Research report: Optimising childhood coverage rate assessment and reporting methodologies

Final report

30 May 2022

Author details and acknowledgments

Review of vaccination coverage analysis and reporting methodologies globally

Brynley Hull, Aditi Dey, Frank Beard

Key stakeholder interviews

Harunor Rashid, Aditi Dey, Brynley Hull, Alexandra Hendry, Frank Beard

Comparison of coverage calculation methodologies routinely used in Australia

Brynley Hull, Alexandra Hendry, Aditi Dey, Frank Beard

AIR data analysis

Brynley Hull, Alexandra Hendry, Aditi Dey, Frank Beard

MADIP linked data analysis

Bette Liu

Overarching input

Kristine Macartney

Acknowledgements

This study was undertaken under the funding agreement between NCIRS and the Australian Government Department of Health (the Department). The project team would like to acknowledge all individuals who participated in key stakeholder interviews, including immunisation experts, staff from the Department, and jurisdictional immunisation coordinators and/or their nominees.

Corresponding author contact details

Frank Beard
National Centre for Immunisation Research and Surveillance
The Children's Hospital at Westmead and The University of Sydney
Locked Bag 4001, Westmead NSW 2145
Telephone: +61 2 9845 1433
Email: frank.beard@health.nsw.gov.au

Contents

List of tables

List of figures

List of appendices

Executive summary

Background

The Australian Childhood Immunisation Register (ACIR) was established in 1996, collecting vaccination data on children aged less than 7 years. In 2016 it expanded to become the Australian Immunisation Register (AIR), collecting data on vaccinations given at all ages. The Australian Government Department of Health (the Department) publishes quarterly rolling annualised (i.e. for the previous 12 months) vaccination coverage data for young children on its website, based on AIR data obtained from Services Australia. Under funding agreements with the Department, the National Centre for Immunisation Research and Surveillance (NCIRS) analyses and reports coverage data from AIR in comprehensive annual reports. Both Services Australia and NCIRS assess 'fully vaccinated' (as defined by the Department, including certain specific vaccine or antigen [component of vaccine] doses that should have been received by the relevant age milestone) and individual vaccine/antigen coverage at 1-, 2-and 5-year age milestones, 6–12 months after vaccines are due, to allow for delayed vaccination, with AIR data extracted and analysed an additional 3 months later to allow for delays in reporting of vaccinations. A 'prior dose assumption' is used, meaning that where a child is recorded as having received the last vaccine in a sequence (e.g. the third dose of the primary course of child formulation diphtheria-tetanus-acellular pertussis [DTPa]-containing vaccine, recorded by the immunisation provider in data transmitted to AIR as 'dose 3'), it is assumed that all prior doses have been given. This assumption has not been validated by scientific research since 2001.

The underlying coverage assessment and reporting methodologies used in Australia have remained largely unchanged over the past 25 years, with relatively minor adjustments to account for inclusion/removal of vaccines from the National Immunisation Program (NIP). While this continuity and consistency has benefits, issues with some of the methodological settings have arisen. The rationale for some of the methodological decisions made over two decades ago is unclear, particularly in relation to the 5-year fully vaccinated assessment algorithm, which was introduced in 2002 and has always assessed only the booster doses of vaccines due at 4 years of age (initially 5 years), unlike the 1- and 2-year algorithms which have since inception assessed most of the vaccines that should have been received by the relevant age. The limited scope of the 5-year assessment algorithm has become increasingly problematic as the NIP schedule has evolved over time. While new vaccines/antigens, including meningococcal, pneumococcal and varicella, have been added to the NIP schedule and to the 1- and/or 2-year assessment algorithms, the 5-year fully vaccinated algorithm has included only the single vaccine now due at 4 years of age since the second dose of measles-mumps-rubella (MMR)-containing vaccine was

moved from 4 years to 18 months in 2013. After a quarter of a century with little change in methodological settings, we considered it appropriate to undertake a thorough review, with consideration of public health rationale and objectives and comparison to approaches taken overseas, and make evidence-based recommendations to optimise childhood coverage assessment and reporting from a public health perspective.

