 51 higher quality studies tabulated by location, design, sample size, response rate, strategy and method of validation (Tables 1-7). Studies investigating immunisation procedures and processes, and letters and editorials that did not report original data on immunisation coverage were excluded.

The most common assessment age was from 24 to 35 months and the proportion of children fully immunised ranged from 51% to 88% (excluding *Haemophilus influenzae* type b (Hib)). The 1995 Australian Bureau of Statistics (ABS) estimates for 24 to 35 months were lower (51.3%) than most other comparable population-based studies (range 60.3% - 88%). Details of the immunisation status of children by age strata are shown in Tables 8-10.

Immunisation coverage in child-care settings for children aged 0-5 years ranged from 60.3% to 70% (excluding Hib) in studies using provider documentation. Coverage in schools for children aged 4-6 years was higher (range 67% to 89% excluding Hib) but likely to be overestimated. While studies in remote Aboriginal communities suggested coverage was much higher than the general population, studies in less remote areas found much lower levels of coverage in Aboriginal children than in the general population.

Comprehensiveness and validity at a national population level were key criteria for data quality, fulfilled only by the ABS surveys. Statewide population databases using provider-held records to assemble a prospective birth cohort had the next highest validity, followed by cross-sectional studies with appropriate sampling and high response rates. Many studies based on retrospective birth cohorts had low response rates with potential selection bias. These more geographically restricted studies have generally produced higher estimates of immunisation coverage than the ABS survey. The first 12 month cohort from the ACIR gave lower coverage estimates for diphtheria-tetanus-pertussis (DTP) and poliomyelitis (OPV), but higher for Hib than the ABS survey. ACIR data are currently incomplete and should be viewed as minimum estimates, but can detect large changes over time such as has occurred with Hib vaccine coverage.

Conclusions

This review showed that methodology strongly influences the final estimates of coverage and supports the need for a nationally consistent methodology, which would make comparisons much easier. The best national estimate of immunisation status in Australian children prior to the ACIR is the 1995 ABS survey. The ACIR should give increasingly accurate estimates as reporting improves.

This can be expected due to current incentive initiatives, but specific surveys of coverage in small populations such as urban Aboriginal communities may still be required. The available data from comparable industrialised countries still indicate suboptimal performance by Australia, with coverage for three doses of pertussis-containing vaccines at around 80% compared with estimates of over 90% in the United Kingdom (UK) and the United States of America (USA).

Introduction

Accurate information on the proportion of children immunised for each vaccine on the recommended schedule is essential for the planning of effective immunisation programs. In Australia, there have been few studies measuring national or statewide immunisation coverage and the methods of data collection have varied in quality. The Australian Childhood Immunisation Register (ACIR) was introduced in 1996 in part to provide more consistent and comparable information about immunisation coverage, but all immunisations for children less than 7 years of age will not be included until after 2001.

This systematic review of the scope and reliability of estimates of immunisation coverage in Australia since 1990 was initiated by the NCIRS to provide the background against which coverage estimates from the ACIR could be judged. The available literature was examined with reference to the following research questions:

1. With the exception of the ACIR:
 - (a) What is the best overall estimate of the current immunisation status of Australian children?
 - (b) What is the best estimate of immunisation status for each scheduled vaccine by age?
2. How do the estimates from other studies compare with those from the ACIR?
3. How does the immunisation status of Australian children compare with overseas estimates?

Background

Australia has had childhood immunisation programs since the 1920s, with enormous advances in eliminating or reducing the impact of vaccine preventable diseases (VPDs) such as poliomyelitis, tetanus and diphtheria.¹ However, outbreaks of measles and rubella continued to occur in the 1990's and pertussis is endemic, with nine deaths in infants occurring in 1996-97.^{2,3} This disease activity is occurring because immunisation coverage remains below the level of 90%-95% required to interrupt transmission of these highly contagious infections.⁴

Concern about Australia's poor record for immunisation coverage prompted a series of national initiatives, beginning with the National Health and Medical Research

Council (NHMRC) convening a panel to review services in 1993. The resulting National Immunisation Strategy set targets for immunisation coverage and control of vaccine preventable diseases (VPDs) and recommended initiatives to achieve these targets.⁴

The recommendations of the National Immunisation Strategy were addressed in several ways. The establishment of the National Notifiable Diseases Surveillance Scheme (NNDSS) in 1991 had already begun the process of national surveillance and reporting of VPDs using common case definitions. From 1996 the ACIR provided both an immunisation recall and reminder system for parents and improved surveillance and reporting of immunisation coverage.

In 1997, the Minister for Health and Family Services initiated the 'Seven Point Plan' to increase the proportion of fully immunised children in Australia. This Plan included monetary incentives, commencing in mid 1998, for parents whose children receive child-care assistance payments and incentives for general practitioners whose practices include a high proportion of fully immunised children. The Plan outlined the measles elimination strategy, a range of educational initiatives, a proposal to introduce uniform school entry legislation relating to immunisation status, and enhancement of research activities which led to the establishment of the NCIRS.

The only national immunisation coverage data, prior to the ACIR, came from national surveys by the Australian Bureau of Statistics (ABS). The most recent survey in 1995 found that 52.1% of children aged 0-6 years were fully immunised for age, excluding Hib. The level of full immunisation for the same age group in the previous ABS survey in 1989-90 was similar (54.1%), although these estimates are not directly comparable due to changes in the standard immunisation schedule and the format of the questionnaire.⁵ The ABS survey showed that coverage levels varied between States and Territories, vaccines, age groups and socioeconomic and ethnic groups.⁵

Other than the ABS surveys, data on coverage were statewide or regional and predominantly from ad hoc surveys. Meaningful comparisons between these studies are difficult because methodology and outcome measures were not uniform. Several States and Territories also developed their own population-based vaccination registers (Australian Capital Territory,⁶ Victoria⁷, Queensland^{8,9} and Northern Territory^{10,11}) to obtain more consistent data for analysis of trends. Comprehensiveness of the data from some of these registers can be questioned due to incomplete reporting by providers and because some children receive their immunisations in both the private and public sectors. Other estimates of coverage have come from a variety of sources including outbreak investigations, serological surveys and field vaccine studies, but this was incidental to their main objective and applied only to particular settings.

This review includes both published and unpublished literature from 1990 to 1998 and focuses on studies in which the primary purpose was to estimate immunisation coverage. These data on childhood immunisation coverage in the 1990s provide the background against which the initiatives begun in 1997 may be compared.

Methods

Search strategy

Studies were included in the review if they gave Australian data and were published or produced between January 1990 and June 1998. University theses and treatises were included, as were conference abstracts and proceedings although efforts were made to identify resulting publications wherever possible. Publication was defined as a peer-reviewed journal, government bulletin or report in the public domain. All other studies were classified as unpublished. Letters and editorials containing relevant data were also included.

While the review focuses on coverage of the primary immunisation schedule in children aged 6 years and under (the age group used in the ACIR and ABS immunisation surveys) studies were also included for young people up to the end of high school. The eligible vaccines were those recommended for use in children during the study period: diphtheria-tetanus-pertussis (DTP), poliomyelitis (OPV), measles, mumps and rubella (MMR), Hib and hepatitis B.

The following sources were searched for studies and reviews on childhood immunisation status in Australia since 1990:

- Medline from 1990 to 1998 using the search terms 'immunisation', 'immunisation programs', 'immunisation status', 'Australia' (in MeSH) and the text words 'immunisation status or cover(age) or rate(s)' and 'vaccination status or cover(age) or rate(s)' for all headings. The term 'vaccination' was coded under 'immunisation'.
- Published and unpublished departmental reports, studies and newsletters from the States and Territories. These were identified by direct contact with immunisation co-ordinators, members of the Communicable Disease Network of Australia and New Zealand (CDNANZ) and the authors themselves.
- Manual and electronic searching of the *Communicable Diseases Intelligence* journal from 1990-1998.
- University theses and treatises in public health located by personal contact with authors and supervisors.
- Follow-up of references from key reports and publications.
- Abstracts and conference proceedings from the Public Health Association (PHA) National Immunisation Conferences of 1991, 1993, 1995 and 1996 and other relevant conferences in Australia, for example the NSW Public Health Network Conference. The authors of these studies were contacted and full reports obtained wherever possible.

Criteria for eligibility

The following study designs were included in the review:

- cross-sectional or cohort studies directly measuring immunisation coverage, both in the entire population and in specific settings, such as child care centres and schools;
- state immunisation databases and data from vaccine distribution systems;
- immunisation coverage measured as part of outbreak investigations;
- serological surveys; and

- studies were excluded if they were surveys primarily measuring attitudes, knowledge and behaviour of providers and consumers, studies of vaccine adverse events or studies monitoring the vaccine cold chain.

Data abstraction

After assessment of eligibility, identified studies were abstracted using a standard proforma, which included:

- type of publication (published / unpublished);
- study design (population based / non-population based and including sub-sets such as schools, child-care services);
- sample characteristics - design, size and response rates;
- vaccines included;
- measures of immunisation status; and
- validation of immunisation status.

These data were entered into a Reference Manager database.

Quality assessment

A group of higher quality studies from a range of designs and settings were selected for tabulation and comparison with the ACIR. Studies were classified as higher quality using criteria including study design, study population, response rates, sample size and validity. Generalisability was a particularly important criterion. For example, population-based cross-sectional studies using large sample sizes and with high response rates were rated more highly than retrospective birth cohorts with sample sizes of less than 50% and evidence of selection bias. Moreover, studies with validated coverage data were rated more highly than those relying on parental recall.

The peer-reviewed published studies in this review were given greater weight than the unpublished studies. However, several State Health Departments routinely used data from non-peer reviewed publications to estimate and monitor immunisation coverage in their regions. Peer-reviewed publication was therefore not the only important measure of data quality.