Methods

We reviewed published and grey literature on vaccination coverage analysis and reporting methodologies in Australia and comparable countries with similar immunisation information systems and schedules, conducted semi-structured interviews with key stakeholders with experience/expertise in coverage assessment, and compared methodologies used by Services Australia and NCIRS. We also analysed AIR data to assess potential methodologies, and conducted exploratory analyses of the MADIP (Multi-Agency Data Integration Project) data asset, which contains linked data from many Australian Government datasets including AIR, to assess feasibility of its use for reporting of coverage for vaccines funded specifically for medically at-risk children.

Results/Discussion

Fully vaccinated coverage algorithms and assessment milestones

We identified considerable variation in coverage assessment and reporting methodologies among other comparable countries, with only two of six assessing fully vaccinated coverage and the remainder assessing coverage for individual vaccines only. However, the key stakeholders we interviewed were all highly supportive of assessment of fully vaccinated coverage in Australia. While assessment age milestones also vary between countries, there was strong stakeholder support for maintaining the current 1-, 2- and 5-year age milestones in Australia. Some interviewees also recommended that an 18-month age milestone be added to allow assessment of MMR dose 1 coverage six months after it is due at 12 months of age, in the context of concerns about maintaining measles elimination. In relation to fully vaccinated assessment algorithms, most interviewees were supportive of a more transparent approach, with all vaccines/antigens (except rotavirus) that should have been received by each age milestone included.

Data lag periods and immediacy of reporting

Interviewees acknowledged the tension between assessment of timely vaccination and actual coverage achieved. Most were supportive of continued use, in primary routine reporting, of the current assessment lag periods, with supplementary secondary analyses of timely vaccination. We found minimal difference in coverage using a shorter 1-month lag between assessment and the

AIR data extraction date, compared with the current standard 3-month period. Now that over 96% of vaccinations are notified to AIR electronically, using this shorter data extraction lag would improve immediacy of reporting without compromising accuracy. Some interviewees also suggested that an interactive online platform be developed to allow providers and consumers timely access to coverage estimates for their own area (e.g. local government area).

Prior dose assumption

We could find no evidence of any comparable countries using a prior dose assumption. Our analysis of AIR data found that using the assumption had less than half a percentage point impact on estimates of 2-dose MMR coverage, but an impact of 3 percentage points with respect to estimated coverage of vaccines with doses due at 2, 4 and/or 6 months of age (including DTPa-containing vaccine). This was driven by children recorded as not having received the first DTPa dose, with impact disproportionately greater in children with delayed Medicare registration (fourfold higher if registered 12 or more weeks after birth compared to less than 6 weeks after birth). This could be due to underreporting to AIR of vaccinations in infants not yet registered with Medicare (including for children born overseas), and/or incomplete reassignment of vaccinations to an infant's AIR record once Medicare-registered. Until these issues around incomplete capture of vaccinations in young infants are resolved, continued use of the prior dose assumption appears appropriate for vaccine series due at 2, 4 and/or 6 months of age, but there seems little rationale for its use for vaccine series due in children aged 1 year and over.

Coverage of additional vaccine doses in Aboriginal and Torres Strait Islander and medically at-risk children

Our interviewees strongly supported regular assessment of fully vaccinated coverage in Aboriginal and Torres Strait Islander (hereafter also referred to respectfully as 'Indigenous') and medically at-risk children, incorporating the additional vaccines/vaccine doses funded under the NIP for these groups. However, most recommended that Indigenous fully vaccinated coverage should primarily be assessed using the standard algorithm (comparing 'apples with apples'), with secondary analysis to include Indigenous-specific vaccines. Very limited information on medical conditions is currently captured in AIR. Our exploratory analyses showed that coverage assessment in medically at-risk children using the MADIP data asset would generally be very incomplete. However, if International Classification of Disease (ICD) coded hospitalisation discharge data could also be integrated into MADIP, more robust coverage estimates would be achievable, although with some delays in reporting required.

Other methodological considerations

Vaccination activity may vary through the year – for example, in relation to school holidays and school enrolment; however, seasonal adjustment methodologies are often complex.