Age strata for coverage assessment

The National Immunisation Strategy in 1993 identified 2 year old children as the primary group for estimates of full immunisation⁴ and this is reflected in the outcomes of many of the studies in this review. More recently, the NHMRC described immunisation outcomes in terms of 'milestones' set at 6 months, 12 months and 18 months.¹² However, the outcomes from the majority of the studies in the review were not classified according to these categories (other than 12 months) and therefore the assessment ages outlined above were used. The Appendix outlines the 1994 NHMRC immunisation schedule current for the 1995 ABS survey and describes the major changes made since the previous survey in 1989-90. The 1996 immunisation schedule is also outlined in the Appendix, including the immunisation 'milestones'.¹²

The outcome measures from the higher quality studies, including data on full immunisation and for individual vaccines, were grouped into the following age strata for

comparability with each other and data from the 1995 ABS survey:

- 12-23 months
- 24-35 months; this was the most common assessment age used in the studies
- 4-6 years; to determine school entry immunisation

Definitions of immunisation coverage

Immunisation coverage is normally expressed as the proportion or prevalence (%) of complete immunisation by particular assessment ages or 'milestones'. Most studies in this review have allowed for a 'grace period' of around 1 to 3 months in assessing coverage, which is up to 6 months for the ACIR cohort.¹³ The definition 'fully immunised' used in this review is receipt of the full course of vaccines scheduled at the time of the study for the assessment age. This definition includes using various outcomes such as 'age appropriately immunised' and 'immunised up to date' but only if separate questions have been asked about each vaccine.¹⁴ The full course of vaccines included are those defined in the standard vaccination schedule at the time of the study (Appendix) but it is noted that a small number of studies in this review have accepted the combined diphtheria and tetanus (CDT) vaccine as a substitute for DTP.^{8,15}

The ABS immunisation surveys

The ABS has conducted national immunisation surveys on a regular basis since 1983, which until the advent of the ACIR, provided the only Australia-wide population, based data on immunisation status. The ABS surveys have been considered a reference standard for estimating immunisation coverage because of their high quality sampling methods.

The most recent survey in 1995 was conducted as part of the regular monthly Labour Force survey, which derives a probability population sample using a stratified, multistage and clustered design.⁵ Each State or Territory was divided into strata, and sampling of Census Collection Districts then undertaken. Around 30,000 private dwellings in total were included, with interviews conducted by trained interviewers over a two week period in April 1995. High response rates, complete population ascertainment and large sample size are notable features of this survey.

Information on children's immunisation and health screening was obtained by parental report for 6,768 children aged 0-6 years from approximately 5,000 households. Of these children, 870 were aged under 1 year, 960 were 12-23 months, 1,021 were 24-35 months, 907 were 36-47 months and 3,010 were aged 4-6 years. Parent Held Records (PHRs) were consulted for 60.6% of children aged 3 months to 6 years. Just over half (52.1%) of the 1995 sample were found to be fully immunised (excluding Hib), and 46% were classified as partially immunised as they had not completed the full course of each vaccine. The remaining children had either an unknown immunisation status (1.1%) or were totally unimmunised (0.4%).⁵

Although the same sample selection procedure is used for all the ABS immunisation surveys, comparability between the 1995 and earlier surveys is limited by changes in the NHMRC schedule and the questions asked.^{5,16} These changes are summarised in the Appendix.

The Australian Childhood Immunisation Register

The ACIR began on January 1, 1996 as part of the 1993 National Immunisation Strategy.⁴ The aim of the register was to provide more accurate and comprehensive information about immunisation coverage and to be a key component of an initiative to improve the immunisation status of Australian children.¹³ The register is administered by the Health Insurance Commission (HIC), which is responsible for both routine reports and a recall-reminder system. The database holds immunisation details on all children under the age of 7 years who are registered for Medicare (approximately 98% of children by 12 months of age) and also for any notification of immunisation to the ACIR for children not registered with Medicare.

Immunisation information may be transferred to the ACIR by all providers in both the public and private sectors. Under-reporting is estimated to reduce immunisation coverage by approximately 10%,^{17,18} especially in States with a higher proportion of general practitioner (GP) providers such as New South Wales (NSW) and Western Australia (WA). Difficulties have also occurred in the transfer of data to the HIC from some regions.¹⁸

Coverage reports from the ACIR are based on 3 month birth cohorts measured at two 'milestones': 12 months (DTP, OPV and Hib vaccines) and 24 months (MMR, DTP, Hib and OPV vaccines).¹³

Results

Studies reviewed

A total of 108 out of 448 studies reporting published and unpublished data on immunisation coverage in Australian children from 1990 to 1998 were eligible for inclusion.

Fifty-one higher quality studies were selected from a range of designs and settings shown in Tables 1-7. These tables summarise the location, design, sample size and age, response rate, strategy and method of validation for each study. Several studies, which indirectly reported coverage data, were included in this review. For example, some evaluated the implementation of immunisation reminder systems¹⁹⁻²¹ others evaluated the effectiveness of the Parent Held Record (PHR),²² or the accuracy of parental report²³ or described an immunisation campaign.²⁴ A preliminary evaluation of the ACIR was also included.²⁵

Excluded studies²⁶⁻²⁹ were primarily those investigating immunisation procedures and processes rather than coverage. Seventeen letters and editorials^{14,30-46} and a review document on the role of parents and service providers⁴⁷ were also excluded as they did not contain original data on immunisation coverage.

Type of publication

The majority (72%) of the coverage studies included in the review were published in either peer-reviewed journals or State/Territory communicable diseases bulletins. Of the remainder, five were Master of Public Health treatises or PhD theses⁴⁸⁻⁵² and 12 studies were either published as government reports or were included in State government annual reports.^{7,53-64}

Methodology

Study populations

Most studies were either population-based (52%) or from specific settings such as child-care (9%), schools (29 %) or population sub-groups such as Aborigines or persons of non-English speaking background (6%). Six studies which were based in clinical or related settings were included in the review, five of which are shown in Table 7.^{23,65-68} Many of the population based studies, including the ABS, used appropriate random sampling methods but the findings may not be generalisable beyond the population from which they were drawn. Thirty school-based studies^{50,62,69-96} including all measles outbreak investigations were identified, with some overlap between primary and high schools in some studies. Nine of these are presented in Table 5 and five outbreak investigations are outlined in Table 6. Ten child-care studies were included,^{55,97-108} six of which are presented in Table 4.

Study design

Cross-sectional study designs accounted for 66% of the total, followed by birth cohorts (28%), of which three were retrospective^{51,109,110} and two prospective.^{104,111} All other prospective cohort studies used data from registers in Victoria (Victorian Maternal and Child Health Nurses (VMCHN) database),⁷ the Australian Capital Territory (ACT) (ACT Central Vaccination Register),⁶ Queensland^{8,9} and the Northern Territory (NT).^{10,11}

Sample size and response rates

The sample size in the studies varied widely, from a final sample of 69 two year old children in child-care¹⁰² to over 6,700 children in the 1995 ABS immunisation survey,⁵ shown in Tables 1-5. In many studies, particularly those using birth cohort methods, low response rates reduced power and generalisability. Furthermore, some studies reported significant differences in the characteristics of respondents and non-respondents, further reducing their representativeness.^{109,110} However, several studies using random sampling achieved response rates of above 90%.^{5,16,112-114} Two studies used the World Health Organization (WHO) method¹¹⁵ of cluster random sampling, one in a sparsely populated rural region⁵⁸ and one in metropolitan Melbourne.¹¹⁶

Vaccines studied

The majority of studies measured all age-appropriate vaccines with a small number measuring individual vaccines only (Table 3). Studies evaluating individual vaccines were primarily focused on recently introduced vaccines such as Hib^{6,61,117} and hepatitis B^{18,119} or were part of outbreak investigations for measles^{72,79,91} rubella,^{49,120} or pertussis.^{15,103}

Validation of immunisation status

The majority of studies in the Tables 1-7 validated at least a subset of their data by sighting Parent Held Records (PHRs) or by contacting the vaccination provider. A small number of serological surveys were conducted^{23,54,68,118,121} while immunisation databases used only data transmitted from providers.

*Validation of parental recall***Validation by Parent Held Record (PHR)**

Most parents use the PHR when it is available and refer to it as their primary source of information. Hall et al found that 80.1% of parents of children 2-4 years used the PHR which was completed correctly in most cases.⁵⁸ With some exceptions,^{121,122} most studies in this review investigating the validity of parental report found significant differences between reported and validated levels of vaccination. For example, a study in Northern Sydney found only 60% agreement between parental report of vaccination status and provider records.¹¹⁰

The 1995 ABS immunisation survey used both parental recall and viewing of PHRs (60.6%) for children aged 3 months to 6 years. Forty-seven per cent of children with records available were fully immunised compared with 33.1% of all children in the survey. The ABS study classified children as unimmunised if the parent could not recall the exact number of doses for each vaccine, which is likely to have underestimated true immunisation coverage.⁵

A study of children attending child-care facilities in Queensland also found that those with a PHR were more likely to be fully immunised at 2 years of age.⁹⁷ The PHR is less likely to be useful among disadvantaged groups, as illustrated by a study of Aboriginal families which found that there was no documentation of vaccinations for 52% of children.¹¹⁴

Serologic validation of parental recall

A serosurvey in Western Sydney medical centres found only 74% of the children in the total sample had protective levels of measles antibody, compared with 84% from parentally reported vaccination, a positive predictive value of 84%.²³ A population-based serologic survey in NSW found a non-significant difference in measles immunity between parents with written records (84% immunity) and those using parental report (76% immunity).¹²¹

Serological surveys

The small number of serological surveys largely focused on specific diseases, for example measles and rubella,^{23,49,54,121} including two studies^{54,121} that were opportunistically added to larger studies, for example the National Survey of Lead in Children. These studies gave valuable data on age-specific seroprevalence but were unable to differentiate between acquired and vaccine induced antibody (Causer et al, 1998; personal communication).

Regional immunisation registers

Coverage estimates from population immunisation databases are more likely to be accurate than parental recall, but underestimates coverage if providers do not report all immunisations given. The VMCHN database⁷ calculates age-specific coverage rates using all births in Victoria as the denominator and all children attending Maternal and Child Health (MCH) clinics as the numerator. The data are likely to be accurate for children up to 1 year of age, as approximately 90% of all children in this age group attend the clinics,⁷ but as attendance progressively falls and children may be immunised by more than one provider, ascertainment through MCH clinics is less complete over this age.

Other regional databases include the NT immunisation database,^{10,11} the ACT Central Vaccination Register⁶ and the Vaccination Information Vaccination Administration System (VIVAS) in Queensland.^{9,21} The VIVAS system includes a vaccine distribution scheme which increases reporting of immunisation encounters. The VIVAS and ACT databases have been modified to transmit data for the ACIR on a centralised reporting basis since early 1996, but the other separate databases have been discontinued.

School entry immunisation certificates

School entry immunisation certificates were made compulsory in NSW, Victoria and the ACT during the period covered in this review. A number of studies have assessed the quality of these data and estimated coverage for children entering school. Many schools do not have a completed certificate for all children in kindergarten or Year 1^{81,96} and those certificates which are completed substantially overestimate immunisation.⁷¹

Acceptance of non-statutory evidence of immunisation was identified as the major factor leading to over-estimation of compliance with the legislation.^{71,93,95} Two studies evaluating the effectiveness of the new legislation in Victoria and NSW found inconsistencies in the issuing and administration of certificates and evidence of schools. To reduce the impact of over-reporting, some studies excluded incomplete certificates from their analysis^{75,78} and one study concluded that school certificates should not be used for assessing coverage.⁸³

Child-care immunisation certificates

Immunisation certificates at entry into licensed child-care services have recently been introduced in many Australian states, some on a compulsory basis (NSW, Victoria, ACT). In 1995 in NSW, the Statewide Sentinel Immunisation Surveillance System (SSISS) database for child-care was established, containing a systematic random sample of child-care immunisation records.¹⁰¹ Among 745 children aged 2 years of age, 70% of children were recorded fully immunised (excluding Hib). Prior to the introduction of legislation in the ACT in 1994, 34% of records in a child-care centre were found to be incomplete during an outbreak investigation for pertussis.¹⁰³

A survey in the NT following the introduction of a voluntary program in 1995, found that centres had documentation for only 66% of children.¹⁰⁶ Similarly, a study reviewing documentation of immunisation records in Family Day Care and child-care centres in NSW in 1995 found that many parents in Family Day Care had not submitted their certificates to the provider.¹⁰² Overall it seems likely that similar problems to school immunisation certificates (poor quality and low levels of compliance) are prevalent with child-care immunisation certificates.

Measures of immunisation status*Full immunisation, partial immunisation and timeliness*

The outcome measure used in the majority of studies was 'fully immunised' and the ages most commonly used in the assessments were 24-35 months and school entry (aged 4-6 years). A summary of outcome measures for age groups of 1 year, 2 years and school entry are shown in Tables 8-10. A small number of studies did report both the coverage and timeliness of the vaccinations, with only 21% of vaccinations given on time in a Northern Sydney study

(within 1-2 weeks for the infant doses and 4-6 weeks for the 12 and 18 month doses).¹¹⁰ In child-care, although 66% of 2 year old children were completely immunised, only 24% had been immunised on time.^{99,100} Several studies measured the level of partial immunisation where one or more doses of vaccine were given but others had been missed. The proportion of partially immunised children ranged from 11% to 33.5%.^{58,69,99,100,106,110,123}

Age of assessment

Many studies showed a drop in the proportion of children immunised after the age of 12 to 18 months. In the ABS 1995 survey, 88.5% of children were fully immunised against D/T at 1 year falling to 63% at 2 years. These data indicate that while many children received the 12 month single dose of MMR, they did not receive the fourth doses of DTP and Hib at the age of 18 months. A child-care coverage survey found that coverage for the primary series of DTP and Hib was over 95%, falling at 18 months by 22%-26%.¹⁰⁶ Similarly, coverage of only 65% for the fourth doses of DTP and Hib was found in a regional Queensland database, where coverage for the first three doses had been 81%-84%.⁸

Vaccines assessed

Many studies reviewed reported coverage for separate vaccines, which while providing more information, made comparisons by age more complex. Moreover, while most studies reported the levels of the combined vaccine DTP, a small number reported levels of the combined diphtheria and tetanus (CDT) vaccine, which excludes pertussis, in their definition of 'fully immunised'.^{8,15}

The major change to the Immunisation Schedule during the review period was the introduction of Hib in April 1993, with free vaccine available from July 1993. As a result, several studies^{5,50,113} undertaken around this time give estimates of full immunisation coverage including and excluding Hib, with large differences between the estimates. For example, a school entry study using PHRs in 1996 found that full immunisation was 47% if Hib was included but that this increased to 74.5% if Hib was excluded.⁵⁰ Similarly, the ABS survey estimated that full immunisation for children aged 0-6 years was 33.1% with Hib and 52.1% without Hib.⁵

Immunisation status of 1 year old children

Only a small number of studies reported immunisation status for children at approximately 12 months of age (Table 8). There is some variation in the estimates for full immunisation as some include MMR and others exclude these antigens. Estimates from the ABS 1995 survey were 51.4% including Hib and 70.8% excluding Hib. Estimates of full immunisation from other studies were generally higher, for example the NT database reported levels of 75% including Hib.¹¹ Where rates for DTP are reported, however, these are similar to the ABS 1995 estimates. Assessment of immunisation status in a cohort of children in Melbourne suggested that 92%-93% of children aged either 9 or 16 months were fully immunised, much higher than both the 1995 ABS estimate and estimates from the VMCHN database. However, a serosurvey assessing the prevalence of measles immunity in NSW found that 77% of children aged 12-23 months were immune, which is 10% lower than the levels reported in the 1995 ABS survey but

consistent with a measles vaccine efficacy of around 90%.¹²¹

Immunisation status of 2 year old children

Table 9 illustrates the range of outcome measures used for children of around 2 years of age in several studies dated from 1994, including the 1995 ABS survey. Most of these studies included 4 doses of DTP and OPV in their definition of 'fully immunised', but at least one of these studies¹¹⁶ included only 3 doses of DTP and OPV in their assessment. Estimates for both full immunisation and DTP showed a very wide range (51%-88% and 58%-93% respectively).

The ABS 1995 rate of full immunisation for 2 year old children is much lower than any other reported estimate for this age group. The other studies that estimated full immunisation, including Hib, ranged from 51.1% - 66.5% compared to 34.3% for the ABS survey. Estimates excluding Hib ranged from 60.3%-87.8%, compared to 51% for the ABS survey. A cross-sectional, population-based, cluster sample survey in Newcastle, NSW,¹¹³ reported estimates both with and without Hib of 51.1% and 77% respectively. While the reported immunisation coverage for DTP and OPV in the two Victorian studies were similar,^{7,116} estimates for the same vaccines differed in the NT, although one of these was a child-care centre based study.^{10,106}

There were also major variations in coverage reported for studies using the same method of data collection. For example, the Victorian immunisation database⁷ showed that 85.3% of children aged 18 months to 3 years in 1996-97 were immunised for DTP while the urban Darwin database in the NT reported that only 60% of children had been immunised for DTP in 1996.¹⁰ The pattern for all other vaccines in these databases was similar with the exception of Hib and it is unclear whether these are caused by technical problems with the database or due to actual differences in coverage between the States.

Immunisation status at school entry

Table 10 shows estimates from school entry and other school surveys, which as discussed above, show a higher level of full immunisation coverage than for younger children. In WA between 80% and 86.5% of children were fully immunised (excluding Hib).^{81,125} In NSW, 89% of children were classified as fully immunised at school entry, based on parental reports.⁶⁹ Overall, the estimates shown in Table 10 are higher than those from the ABS 1995 survey but are likely to be overestimates (see Methods).

Child-care settings

Studies based in child-care centres using provider held documentation, show estimates of full immunisation for 2 year olds ranging from 60.3%-85%.^{97,99,100,106-108} One study in the NT found that 67% of 2 year old children with child-care immunisation certificates were fully immunised and that this rate was higher than in the general population of 2 year olds in Darwin,¹⁰ although estimates in Darwin were lower than those using data from all seven NT databases.¹¹ A prospective cohort study in Perth found higher rates of full immunisation (excluding Hib) than other comparable studies, with levels ranging from 86% at 12 months to 85% at 24 months.^{104,105} However, these data were based on parental report only and are likely to be overestimates.

Immunisation status in States and Territories

State by State coverage results from population-based studies and for children aged 2 years are reported in Table 11 and are compared with the ABS 1995 results. In all regions, with the exception of Tasmania and one study in the NT, the fully immunised coverage estimates from studies other than the ABS are much higher. This appears to be largely due to low proportions of DTP in the ABS data, (48%-66%). Rates for OPV and MMR, however, are largely comparable with the ABS estimates and as expected, Hib rates are lower in the ABS than the other studies. Interestingly, the ABS estimates vary considerably between States, with Tasmania showing full coverage of only 23.9% (including Hib) compared to 42.5% in WA. Estimates without Hib for these two States were 37.3% and 58.3% respectively.