Consistency of coverage assessment and reporting in Australia

We identified several differences in the coverage assessment methodologies used by Services Australia and NCIRS, including in approaches to identifying dose numbers greater than the nominal last dose and ascribing area of residence for children with multiple Medicare cards. These differences could contribute to the discrepancies in coverage estimates reported by the Department and NCIRS. While relatively minor (less than 1 percentage point), these discrepancies are not optimal. Ongoing discussion between the three agencies is advisable to ensure consistent methodological approaches.

Appropriate level of precision in reporting of vaccination coverage data

Excessive precision in reporting of data should be avoided as it tends to overcomplicate and obscure the associated messaging. Appropriate level of precision also needs to be considered in relation to cohort size. For example, there are approximately 20,000 Aboriginal and Torres Strait Islander children in the national cohorts for which vaccination coverage is assessed at the 1-, 2- and 5-year age milestones. A change in coverage of 0.01% would therefore equate to uptake in approximately two children, making use of two decimal places unhelpful and inappropriate. NCIRS reports all vaccination coverage data using a single decimal place, whereas Services Australia and the Department report using two decimal places. Given the inherent limitations in the data (some level of fluctuation and underreporting), and that none of the six other comparable countries reviewed report to more than one decimal place, a single decimal place is the appropriate level of precision for reporting of most Australian vaccination coverage estimates.

Handling and communicating changes in coverage assessment and reporting methodology

A coverage assessment algorithm at the 5-year age milestone including all vaccines/antigens that should have been received by that age (except rotavirus, with continued use of prior dose assumption for infant vaccine series) would result in fully vaccinated coverage 4.2 percentage points lower than the current algorithm for children overall (90.1% versus 94.3%) and 2.9 percentage points lower for Indigenous children (93.7% versus 96.6%). A similarly amended algorithm at the 2-year age milestone would result in less than half a percentage point difference, due to more minor changes involved, with no change needed to the 1-year algorithm. A potential perception of a ‘drop’ in fully vaccinated coverage due to new algorithms, particularly at the 5-year mark, could create undue concern and communications issues. To maximise the public health usefulness of both new and old benchmarks, parallel reporting using both new and old algorithms would be advisable until the new algorithms are well bedded in with appropriate trend data.

Conclusions

The underlying coverage assessment and reporting methodologies used in Australia have remained largely unchanged over the past 25 years. While this continuity and consistency has its benefits, our findings show that some of these methodologies are no longer optimally fit for purpose from a public health perspective. A refresh of methodological settings is therefore warranted, in line with the recommendations presented in this report. Further consultation with key stakeholders would be of benefit to refine and operationalise these recommendations.

Recommendations

1. **Fully vaccinated coverage**
    a. Continue quarterly/annual assessment at 12, 24 and 60 months of age.
    b. Consider addition of quarterly/annual assessment at 18 months for vaccines due before that age.
    c. Primary assessment/reporting to include all vaccines due by each age milestone, except rotavirus.
    d. Secondary assessment/reporting at 12 months of age to include all vaccines due including rotavirus; assessment at later stages not needed for rotavirus due to strict upper age limits.

2. **Individual vaccine coverage**
    a. Continue quarterly/annual assessment and reporting of individual vaccine coverage at 12, 24 and 60 months of age.
    b. Consider addition of quarterly/annual assessment at 18 months of age.

3. **Aboriginal and Torres Strait Islander children**
    a. Conduct primary assessment and reporting of fully vaccinated coverage' using same algorithm as overall.
    b. Secondary assessment/reporting of fully vaccinated coverage should also include additional NIP-funded vaccines in algorithm at relevant milestones: meningococcal B (all jurisdictions), hepatitis A/extra dose of 13vPCV (Queensland, NT, SA, WA only).
    c. Quarterly/annual assessment and reporting of individual vaccine coverage, with annual reporting of additional doses, as above.

4. **Medically at-risk children**
    a. Once hospitalisation data are included in the MADIP data asset, assess and report fully vaccinated and individual vaccine coverage on annual basis by medical risk factors, using ICD-coded hospital discharge data and other data indicating presence of medical conditions (e.g. MBS-PBS item numbers).