Hib

Two studies in the review assessed the pre and post uptake of Hib after its introduction in 1993 and one of these also compared the age-specific incidence of Hib with changes in uptake of Hib.^{6,61,122} In Sydney, uptake of Hib was estimated at 9% in May 1993 rising to 48% in August 1993 for children under 18 months of age and rising from 31% to 45% in the same period for children aged 19-60 months.^{61,122} The ACT immunisation register estimated that 68% of 9 month old children and 34% of 2 year old children had received Hib vaccine by March 1995.⁶

Hepatitis B

Three studies assessing the level of coverage of hepatitis B in specific populations, including Aboriginal and non-English speaking groups were involved in the review.^{68,118,119} Coverage was generally low, with only 54% of Aboriginal children (median age of 24.5 months) in North Queensland immune to hepatitis B.¹¹⁸ In one study however, 81.6% of infants from 'at risk' groups in Victoria received one or more doses of hepatitis B vaccine.¹¹⁹

Aboriginal communities

Some studies assessing coverage in Aboriginal children from remote communities in the NT and WA suggested a higher than average rate of immunisation.^{112,125} For example, the NT study estimated that over 97% of 2 year old children had been immunised for all vaccines other than fourth doses of DTP and polio.¹¹² Conversely, studies in urban and less remote rural areas found a much lower level of coverage in Aboriginal children compared to non-Aboriginal children from the same populations.^{57,114} For example, a study in western NSW estimated that only 60% of Aboriginal children aged between 2 and 4 years of age were fully immunised compared to 84.1% of the non-Aboriginal children.⁵⁷ Furthermore, a study in the North Coast region of NSW reported ABS estimates which showed the immunisation status for Aboriginal children was only half that of the overall population.¹¹⁴

Evaluating Australian coverage studies

The 51 higher quality studies summarised in Tables 1-7 included 38 published in peer-reviewed journals, the two ABS surveys (1989-90 and 1995)^{5,16} and 12 government reports, treatises and abstracts. Attempts to evaluate all these studies were difficult for reasons previously outlined in this review due largely to variations in age groups, vaccines studied and definitions of immunisation status, in

addition to study design and other criteria used for assessing quality. Generalisability and reliability at a national population level were key determinants of quality and in this review only the ABS surveys fulfilled these criteria.

The studies with highest validity at a State level were databases using provider-held records and calculating coverage from a prospective birth cohort, such as the VMCHN database,⁷ the ACT vaccination database⁶ and the NT database.^{10,11} The NT database was also sensitive enough to give data on specific small populations such as remote Aboriginal communities.¹¹²

The second category of coverage studies was cross-sectional studies with appropriate sampling and high response rates that are likely to have high validity for the specific populations included. These included a cluster sample from metropolitan Melbourne,¹¹⁶ a cluster sample from Newcastle, NSW¹¹³ and a cross-sectional study of Hib vaccine coverage in Sydney.^{61,122} A household study in central Sydney investigating coverage of measles and rubella used serology to validate parental report and while this provided optimum validation it was only generalisable to the local area.⁵³ All these surveys had positive features but generalisability of the findings was limited by the differences in vaccine delivery and uptake between regions in Australia.

The third category of coverage surveys was retrospective birth cohorts, which shared the problem of low response rates and selection bias. Response rates in Sydney,¹¹⁰ Western Australia⁵¹ and Queensland¹⁰⁹ were 49%-58%. It is likely that respondents have higher immunisation coverage than non-respondents and that this study design will overestimate coverage.

The ABS immunisation survey remains the reference standard in this review for generalisability and reliability. This is followed by State immunisation databases and then a small number of coverage surveys. However, all these designs exhibit different biases and comparisons are difficult. A national, prospective birth cohort design in which data is complete is clearly the ideal method, complemented by ad hoc coverage surveys to assess coverage in small populations with special needs such as urban Aboriginal communities.

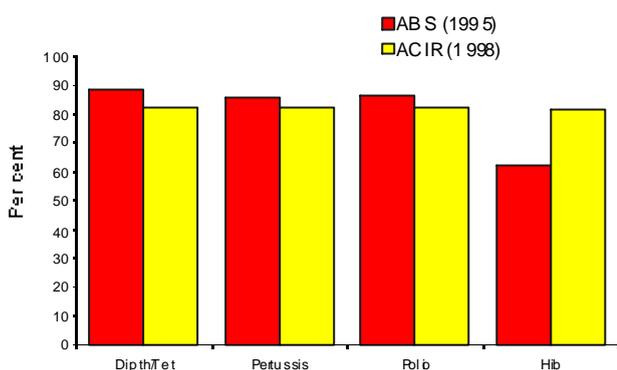
Comparison of data from the ACIR with the ABS

Table 12 compares the proportion of children fully immunised with DTP, OPV and Hib in each State and Territory using the ABS 1995 survey and the ACIR coverage estimates.¹⁸ The estimates for DTP and OPV from the ABS are much higher than those for the ACIR for all States/Territories with the exception of Queensland, probably reflecting the more complete data available from the VIVAS reporting system which is linked to the vaccine supply.

It is important to note that ABS estimates for full immunisation at 1 year were derived from a cross-sectional sample at 12-23 months of age whereas the ACIR reports the status of a birth cohort at 12 months of age. This means that children who received the third dose of a vaccine scheduled in the first year of life after 12 months of age are deemed immunised by the ABS but not by the ACIR, which may slightly increase the ABS estimates.

As expected, Hib coverage is lower in the ABS estimates than in those from the ACIR because the ABS survey was conducted soon after the introduction of Hib vaccine, while ACIR data refer to a 1996 birth cohort (Figure 1). The comparison shows how rapidly uptake of Hib vaccine occurred, with an average increase of 17% for all of Australia. The only region with similar Hib vaccine estimates in both the ACIR and the 1995 ABS survey is the NT, where the two dose primary course and widespread publicity may have promoted early Hib uptake.

Figure 1. Immunisation coverage for one year olds: ABS 1995 and ACIR 1998



Overall, ACIR estimates should be viewed as preliminary minimum estimates consistent with the estimates from the ABS survey. Coverage as measured by the ACIR is likely to improve dramatically with the introduction of a range of incentives for parents and providers to immunise and to report to the ACIR.

Comparisons with overseas studies

Immunisation coverage estimates overseas in comparable industrialised countries such as the UK and the USA are higher than in Australia. Estimates for five other English speaking countries are shown in Table 13. The vaccination coverage statistics for children at 12 months of age in the UK for three doses of DTP, OPV and Hib are between 91.7% and 92.8%, compared with estimates from the ABS 1995 survey of 83%-86% for DTP and OPV (Figure 2).

Coverage for children aged 2 years in the UK is higher than at 12 months, contrasting with the situation in Australia in which a reduction in coverage occurs after 12 months of age. However, the UK immunisation schedule does not include a fourth dose of DTP or Hib at 18 months, in contrast to Australia. In the UK, regional databases submit immunisation data to a centralised register from which quarterly reports are prepared. This system commenced in 1987 and uses the birth cohort method to analyse data, which is similar to the ACIR. It also incorporates a financial incentives scheme for GPs to encourage high immunisation levels and the British national target now exceeds 90% coverage for each antigen.

In the USA, the National Immunisation Survey (NIS)¹²⁸ was initiated in 1994 as the main method to estimate coverage for children aged 19-35 months. In this quarterly random

telephone survey, response rates are around 67% and providers are also contacted for verification of immunisation status. The 12 month estimate for the period January to December 1997 was 95% for three doses of DTP or CDT, 91% for OPV and 93% for Hib and 91% for a measles-containing vaccine (MCV).¹²⁸ The equivalent proportions for the 1995 ABS survey are comparable for measles but much lower for DTP (at only 63% for diphtheria /tetanus and 58% for pertussis) and also for OPV (87%). Estimates of full immunisation at around 24 months of age show that 78% of children in the USA were fully immunised in comparison to 51.3% of children in Australia.¹²⁸

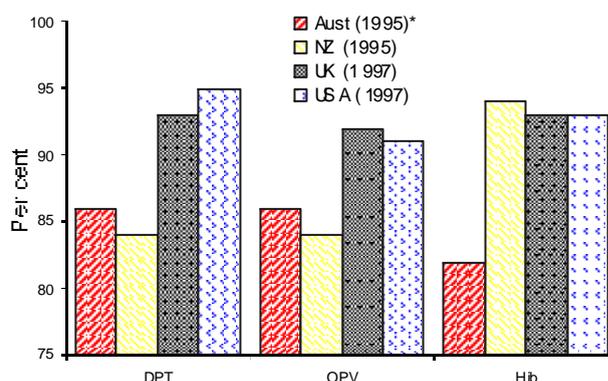
Prior to the implementation of the NIS, coverage was measured by ad hoc surveys and it was found that while most children (87%) were fully immunised at school entry because of legislation requiring compulsory immunisation, the proportions for children aged 2 years old were much lower at 44%.¹²⁹ Coverage for very young children in the USA has therefore increased substantially since 1994.

The Canadian experience mirrors that of the USA in that immunisation estimates were not collected in a standardised manner until 1994, when a system which collects data by mailed questionnaire for four cohorts of children turning 2 years of age during 1994-96 was implemented.¹³⁰ Coverage for this period ranged from 85%-87% for four doses of DTP, and was 90% for polio. Coverage for MMR was high at 97% and has remained fairly constant while the lower rates for Hib vaccine reflect its introduction during the period of data collection.

Vaccine specific estimates increased by 1% -3% above baseline in the period from 1994 to 1996.¹³⁰

New Zealand immunisation estimates were obtained by coverage surveys and by health benefit claim data. Immunisation estimates in the 1990s show a progressive increase in coverage from a relatively low level. For example, a cohort study of children born in 1990-1991 found a complete immunisation rate of 75% by 6 months of age¹³¹ while a more recent cohort study in Christchurch in 1995 estimated that 93% of children had been fully immunised by 8 months of age.¹³³ Health Benefit data from 1994 are shown in Table 13, with an estimated a range of 79%-87% for most vaccinations for children aged

Figure 2. Immunisation coverage at age one year: international comparisons



12-18 months.¹³³ Recent New Zealand coverage data for the same age group indicates that coverage levels of DTP/Hib in 1997 dropped slightly to 87.3% after an overall increase to 90.6% in 1996.¹³⁴ This may be due to changes in processing claims rather than a real decrease. Coverage for Maori and Pacific Islander children was lower in northern New Zealand than for all other children, reflecting a similar pattern similar to Aboriginal children in Australia.^{58,114,135}

While there is some variation with the immunisation schedules in some overseas countries, the available data suggest that the UK, USA and Canada out-perform both Australia and New Zealand particularly for immunisation with pertussis containing vaccines. The differentials are especially large when comparing coverage for the fourth dose of DTP, with estimates in Australia falling well behind those of the other countries in Table 13. The UK appears to have the highest coverage levels of all the countries surveyed, with estimates of between 90%-95% for all antigens shown in this table. While the Australian data are not as recent as all the other estimates in Table 13, they remain the only population-based estimate available for comparison, while the ACIR is still in the developmental stage.

Coverage levels in most other countries in the world are reported on the WHO Internet site.¹³⁶ These data are obtained from routine national reports without details of methodology and are therefore difficult to compare with those outlined above.

Discussion

The best estimate of immunisation status in Australian children, or reference standard, in 1998 is the 1995 ABS survey. It is the only national coverage study that is generalisable to the whole population, despite concerns about reliance on unvalidated parental report for almost half of the responses. However, it is likely that the ACIR will take over this role when it becomes fully established.

The estimate for full immunisation in the ABS study for children aged 2 years (51%), even when Hib was excluded from the analysis, was substantially lower than those in other coverage studies in this review (range 60% to 88%). This appears to be due largely to lower reported levels of DTP rather than the levels of OPV and MMR. With the exception of serological surveys which tend to focus on assessing coverage for single vaccines in specific populations, the ABS was also the best estimate of coverage for specific vaccines and 'milestones'.

When estimates from the ABS 1995 survey were compared with the first 'milestone' data from the ACIR (Table 12), the ABS estimates were higher than the ACIR for most vaccines and some statewide differences did emerge in this comparison. However, any meaningful interpretation is complicated by technical difficulties with the ACIR resulting in underestimates of coverage at present. This may improve with the introduction of financial incentives to GPs based on their performance as recorded by the ACIR, from July 1998. The exception was the difference between the low levels of Hib in the ABS 1995 survey (during the phasing-in of the vaccine) and the higher estimates of the ACIR. This comparison is useful as it shows how quickly the uptake of Hib has occurred in younger Australian children.

This review included both published and unpublished literature, reducing the possibility of publication bias resulting in an overly optimistic view of immunisation coverage. The extent to which the large variation in coverage estimates was attributable to methodological problems in study design and analysis was often impossible to assess, as very few publications provided adequate data. It was difficult to determine whether the net effect of a particular study had been to underestimate or overestimate vaccine coverage.

The higher quality studies were larger and population based. Retrospective cohorts suffered from low response rates and selection bias, leading to an overestimate in coverage. Cross-sectional studies, although largely free of bias, provided only a snapshot at one point in time and could not monitor trends. Most of the immunisation databases cited in the review were derived from prospective birth cohorts, as was the ACIR and the well established COVER database in the UK. This method is clearly the best design if reporting is complete, and provided there has been adequate time for the operation of the database to become established.

Serological surveys, while the most accurate method for validating coverage, have sample sizes that are necessarily limited and therefore differences between population subgroups cannot be examined. At the whole population level, serological surveys have been shown to be very useful in demonstrating trends in susceptibility to vaccine preventable diseases, as in the UK.¹³⁶ The first population-based serological surveys using opportunistically collected sera are currently underway in Australia sponsored by the National Centre for Disease Control and conducted by the NCIRS. These surveys will be repeated on a two or three-yearly basis.

In contrast, parental recall is the simplest means of estimating immunisation status, but frequently overestimates coverage. The PHR is more accurate than parental recall, but is dependant on the quality of the information added to the record and the book being kept up-to-date. Well maintained provider-held records overcome these problems but must be adequately linked for children who have multiple providers and/or high mobility. Providers are the source of data for the State/Territory immunisation databases in this review, for the ACIR and for coverage in the UK¹²⁶ and the USA.¹²⁸

As methodology strongly influences the final estimates, this review supports the need for a nationally consistent methodology, facilitating comparisons between regions. A national, prospective birth cohort design in which data are complete is clearly the ideal method, complemented by ad hoc surveys to assess coverage in small and specific populations, for example urban Aboriginal communities.

Immunisation coverage in developed countries overseas, particularly the UK, is reportedly higher than in Australia (over 90% for all antigens at 24 months). Both the USA and Canada collect national data regularly using national surveys. The USA has recorded increased uptake in infants and very young children since the implementation of their quarterly surveys. The UK has a well established centralised immunisation database which reports coverage data on a quarterly basis. The use of 1995 data from Australia, however, meant that it was not as up to date as the other overseas estimates. A fundamental requirement

in comparing such estimates is the need for timely, accurate Australian data which should be achievable through the ACIR.

Failure to develop a regular system of measuring immunisation coverage which is high quality and generalisable at a national population level will result in continued confusion about the true levels and trends of coverage in Australia. It is only by having a sensitive and

timely system that interventions to improve and maintain coverage can be assessed and gaps identified. Only when true coverage rates regularly exceed 90% can we hope to achieve and maintain the levels of herd immunity needed to interrupt transmission of vaccine preventable diseases in Australia. We will then be able to eliminate diseases such as measles and take a responsible role in the world-wide eradication efforts planned by the World Health Organization.

Tables

Table 1. Immunisation coverage : Population-based studies (national and regional) with high response rates

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy and date	Validation
ABS (1989) ⁶	Australia (national)	Cross-sectional population survey	Multistage, random sample of 12,732 children aged 0-14 years	96%	Household interviews with data for children 0-14 years collected by parental report	Parent Held Record (PHR) consulted in 45% cases
ABS (1995) ⁵	Australia (national)	Cross-sectional population survey	14,591 children aged 0-14 years (6,768 aged 0-6 years)	>95%	Household interviews. Parental report	PHR consulted in 61% cases
Australian Childhood Immunisation Register (ACIR) ¹⁸	Australia (national)	Birth cohort, Immunisation Register	All Australian children aged 0-6 years (birth cohort 259,167 children in 1996)	>76% NSW >86%Victoria	Providers submit immunisation data to national database	Provider held records used
Victorian Maternal and Child Health database ⁷	Victoria (statewide)	Birth cohort using MCH records	All children age 0-6 years attending maternal & child health clinics (birth cohort 62,857 children in 1996)	90% of all births, decreasing with increased age	MCH nurses collect data and this is collated annually	Use verified records
Carnie J et al 1995 ¹¹⁶	Three areas of metropolitan Melbourne	Cross-sectional population survey	Cluster sample (WHO method) of 630 children aged 18 months to 3 years	N/A	Household interviews in 1991. Parental report	PHR or provider held records used
Thorman et al (1997) ¹¹	Northern Territory (NT) (statewide)	Birth cohort, Immunisation Register	All children born after January 1996 (part of ACIR) (birth cohort 35,000 in 1996)	87%	Providers submit immunisation data to NT database	Provider held records used
Mitchell et al (1997) ¹⁰	Darwin urban area	Birth cohort, Immunisation Register	All children immunised in Darwin urban area (approx birth cohort 2,500 in 1995)	91%	Providers submit immunisation data to database	Provider held records used
Skinner et al (1995) ¹¹⁰	Northern Sydney Health region	Birth cohort (retrospective)	1,004 children aged 2 years from a 3 month birth cohort	58%	Parent questionnaire (sent by mail) in 1994	Providers contacted. 60% agreement with parents
Herceg et al (1995) ¹¹³	Newcastle, NSW	Cross-sectional population survey	Cluster sample of 187 children aged 2 years	97%	Household interviews in 1994. Parental report	PHR or provider held record

Table 1. Immunisation coverage : Population-based studies (national and regional) with high response rates, continued

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy and date	Validation
Sullivan et al (1998) ¹²⁴	NSW	Cross-sectional population survey	Multistage, random sample of 322 children aged 3-24 months	100%	Household interviews undertaken in 1992	PHR only (produced in 84% of cases)
Bond et al (1998) ¹⁷	NW Melbourne Victoria	Randomised controlled trial	405 children 9 months or 16 months	100%	Children on the ACIR who were late for their vaccinations were randomised with 2 arms to evaluate a home vaccination service	PHR and provider held records used
Parker et al (1996) ⁸	Darling Downs, SW Queensland	Birth cohort, Immunisation Register	50,000 vaccination events for children born 1994 onwards	N/A	Vaccination rates calculated from vaccination events	Provider held records used
Guthridge et al (1993) ¹¹²	NT (remote Aboriginal communities in 3 districts)	Birth cohort, Immunisation Register	461 Aboriginal children born in 1990, and aged between 12-24 months	90%	Data analysed on all vaccinations received by cohort until December 1992	Provider held records used
Young et al (1994) ¹¹⁴	North Coast Health Region of NSW	Cross-sectional survey	1,094 Aboriginal children aged from 0-11 years	93% of study population	Review of provider held immunisation records from 10 areas in Region in 1991	Provider held records used
Hall et al (1994) ⁵⁸	Western NSW (4 rural health districts)	Cross-sectional survey	Cluster sample of 211 children (WHO method) aged 2-4 years	>98%	Survey by telephone and household interview using modified WHO method in 1993	PHR cited in most cases
McCall et al (1995) ¹⁰⁹	West Moreton, Queensland	Birth cohort (retrospective)	108 children aged 18 months	55%	Household interviews. Significant difference between respondents and non-respondents	Provider held records used
Hanna et al (1995) ¹¹⁸	Queensland (10 Aboriginal and Torres Strait Islander communities)	Cross sectional serological survey (HBV, OPV, measles)	101 Aboriginal children median age 24.5 months (non-random)	N/A	Serosurvey of fully vaccinated children to assess immunity to HBV, OPV, measles	Provider held records and serosurvey
Kilmartin et al (1998) ¹¹¹	Southern Tasmania	Prospective birth cohort	242 mothers of infants born between June 1994 and February 1995	75% at 1 week and 61% at 12 months	Mothers completed questionnaires by interview (1 week) and mail (12 months) post-partum	PHR used
Andrews et al (1995) ³⁰ Part 1 of study, see Table 4	Victoria (Upper Yarra)	Retrospective review of immunisation records	845 children aged 2-4 years	N/A	Review of immunisation records from Shire of Upper Yarra's Shire database in 1995	Provider held records used