5. **'Prior dose' assumption**
    a. Cease use for vaccine series in children aged 1 year and over.
    b. Explore reasons for incomplete capture of vaccinations in young infants, and address where possible.

c. Until issues around incomplete capture of vaccinations in young infants are delineated and resolved, continue use for vaccine series due at 2, 4 and/or 6 months of age.

6. Lag times and immediacy of reporting

a. Change from current 3-month to a 1-month lag between assessment date and AIR data extraction.
b. Consider feasibility of interactive site allowing public/clinician access to fully vaccinated and individual vaccine coverage data down to local government area.

7. Other methodological considerations

a. The Department should engage with relevant experts to consider extent of seasonality in AIR data, and appropriate strategies to account for this, being mindful of need to communicate any such approach simply to broad audiences.

8. Consistency of analysis and reporting of coverage data

a. The Department, Services Australia and NCIRS should hold regular ongoing (e.g. quarterly) discussions to ensure clear and consistent methodological approaches and optimise methods of data handling.
b. The Department, Services Australia and NCIRS should consider strategies that would promote consistency of analysis and reporting by key stakeholders such as state and territory health department staff.

9. Appropriate level of precision in reporting of vaccination coverage data

a. Use one decimal place as standard level of precision in reporting of vaccination coverage estimates.

10. Handling and communicating changes in coverage assessment and reporting methodology

a. Utilise parallel reporting of vaccination coverage (both new and old algorithms) until new algorithms are well established with appropriate trend data.
b. Ensure clear strategy to communicate rationale and address any concerns of the public and other key stakeholders when new methodologies indicate lower than previously reported coverage.

Background

The Australian Childhood Immunisation Register (ACIR) was established on 1 January 1996 by incorporating data on all Medicare-enrolled children aged less than 7 years.[1] On 30 September 2016, the ACIR expanded to become the Australian Immunisation Register (AIR) for the purposes of collecting data on vaccinations given at all ages. Data are transferred to AIR when a recognised immunisation provider supplies details of an eligible vaccination. All people registered with Medicare are automatically added to AIR and assigned a Personal Identification Number (PIN) that then travels with that person for life, across all relevant Medicare card numbers (e.g. where a person has multiple cards due to family circumstances or maturity). Participation in AIR is 'opt out' and so constitutes a nearly complete population register for Australian residents. Individuals who are not Medicare-registered, but for whom a vaccination encounter is reported to AIR, are assigned a Supplementary Identification Number (SIN),[2] with subsequent assignment of a PIN where the individual is identified to be Medicare-registered.

The Australian Government Department of Health and Aged Care (the Department) publishes on its website quarterly rolling annualised (i.e. for the previous 12 months) 'fully vaccinated' (as defined by the Department, including certain specific vaccine or antigen [component of vaccine] doses that should have been received by the relevant age milestone) and individual vaccine/antigen coverage data for young children, by state/territory. These data are from AIR and are provided to the Department by Services Australia. Under funding agreements with the Department, the National Centre for Immunisation Research and Surveillance (NCIRS) has undertaken regular analysis and reporting of immunisation coverage data from the ACIR, since its inception in 1996, and then the expanded AIR from 2016. NCIRS reports supplement the coverage data published by the Department with more comprehensive analysis and interpretation of data, including in relation to vaccines available on the National Immunisation Program (NIP) only for Aboriginal and Torres Strait Islander (hereafter also respectfully referred to as 'Indigenous') children, and timeliness of vaccination, through both annual immunisation coverage reports and standalone research reports.

AIR contains limited information for each individual (PIN/SIN, date of birth, gender, Indigenous status, postcode) and vaccinations received (brand/type, dose number, date, immunisation provider). Although some vaccines are included on the NIP schedule specifically for children with relevant medical conditions, coverage in this group is not routinely reported due to limited data on comorbidities in AIR. Only limited (grant-funded) intermittent analyses have been undertaken for select NIP vaccines in children eligible for additional doses under the NIP.[3] However, NCIRS is supporting the Health Economics and Research Division (HERD) of the Department in analysis of

the Multi-Agency Data Integration Project (MADIP) data asset, into which AIR data have been integrated, which has potential to allow more granular analyses and reporting of vaccination uptake, including in medically at-risk groups.