* Response rate shows % of original sample in the final sample

Table 2. Immunisation coverage: Studies (population and settings based) with less than 50% response rates

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy and date	Validation
EdwardsBM et al (1995) ⁵¹	Western Australia (WA) (statewide)	Birth cohort (retrospective)	487 children born in April 1993 (and aged 2 years at time of survey)	49%	Questionnaire mailed to mothers across WA, randomly selected from midwives database	96.5% mothers referred to PHR (not validated by researchers)
Conaty et al (1996) ⁵⁷	Western Sydney, NSW	Cross-sectional telephone survey	483 children aged 2 years	36%	Telephone household survey conducted in 1995 in Western Sydney and Wentworth Health Areas	86% respondents cited PHR
Ferson MJ et al (1995) ⁷⁴	NSW (Eastern Sydney)	Randomised controlled trial of primary school intervention	103 in final sample (249 randomised) from kindergarten in 1991	43% of randomised children	Kindergarten children screened and non-fully immunised children randomised into 2 intervention arms	Screening cards completed by school nurses
Miles et al (1996) ¹⁰²	Hunter Health Area, NSW	Cross-sectional survey	69 children aged 2 years attending formal child-care	29%	Review of immunisation records held by child-care services in 1995	Provider held record used

* Response rate shows % of original sample in the final sample

Table 3. Immunisation Coverage: Population-based studies (national and regional) single vaccine studies

Study	Location	Design	Sample size and age	Response rate* (%)	Strategy and date	Validation
Causser et al (1998) ⁵⁴	Central and Southern Sydney, NSW	Cross-sectional serological survey (measles & rubella only)	580 children aged 18 months to 5 years	75% approx.	Household interviews and venous blood samples	PHR and serosurvey
McIntyre et al (1995) ¹²²	Sydney Statistical Division	Cross-sectional population survey (Hib only)	549 children aged 0-4 years from 412 households	82%	Random telephone sample to households in August 1993	50% sub-sample had records verified from providers
McIntyre et al (1994) ⁶¹	Sydney Statistical Division	Cross-sectional population survey (Hib only)	551 children aged 0-4 years from 394 households	74%	Random telephone sample to households in August 1994 (repeat of 1993 survey)	50% sub-sample had records verified from providers
O'Brien et al (1997) ⁶	ACT (statewide)	Birth cohort using immunisation register (Hib only)	9,790 children aged either 9 or 24 months	N/A	Providers submitted immunisation data to ACT central database	Provider held records used
Oman et al (1997) ¹¹⁹	Victoria (statewide)	Birth cohort using MCH records (Hepatitis B only)	3,611 children at risk of HBV aged 12-24 months	63% of infants at increased risk of HBV	MCH nurses collected data on 'targeted' infants born between July 1992 - June 1993	Provider held records used
Ferson et al (1998) ¹²¹	NSW	Population-based serosurvey using data from National Survey of Lead in Children	347 children aged 1-4 years in 1995 who provided adequate blood sample for two assays	50% provided adequate blood sample	Blood samples collected from National Lead survey were tested for measles and compared with parental report and PHRs	Serosurvey

* Response rate shows % of original sample in the final sample

Table 4. Immunisation coverage in child-care settings

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy	Validation
Hanna et al (1994) ⁹⁷	Northern Queensland (Cairns area)	Cross-sectional survey	Cluster sample of 613 children aged 0-5 years attending formal child-care	94%	Review of immunisation status using PHR and provider held records	PHR and provider held records used
Lloyd et al (1996) ⁹⁹	Illawarra region, NSW	Cross-sectional survey	1,109 children aged 0-2 years attending 80 child-care centres	94% of child-care centres	Review of immunisation records held at child-care centres in 1995	Provider held records used
Menzies et al (1996) ¹⁰¹	NSW (statewide)	SSISS Immunisation register†	745 children aged 2 years attending child-care centres	N/A	Review of sample of records in SSISS register in 1995	Provider held records used
Chow et al (1995) ⁵⁵	Western Sydney, NSW	Cross-sectional survey	1,092 children aged 2-3 years attending 95 long day care centres	83% of child-care centres	Review of immunisation records held by centres in Western Sydney and Wentworth Health Areas	Provider held records used
Mitchell et al (1997) ¹⁰⁶	NT (Territory-wide)	Cross-sectional survey	269 children aged 2 years in 39 child-care centres	66% of children from 87% of centres	Review of immunisation records held at child-care centres in 1995	Provider held records used
Andrews et al (1995) ⁴⁸ Part 2 of study (see Table 1)	Victoria (Upper Yarra)	Cross-sectional survey	250 children randomly selected from 700 Family Day Care and pre-school records in 1995 (2-4 years old)	75%	Parent questionnaire (mailed)	Immunisation Register used to validate responses

* Response rate shows % of original sample in the final sample

† Statewide Sentinel Immunisation Surveillance System

Table 5. Immunisation coverage in schools

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy	Validation
Watt et al (1996) ⁹⁶	NSW Central Coast	Cross-sectional survey (school entry)	3,741 children from 68 schools, enrolled in kindergarten in 1994	97% of total kindergarten enrolments	Review of immunisation certificates in all North Coast schools including non-government schools	School entry certificates used (90% completed)
Kelly et al (1993) ¹²⁶	WA (Midwest & Gasgoyne regions)	Cross-sectional survey (school entry)	1,008 children from 49 schools, enrolled in Grade 1 in 1992	N/A	Review of immunisation status by school nurse using a range of documentation and maternal report	86.7% of children had 'adequate' documentation
Kelly et al (1994) ⁸¹	WA (Great Southern Region)	Cross-sectional survey (school entry)	1,220 children enrolled in Grade 1 in 1994	N/A	Review of immunisation status by school nurse using documentation and maternal report	84% had immunisation cards or school records
Gilchrist et al (1993) ⁷⁶	NSW (South West Health Area)	Cross-sectional survey (school entry)	3,666 kindergarten children attending schools in 1992	86%	Questionnaire mailed to parents by school nurses	Most parents consulted PHR - not validated by researchers

Table 5. Immunisation coverage in schools, continued

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy	Validation
Bell et al (1993) ⁶⁹	NSW (western Sydney)	Cross-sectional survey in primary schools	966 kindergarten children in 1992	91% sample	Questionnaire mailed to parents, including non-government schools	No - parental report only
Kempe et al (1995) ⁸²	ACT (Territory-wide)	Cross-sectional survey (school entry)	Random sample of 350 immunisation records from 3,398 kindergarten records	85% parents returned child's record to school (N=3,398)	Review of a sample of school immunisation records for kindergarten children in 1994	Providers authorised the records
Leckie et al (1996) ⁸³	NSW (Auburn LGA)	Cross-sectional survey (school entry)	737 kindergarten children in all primary schools in 1994	100%	Review of all school immunisation records by school nurses	Most had provider authorised records
Watson (1997) ⁹⁵	WA (Swan Health Service)	Cross-sectional survey (school entry)	405 kindergarten children from 9 primary schools	100%	Review of all school immunisation records by school nurses and follow-up as required	Provider authorised records used
Duffield (1997) ⁵⁰	WA (Southern Region)	Cross-sectional survey (school entry)	2,203 kindergarten children from 158 schools in 1995-6	55%	Review of immunisation records by school nurses with follow-up if no record produced at enrolment	Provider authorised records only used

Table 6. Immunisation coverage: Outbreak studies

Study	Location	Design	Final sample size and age	Response rate* (%)	Strategy	Validation
Herceg et al (1994) ⁷⁹	ACT (one primary school)	Cross-sectional survey (outbreak investigation for measles)	384 children attending a primary school aged 4-12 years	78%	Questionnaire mailed to parents and cases identified in 1993	Parents asked to consult PHR
Miles et al (1992) ⁸⁸	Port Stevens Shire, NSW	Cross-sectional survey (outbreak investigation for measles)	158 cases including 116 school pupils (average age 7 years, 7 months) 73% school children	N/A	Data was collected on all cases in a measles outbreak by active surveillance and contact tracing in 1990	Record of clinical or serological diagnosis
Donnelly et al (1994) ⁷²	Bunbury, WA	Cross-sectional survey (outbreak investigation for measles)	53 cases from high and primary schools	N/A	All cases notified received a telephone questionnaire and contacts were identified	Serological confirmation in 40% of cases
Lush et al (1994) ⁸⁴	Alice Springs, NT	Review of measles notifications (outbreak investigation for measles)	258 cases notified aged from <1 year to over 30 years (55% Aboriginal)	N/A	Review of notifications and hospital records of measles cases	Serosurvey and clinical diagnosis
McDonnell et al (1995) ⁸⁵	NSW (Western Sydney)	Matched case-control study (measles vaccine)	79 children aged 5-9 years in 5 primary schools in 1993	91% response from initial screening survey	Screening for measles by parent questionnaire (mailed). Cases and controls selected, parents interviewed at home	PHR / provider held records used

* Response rate shows % of original sample in the final sample

Table 7. Immunisation coverage in other settings

Study	Location	Design	Final sample size and age	Response rates*	Strategy	Validation
Burgess et al (1996) ⁶⁵	NSW (Central Sydney)	Cross-sectional survey in Early Childhood Centres (ECCs), GP surgeries and hospital A&E	5,162 children age 0-15 years during an 8 week period in 1993	N/A	Questionnaire completed by all parents prior to their child receiving service (ECC, GP or A&E). 'On the Spot' vaccination given if required	Provider records used where possible (or parental recall)
Jones et al (1992) ⁶⁷	NSW (Camperdown, Sydney)	Cross-sectional survey (hospital based)	All children (N=520) attending casualty over a 10 day period in 1989	100%	Parents of all children attending a paediatric casualty dept. were interviewed	PHR and provider held records where possible
Thompson et al (1998) ⁶⁸	Melbourne Juvenile Justice Centre (MJJC)	Cross-sectional serological survey	90 adolescents participated and 85 agreed to venipuncture	69% participated	Questionnaire completed and blood sample taken from trainees at the MJJC	Serosurvey
Hawe et al (1991) ²³	NSW (Western Sydney)	Cross-sectional serological survey (measles only)	128 children in final sample in 1986-87	80%	Parents were approached in four 24 hour medical centres waiting rooms and interviewed. Blood sample also taken	Serosurvey
Ewald et al (1998) ⁶⁶	Alice Springs, NT	Cross-sectional study of PHRs in three General Practices	146 children aged 0-6 years attending GPs in Alice Springs in 1997	100%	Parent interviews at the GP surgeries. PHRs viewed and results checked against ACIR database	PHRs, providers records and ACIR