Immunisation coverage in young children at the population level (national and state/territory) has been calculated by the cohort method using a standard methodology since the ACIR's inception. Vaccine/antigen doses included in the algorithms to assess whether a child is fully vaccinated are set by the Department. Initially, algorithms for fully vaccinated at the 1- and 2-year age milestones included all vaccines/antigens listed in the national vaccination schedule due by those ages, but using a 'prior dose assumption', meaning that where a child is recorded as having received the last vaccine in a sequence (e.g. the third dose of the primary course of diphtheria-tetanus-acellular pertussis [DTPa]-containing vaccine), it is assumed that all earlier doses have been given.[4] An algorithm for assessing fully vaccinated coverage at the 6-year age milestone was introduced in 2002, which included only those vaccines/antigens due at the then NIP schedule point of 5 years of age;[5] this was changed in 2008 to a 5-year age milestone following the move of the NIP schedule point from 5 to 4 years of age.[6] Thus, while all three algorithms have been variously modified over time to align with changes to the NIP schedule, as a result of these cumulative changes, the 5-year milestone assessment algorithm now includes only the antigens contained in the single vaccine dose scheduled at 4 years of age (DTPa-polio; diphtheria-tetanus-acellular pertussis with inactivated polio vaccine). The fully vaccinated coverage algorithm at the 2-year age milestone assesses antigens from one vaccine due at 6 months of age, two vaccines due at 12 months of age and three vaccines due at 18 months of age.[7] A previous NCIRS report[8] and a recent Australian National Audit Office audit report[9] have identified the potential for this to lead to misinterpretation of what 'fully vaccinated' means at the 5-year age milestone, and to render the 5-year coverage data less useful in monitoring and evaluating uptake and effectiveness of the NIP from a public health perspective than a more comprehensive algorithm would be. Additionally the prior dose assumption was last validated in 2001[10] – that is, prior to the widespread adoption of electronic reporting[2, 7] – and, more recently, the introduction of mandatory reporting to AIR (2021).[11]

The standard methodology used by Services Australia/the Department and NCIRS assesses coverage at 6–12 months after vaccines are due, to allow time for delayed vaccination, with AIR data analysed an additional 3 months later to allow for potential delays in reporting of vaccinations by providers to AIR. This approach, which contributes a degree of 'lag' in reporting of coverage data, has not been reviewed for over two decades, particularly in relation to appropriateness in light of electronic and mandatory reporting.

While NCIRS uses the coverage assessment algorithms set by the Department, there have been ongoing, though relatively minor inconsistencies (usually less than one percentage point) between the coverage figures published by the Department and NCIRS, above and beyond those that might be expected from the different methodologies used (i.e. the Department's use of a quarterly rolling annualised approach), suggesting some differences in how NCIRS and Services Australia operationalise the algorithms.

Aims

In relation to analysis and reporting of AIR coverage data for young children, our aims in this report are to:

- recommend evidence-based approaches to optimise assessment and reporting in Australia from a clinical and public health perspective
- assess the accuracy, appropriateness and consistency of the Department's and NCIRS' current coverage assessment methodologies and reporting.

Methods

Literature review

We reviewed published and grey literature on immunisation coverage analysis and reporting methodologies in Australia and comparable countries, focusing on those with similar immunisation information systems and schedules.

Key stakeholder interviews

Semi-structured interviews were held with senior NCIRS and Department staff, members of the Australian Technical Advisory Group on Immunisation (ATAGI) members, jurisdictional immunisation program managers and other identified key stakeholders with experience/expertise in coverage assessment to identify and delineate:

- information needs of key stakeholders
- what the objectives of coverage analysis and reporting should be, from a clinical and public health perspective
- what constitutes optimal coverage analysis and reporting, from a clinical and public health perspective.

Implied and/or verbal consent was obtained from all participants for interviews, and verbal consent for recording of interviews. Virtual interviews were conducted via videoconferencing platforms,

professionally transcribed and thematically analysed, with all information included in this report deidentified.

Comparison of coverage calculation methodologies used in Australia

We obtained a copy of the general coverage information and AIR rules used by Services Australia to calculate immunisation coverage and compared these with methodologies used by NCIRS.

Analysis of AIR data

Using coverage analysis methodologies identified as having potential to optimise coverage analysis and reporting, we analysed selected AIR data to assess utility and impact of new or modified methodologies. We also analysed selected AIR data to quantify and delineate any discrepancies between the immunisation coverage calculation methodologies used by Services Australia/the Department and NCIRS.

Analysis of MADIP data

We worked with HERD to conduct exploratory analyses to assess the feasibility of using MADIP data for regular reporting of coverage for NIP vaccines specific to medically at-risk children.

Ethical considerations

Ethical approval for this study was sought and granted by the Sydney Children's Hospital Network's Human Research Ethics Committee, protocol 2022/ETH00254.

Results

Literature review

A summary of immunisation coverage analysis and reporting methodologies, in Australia and selected comparable countries with similar immunisation systems and schedules to Australia, is provided below, with further detail in Appendix 1. The countries selected all have national immunisation registers, apart from the United Kingdom which aggregates data predominantly from local health authority immunisation information systems.

All seven countries included in our review use the cohort method to calculate coverage.[12-18] Only three out of seven countries assess fully vaccinated coverage: Australia (quarterly [rolling annualised] and annually at 12, 24 and 60 months of age); New Zealand (quarterly [raw and rolling annualised data] at 6, 8, 12, 18, 24, 54 and 60 months of age); and the Netherlands (annually at

24 months of age only), with the remainder assessing coverage for individual vaccines only (Norway, United Kingdom [quarterly raw data reporting], Denmark [annual reporting] and Ireland [quarterly raw data and annual reporting]). For countries reporting individual vaccine coverage only, there were variations in age milestones used. The United Kingdom and Denmark use the same age milestones as Australia (12, 24 and 60 months of age), while Ireland uses 12- and 24-month age milestones and the Netherlands uses 24-month, 60-month and 10-year age milestones. Australia is the only country reviewed that reports coverage to two decimal places (for quarterly reporting only), with all other countries reporting to one or zero decimal place.

Of the three countries which calculate and report fully vaccinated coverage, New Zealand and Netherlands calculate it is as the proportion of children who have completed all age-appropriate vaccinations by the milestone age (including rotavirus in NZ, noting rotavirus is not included in the Netherlands program), while Australia includes selected vaccinations depending on the milestone.

Apart from Australia, which reports fully vaccinated vaccine coverage in Aboriginal and Torres Strait Islander people quarterly (the Department) and annually (NCIRS), and New Zealand, which reports coverage data quarterly by ethnicity and level of deprivation, no other country reviewed routinely reports coverage data by ethnicity. None of the seven countries routinely report coverage data for medically at-risk groups.

Of all seven countries reviewed, including those reporting individual vaccine coverage only, we could find no evidence that any apart from Australia use the prior dose assumption.

Key stakeholder interviews

Twelve key stakeholders were invited to participate in the study. Seven agreed to participate and were able to be interviewed within the time constraints. Two interviewees invited a colleague to attend, making a total of nine participants across seven interviews. Two participants who attended a joint interview sent written responses in addition to participating in the virtual interview. Participants included ATAGI members, other key immunisation experts, jurisdictional immunisation program managers and Department staff.

Key stakeholder perspectives and their recommendations

The key stakeholders we interviewed were broadly supportive of aspects of current coverage analysis and reporting settings, but identified areas where improvements could be made to increase transparency and relevance from public health and program management perspectives.

Stakeholder perspectives and their recommendations on coverage analysis and reporting in children are summarised in Table 1, with further details and relevant quotes included below.