* Response rate shows % of original sample in the final sample

Table 8. Summary of immunisation status for children aged 12-23 months (using studies dated from 1995)

Study State	Age	DTP (3 doses) (%)	OPV (%)	MMR (%)	Hib (%)	Fully immunised (%)
ABS (1995) (Australia) ⁵	12-23 months	88.5% (D/T) 86.2% (P)	86.3%	86.8% measles 86.0% mumps 81.4% rubella	62.3%	51.4% (incl. Hib) 70.8% (exc. Hib)
Bond et al (1998) (Vic) ¹⁷	9-16 months	N/A	N/A	N/A	N/A	9 months: 93.1% (includes Hib) 16 months: 92%
Victorian Maternal & Child Health nurses (1995-6) (Vic) ⁷	1-2 years	85.2%	85.4%	77%	N/A	N/A
Thorman et al (1997) (NT) ¹¹	12-14 months	89%	87%	91%	79%	75%
Parker et al (1995) (Qld) ⁸	12-18 months	85-86% (DTP/OPV/Hib)		81%	N/A	N/A
Kilmartin et al (1998) (Tas) ¹¹¹	12 months (54 weeks)	N/A	N/A	N/A	N/A	94%
Skinner et al (1995) (NSW) ¹¹⁰	12 months	N/A	N/A	N/A	N/A	21% (on time)

Table 9. Summary of immunisation status for children aged 2 years (using studies dated from 1994)

Study State	Age range	DTP (%)	OPV (%)	MMR (%)	Hib (%)	Fully immunised (%)
ABS (1995) (Australia) ⁵	24-35 months	63% (D/T) 57.5% (P)	86.9%	91.5% measles 90.1% mumps 81.1% rubella	52%	34.3% (inc. Hib) 51.3% (exc. Hib)
Skinner et al (1995) (NSW) ¹¹⁰	21-24 months	N/A	N/A	N/A	N/A	86% (exc. Hib)
Herceg et al (1995) (NSW) ¹¹³	24-35 months	80.9%	95.5%	93%	59.2%	51.1% (inc. Hib) 77% (exc. Hib)
Lloyd et al (1996) (NSW) ⁹⁹	24-35 months	69.9%	79.8%	86.5%	N/A	63.8% (exc. Hib)
Hall et al (1994) (NSW) ⁵⁸	2-4 years	84%	89.6%	90.6%	N/A	80.2% (exc. Hib)
Sullivan et al (1998) (NSW) ¹²⁴	3-24 months	N/A	N/A	N/A	N/A	66% (exc. Hib)
Hanna et al (1994) (QLD) ⁹⁷	24-35 months	63.8%	82.4%	81.9%	N/A	60.3% (exc. Hib)
Victorian Maternal and Child Health Nurses (1996-7) (VIC) ⁷	24-35 months	85.3%	86.7%	76%	85.2%	N/A
Carnie et al (1995) (VIC) ¹¹⁶	18-36 months	93.1% (DTP/ OPV)		89.9%	N/A	87.8% (exc. Hib)
Mitchell et al 1996 NT child-care services (NT) ¹⁰⁶	24-35 months	77%	73%	92%	76-81%	66.5% (inc. Hib)
Mitchell et al 1996 Urban Darwin area (NT) ¹⁰	24-35 months	60%	60%	76%	50%	N/A

Table 10. Summary of immunisation status for children at school entry, aged 4-6 years, using selected studies from the review

Study State	Location	Age	Fully immunised (%)*†
ABS (1995) (Australia) ⁵	National	6 years	21.5%
Bell et al (1993) (NSW) ⁶⁹	NSW (Western Sydney)	4-6 years	89%
Watt et al (1996) (NSW) ⁹⁶	NSW (Central Coast)	5 years	79%
Roden et al (1992) (NSW) ⁹⁰	NSW (Western Sydney)	5 years	84%
Kempe (1995) (ACT) ⁸²	ACT	4-5 years	67%
Kelly et al (1994) (WA) ⁸¹	Western Australia	4-6 years	80%
Watson et al 1997 (WA) ⁹⁵	Western Australia	4-5 years	80%

* These children were not be eligible for Hib

† 5th dose PT only came in early 1994 and would exclude many of these children

Table 11. Regional studies by vaccine: Population studies only

Study and date	Age coverage estimated	DTP (%)	OPV (%)	MMR (%)	Hib (%)	Fully immunised (%)
New South Wales						
NSW ⁵	24-35 months	63% (D/T) 59.7% (P)	85.9%	89.2% measles 86.9% mumps 76.3% rubella	48.7%	33.6% inc. Hib 54.2% exc. Hib
Newcastle ¹¹³	24-35 months	80.9%	95.5%	93%	59.2%	51.1% inc. Hib 77% exc. Hib
Northern Sydney ¹¹⁰	21-24 months	N/A	N/A	N/A	N/A	86% exc. Hib
Western NSW ⁶⁸	2-4 years	84%	89.6%	90.6%	N/A	80.2% exc. Hib
Central Sydney ⁵⁴	18-60 months	N/A	N/A	88.8% measles 91.9% rubella	N/A	N/A
Victoria						
Victoria ⁵	24-35 months	58.4% (D/T) 52.4% (P)	88.2%	92.5% measles 92.0% mumps 85.2% rubella	55.6%	34.4% inc. Hib 47.6% exc. Hib
Victoria ⁷	24-35 months	85.3% (DTP)	86.7%	76.0%	85.2%	N/A
Melbourne ¹¹⁶	18-36 months	93.1% (DTP/OPV)	see rate for DTP	89.9%	N/A	87.8%
Queensland						
Queensland ⁵	24-35 months	58.2% (D/T) 59.5% (P)	86.9%	93.2% measles 92.4% mumps 79.0% rubella	53.6%	33.1% inc. Hib 50.4% exc. Hib
West Moreton ¹⁰⁹	18 months	95% (12 months)	N/A	N/A	N/A	74% inc. Hib 85% exc. Hib
Darling Downs ⁸	12-18 months	85-96% (DTP/OPV/Hib)	see DTP	81%	See DTP	N/A
Australian Capital Territory						
ACT ⁵	24-35 months	62.2% (D/T) 60.0% (P)	84.4%	93.3% measles 93.3% mumps 93.3% rubella	55.6%	42.2% inc. Hib 57.8% exc. Hib
ACT ¹³	9 and 24 months	N/A	N/A	N/A	(9m) 68% (24m) 34%	N/A N/A
Western Australia						
WA ⁵	24-35 months	70.4% (D/T) 66.0% (P)	90.3%	91.5% measles 91.1% mumps 91.8% rubella	58.3%	42.5% inc. Hib 58.3% exc. Hib
Northern Territory						
NT ⁵	24-35 months	65.4% (D/T) 65.4% (P)	61.5%	99.9% measles 99.9% mumps 99.9% rubella	46.2%	38.5% inc. Hib 53.8% exc. Hib
NT ¹¹	12-14 months	89%	87%	91%	79%	75% inc Hib
Darwin ¹⁰	24-35 months	60%	60%	76%	50%	N/A
Remote NT ¹¹²	12-24 months	91 (4th dose)	91% (4th dose)	97%	N/A	N/A

Table 11. Regional studies by vaccine: Population studies only, continued

Study and date	Age coverage estimated	DTP (%)	OPV (%)	MMR (%)	Hib (%)	Fully immunised (%)
South Australia						
SA ⁵	24-35 months	57.9% (D/T) 50.8% (P)	89.3%	91.9% measles 90.9% mumps 97.8% rubella	52.8%	31.0% inc. Hib 47.2% exc. Hib
Tasmania						
Tasmania ⁵	24-36 months	52.2% (D/T) 47.8% (P)	77.6%	89.6% measles 86.6% mumps 79.1% rubella	40.3%	23.9% inc. Hib 37.3% exc. Hib
Southern Tasmania ¹¹¹	12 months	N/A	N/A	N/A	N/A	94% inc. Hib

Table 12. Percentage of children fully immunised with Diphtheria, Tetanus, Pertussis (DTP), Oral Polio (OPV) and *Haemophilus influenzae* type b (Hib) vaccines by State and Territory assessed at 12 months of age[‡]

State	Vaccine						Fully Immunised		
	DTP (%)		OPV (%)		HIB (%)		(%)		
	ACIR*	ABS†	ACIR*	ABS†	ACIR*	ABS†	ACIR*	ABS§	ABS**
New South Wales	78%	87%	78%	88%	78%	63%	76%	54%	74%
Victoria	83%	90%	83%	88%	83%	66%	82%	54%	77%
Queensland	84%	79%	85%	83%	85%	52%	83%	41%	62%
South Australia	81%	86%	81%	85%	81%	57%	79%	45%	69%
Western Australia	77%	87%	77%	84%	77%	71%	75%	50%	69%
Tasmania	83%	87%	83%	91%	83%	63%	82%	44%	62%
Australian Capital Territory	86%	87%	85%	87%	82%	69%	82%	57%	71%
Northern Territory	67%	85%	67%	70%	71%	70%	62%	59%	63%
AUSTRALIA‡	81%	83%-86%	81%	83%-86%	81%	55%-62%	79%	51%	71%

[‡] Totals from ABS 1995 range from children aged 7-12 months to children 12-23 months

* ACIR: Assessment date 31/12/97 for cohort of children born between 1/7/96-30/9/96

† Australian Bureau of Statistics: Children's Immunisation Survey, April 1995. Data for children aged 12-23 months.