Table 1. Summary of stakeholder perspectives and recommendations

Domain	Stakeholder perspectives	Stakeholder recommendations
Overall opinion about current methodologies	Current methodologies have been around since inception of the ACIR, with minor adjustments as new vaccines added or removed from the NIP schedule. This provides relative consistency in estimates across years/decades, but there is a need to supplement with data on timeliness of vaccination and coverage in medically at-risk groups. Primary consideration in relation to methodologies should be public health rationale and benefits.	Continue to assess coverage, including fully vaccinated, at 12-, 24- and 60-month age milestones. Continue to assess coverage at 6 months after last dose of vaccine series due for all milestones except 5-year age milestone where 12 months remains appropriate. Add 18-month age milestone to allow assessment of coverage for key vaccine (MMR) 6 months after it is due at 12 months of age. Use MADIP data, once hospitalisation data are integrated, to assess and report coverage for at-risk populations.
Objectives of coverage analysis and reporting	Provide accurate and timely data with comparison at appropriate geographical level to: • inform policy and program decisions • maintain transparency and public confidence in the NIP • provide feedback to encourage agencies, providers and communities to improve vaccination rates • facilitate accountability of agencies and providers involved in immunisation delivery and program coordination.	Reconsider use of coverage targets as performance indicators for states and territories under the National Partnership on Essential Vaccines, given that GPs, who are not accountable to state and territory governments, provide the vast majority of childhood vaccinations in most jurisdictions. Develop interactive online platform to allow providers and consumers to access timely coverage estimates for their own area (e.g. local government area).
Strengths	Continuity and consistency of approach over many years. Accurate and high-quality childhood coverage data.	Maintain coverage reporting on a quarterly and annual basis.

Domain	Stakeholder perspectives	Stakeholder recommendations
	Methods mostly transparent and easy to understand.	
Limitations	Fully vaccinated algorithm for 5-year age milestone includes only a single vaccine – not transparent or optimally useful from a public health perspective. Due to lag times in reporting can be difficult to work out what age cohort and time period coverage data relate to. Difficulty comparing Australian coverage data with other countries, given different methodologies used.	For primary reporting purposes, include all vaccines/antigens (except rotavirus) due by each age milestone in fully vaccinated algorithm. For secondary reporting purposes include all vaccines/antigens (including rotavirus) in 12-month fully vaccinated algorithm. Report coverage by both 'old' and 'new' algorithms for transitional period. Improve clarity in reporting in relation to age cohort involved and when vaccinations would have been due.
Prior dose assumption	Was appropriate when reporting was predominantly via hard-copy forms, but merits reconsideration now that AIR reporting is predominantly electronic, and mandatory.	Reassess appropriateness of prior dose assumption.
Additional vaccines for Indigenous and medically at-risk populations	Very important to assess additional vaccines, both separately and as part of fully vaccinated coverage, although should compare 'apples with apples' in primary reporting.	Report fully vaccinated coverage in Indigenous and all Australians using same algorithm (primary reporting). Report additional Indigenous-specific coverage, both for individual vaccines and included in 'fully vaccinated algorithms (secondary reporting). Use MADIP data (once hospitalisation data integrated) to assess and report coverage annually in medically at-risk children, both for individual vaccines and with additional vaccines included in fully vaccinated algorithm.

Strengths of current methodologies

The key stakeholders interviewed identified several strengths of current coverage analysis and reporting methodologies, in particular their consistency over time and role in driving improvements in coverage through provision of regular feedback on progress.

> *I think there's a lot to be really positive about in terms of the way the reporting is done … I think since AIR commenced – ACIR commenced in 1996 – I think it's been a real, probably big key instrument that's driven improving coverage. Obviously there's a whole lot of other work that goes on to improve coverage … I think it all hinges and reflects on the data that comes from ACIR and now AIR* (Key immunisation expert)

> *So the real strength actually is that it's made it relevant. It has made vaccine coverage something that we aspire to, something that we measure and something that we seek to improve.* (ATAGI member)