§ 1994 schedule including Hib

** 1994 schedule excluding Hib

Table 13. Comparison of ABS immunisation coverage data with overseas studies

Study	Age	DTP (%)*	OPV (%)*	MMR (%) (1 dose)	Hib 3 (3 doses)	Fully immunised (%) (exc. Hib)
ABS (1995) ⁵	12-23 months	85.5% (D/T) 86.2% (P)	86.3%	86.8% measles 86.0% mumps 81.4% rubella	62.3%	51.4% inc. Hib 70.8% exc. Hib
	24-35 months	63% (D/T) 57.5% (P)	86.9%	91.5% measles 90.1% mumps 81.1% rubella	52%	34.3% inc. Hib 51.3% exc. Hib
UK (1998) ¹²⁶ (1997 data)	12 months	92.8%	91.7%	N/A	92.6%	
	24 months	95.8%	94.3%	90.5%	95.5%	N/A
USA (1998) ¹²⁷ (1997 data)	19 months	95%	91%	91%†	93%	N/A
	35 months	81% (4 doses)	91%	91%		76% (4DTP/3 OPV/ 1MCV/3Hib)
New Zealand (1995) ¹³³ (1994 data)	12 months- 18 months	84.1%	84.4%	86.6%	94.1% (Monovalent Hib)	N/A
Canada (1996) ¹³⁰ (1994-96 data)	2 years	87.1% (D) (4 doses) 84.8% (T) (4 doses) 85.9% (P) (4 doses)	89.9% (3-4 doses)	97.0%	69.3%	N/A

*3 doses unless stated

† Measles containing vaccine

Appendix

Appendix 1. Australian Standard Vaccination Schedule, August 1994

Age	Disease	Vaccine
2 months	Diphtheria, tetanus, pertussis, poliomyelitis, Hib	DTPw* OPV-Sabin vaccine, Hib vaccine (HbOC or PRP-OMP)**
4 months	Diphtheria, tetanus, pertussis, poliomyelitis, Hib	DTPw* OPV-Sabin Vaccine, Hib vaccine (HbOC or PRP-OMP)**
6 months	Diphtheria, tetanus, pertussis, poliomyelitis, Hib (HbOC schedule only)	DTPw* OPV-Sabin Vaccine, Hib vaccine (HbOC)
12 months	Measles, mumps, rubella, Hib (PRP-OMP schedule only)	MMR, Hib vaccine (PRP-OMP)
18 months	Diphtheria, tetanus, pertussis, Hib (HbOC schedule only)	DTPw, Hib vaccine (HbOC)
Prior to school entry: 4-5 years	Diphtheria, tetanus, pertussis, poliomyelitis	DTPw, OPV-Sabin vaccine
10-16 years	Measles, mumps, rubella	MMR
Prior to leaving school: 15-19 years	Diphtheria, tetanus, poliomyelitis	Td (ADT)*** OPV-Sabin Vaccine

* DTPw is the abbreviation for Diphtheria-Tetanus-Pertussis vaccine (whole cell).

** Abbreviations for Hib vaccines - HbOC is 'HibTITER'; PRP-OMP is 'PedvaxHIB'. HbOC is given at 2, 4, 6 and 18 months. PRP-OMP is given at 2, 4 and 12 months.

*** Td is combined Diphtheria-Tetanus vaccine. The DT formulation for children is often referred to by the trade name 'CDT'. The Td formulation for adults is often referred to by the trade name 'ADT'.

Appendix 2. Changes to Australian Standard Vaccination Schedule between 1989 and 1994*

The following changes have been made to the schedule since the ABS last collected information on immunisation status in the 1989-90 NHS (which used the 1986 version of the schedule):

- The introduction of a DTP vaccination to replace the CDT vaccination at 5 years or prior to school entry

- Introduction of vaccination against Hib, not previously included in the schedule. This vaccine was recommended for inclusion in 1993. For the purpose of measuring uptake of the vaccine and its effect on the overall immunisation status of the child, the Hib vaccine was excluded in the derivation of overall status against the previous schedule; and
- Introduction of a combined Measles, Mumps and Rubella vaccination at one year of age.

* Taken from ABS 1995 ⁵

Appendix 3. Australian Standard Vaccination Schedule,¹¹¹ November 1996

Age	Disease	Vaccine	Milestones
2 months	Diphtheria, tetanus, pertussis poliomyelitis Hib	DTPw* OPV-Sabin vaccine Hib vaccine (HbOC or PRP-OMP)**	
4 months	Diphtheria, tetanus, pertussis poliomyelitis Hib	DTPw* OPV-Sabin Vaccine Hib vaccine (HbOC or PRP-OMP)**	
6 months	Diphtheria, tetanus, pertussis poliomyelitis Hib (HbOC schedule only)	DTPw* OPV-Sabin Vaccine Hib vaccine (HbOC)	First (6 months)
12 months	Measles, mumps, rubella Hib (PRP-OMP schedule only)	MMR Hib vaccine (PRP-OMP)	Second (12 months)
18 months	Diphtheria, tetanus, pertussis Hib (HbOC schedule only)	DTPa* or DTPw* Hib vaccine (HbOC)	Third (18 months)
Prior to school entry : 4-5 years	Diphtheria, tetanus, pertussis poliomyelitis	DTPa* or DTPw* OPV-Sabin vaccine	
10-16 years	Measles, mumps, rubella Hepatitis B (1st dose)	MMR HBV	
1 month later	Hepatitis B (2nd dose)	HBV	
6 months after 1st dose	Hepatitis B (3rd dose)	HBV	
Prior to leaving school:15-19 years	Diphtheria, tetanus poliomyelitis	Td (ADT)*** OPV-Sabin Vaccine	

* DTPw is the abbreviation for Diphtheria-Tetanus-Pertussis vaccine (whole cell); DTPa is the abbreviation for Diphtheria-Tetanus-Pertussis vaccine (acellular).

** Abbreviations for Hib Vaccines - HbOC is 'HibTITER'; PRP-OMP is 'PedvaxHIB'. HbOC is given at 2, 4, 6 and 18 months. PRP-OMP is given at 2, 4 and 12 months.

*** Td is combined Diphtheria-Tetanus vaccine. The DT formulation for children is often referred to by the trade name 'CDT'. The Td formulation for adults is often referred to by the trade name 'ADT'. Hepatitis B schedule for adolescents - give the 1st dose at the same time as MMR (10-16 years), the 2nd dose about 1 month later, and the 3rd dose 6 months after the 1st dose.

Interim hepatitis B schedule for infants

The NHMRC has endorsed the use of hepatitis B vaccine (HBV) for all infants. HBV should be administered at birth, 1 month, and 6-12 months of age. Hepatitis B vaccine has not yet been included in the standard infant schedule because it is only available as an additional injection. Parents who express an interest in infant HBV should be encouraged to have their children vaccinated, as long as compliance with schedule vaccines is not jeopardised.

The NHMRC strongly recommends that HBV be offered to all infants born to HBsAg+ mothers and to all infants and

young children from groups with hepatitis B carrier rates of over 2%.

Editorial Note:

This historical article describes the Australian Standard Vaccination Schedule in 1994 and 1996. The current schedule at May 1999 includes DTPa vaccine as an Alternative to DTPw for infants and has the second dose of measles, mumps and rubella vaccine at age 4-5 years (rather than at 10-16 years).

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Cryptosporidium in Water

Report of the consensus conference on Cryptosporidium in Water, Melbourne, October 1998

Robert Douglas¹ and Martha Sinclair²

Introduction

The *Cryptosporidium* in Water conference, held in Melbourne in October 1998, provided an overview of the current scientific knowledge on *Cryptosporidium*, and an opportunity to discuss the needs for future research, public health strategy, and risk assessment and management for water supplies.

More than 290 delegates from diverse backgrounds in water supply and management, parasitology, general microbiology, epidemiology and public health attended the conference.

The conference was divided into three themes, each with its own objective:

- Parasitology and genetic typing, to introduce genetic typing to assist in locating the source of the parasite;
- Epidemiology, to improve epidemiological surveillance, outbreak management and public health response; and
- Risk assessment and management, to understand and manage the health risks implied by *Cryptosporidium* monitoring results.

During the opening session, five speakers presented an overview of the latest *Cryptosporidium* research. The conference was then divided into the three parallel workshops for more specialised presentations on each of the themes. The conference closed with a plenary session in which the discussions on each theme were summarised by expert reporters, and questions were invited from the audience.

On the day following the general conference, small groups of experts continued discussions on each theme, with the aim of arriving at consensus positions on parasitology research needs, public health strategy and risk management principles. The deliberations and conclusions

of the Epidemiology workshop group are summarised in the following Consensus Statement.

Consensus Statement: Epidemiology workshop group

Discussions led to the identification of a number of areas of research priority as well as the need to develop rational public health policies despite the current limitations in our understanding. The group agreed that the primary aims of public health in relation to *Cryptosporidium* in water supplies are to:

- control disease;
- only intervene when needed; and
- use public funds as efficiently as possible.

Research priorities

The research priorities agreed by the group highlighted the current inadequate understanding of the natural history of the disease in humans, the nature and role of the immune response and the determinants of disease.

It was agreed that in this current state of uncertainty, there is a need to invest in well-targeted research that:

- will help us to understand the natural history of the disease and its immunology;
- explores the factors which enhance transmission of the infection in humans and the risk factors which predispose to that infection; and
- explores the effect of prior serological experience on infection outcomes.

Phenotyping or genotyping of strains

It was agreed that considerable effort should go into developing methods for routine phenotyping or genotyping of strains isolated from humans and from water. Such techniques would represent a significant advance in epidemiology by allowing us to trace the origins of

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