Interviewees were generally satisfied with many aspects of current assessment and reporting settings, including the quarterly routine reporting of both fully vaccinated and individual vaccine coverage by the Department and more extensive annual analyses by NCIRS. While keen in principle to minimise lags in reporting and maximise immediacy and relevance, interviewees were generally supportive of current lag time settings – that is, 6 months after last vaccine dose assessed due at the 12- and 24-month age milestones, but 12 months after last vaccine dose assessed at the 60-month age milestone (due to less frequent attendance at healthcare providers by children of this age and that the vaccine due at 4 years is a booster rather than part of a primary course). Interviewees acknowledged the compromises that need to be made from a public health perspective in terms of assessment settings – choosing, on the one hand, a shorter lag time (e.g. 3 months) to capture 'timely' vaccination and, on the other, a longer lag time to more accurately capture actual coverage achieved, but not too long so as to lose immediacy. These competing objectives could be accommodated through progressive assessment using multiple lag times (e.g. assessment of coverage for the same age cohort at 3 months and then 6 months, and potentially at additional later points). However there was consensus that this would introduce too much complexity into the routine reporting process, and that 'timely vaccination' would be better assessed and reported through separate processes.

> *I'm not suggesting that we would change the timepoints for our [routine] reporting. In fact, it's a real strength to keep those consistent. But understanding actually how timeliness is relevant in this space for specific antigens I think would be very useful. Pertussis, pneumococcal being probably quite high on the list.* (ATAGI member)

Interviewees also highlighted the inevitable amount of 'noise' that exists in a coverage assessment and reporting system, and emphasised that not too much weight should be placed on minor fluctuations in quarterly coverage figures, with sustained trends in data being more important.

Limitations of current methodologies

Most interviewees highlighted issues with assessing and reporting fully vaccinated coverage at the 5-year age milestone as one of the most significant limitations of current assessment and reporting methodologies, and recommended an updated approach to improve transparency and relevance from a public health and program management perspective.

> *So the 4-year olds or when they're measured at 5, [it] looks like they're vaccinated but there's only four antigens included in that definition at 5 years … we've tried to look at what their real coverage might be and in the reports that we receive from the Commonwealth that might look like that they might be 95% vaccinated, but they're probably more low 90s if you look at all vaccines including in that 5-year-old definition.* (Jurisdictional immunisation program manager)

Interviewees supported inclusion of a more comprehensive range of vaccines/antigens in the 5-year assessment algorithm, with most supportive of including all vaccines that should have been received except for rotavirus vaccine due to the strict upper age limits. Interviewees also considered that reporting by both 'old' and 'new' algorithms for an extended 'transitional' period would be important, given the length of time the current methodology has been in place and potential communication issues surrounding a drop in headline coverage rates.

> *We shouldn't throw the baby out with the bathwater, we should continue to have some of the existing readouts that we've had, and we should build on them … So, I mean it's the same also with the old algorithm for five years. I wouldn't ditch that initially in the transition period, I would keep that in there, because it's kind of like your tidemark, and then you might reset where you want your benchmark to be, but you don't lose your old tidemark too.* (Key immunisation expert)

Some interviewees suggested that coverage should be assessed at an additional 18-month age milestone, so that coverage for the MMR vaccine, which is of particular public health importance in relation to maintaining measles elimination, could be assessed. Some interviewees also suggested that secondary analyses at the 12-month age milestone should be undertaken, specifically with rotavirus included in fully vaccinated coverage, so that the public health importance of rotavirus is not obscured merely because of the age limit issues.

Interviewees identified the lack of ability to assess and report on vaccination coverage in medically at-risk groups, for whom additional vaccines are funded under the NIP, as another significant limitation, and noted that due to lag times it can be difficult to work out what age cohort and time period coverage data actually relate to.

> *Does not allow for reporting against some target groups (e.g. medically at-risk), difficult to match the cohorts of identified children against the ones that form the denominator/numerator of quarterly statistical reports.* (Jurisdictional immunisation program manager)

In relation to assessment and reporting of the additional NIP-funded vaccines for Indigenous children, most interviewees considered that we should be comparing 'apples with apples' – in other words, that Indigenous fully vaccinated coverage should primarily be assessed using the standard algorithm, but with secondary analysis including Indigenous-specific vaccines.

> *It's tricky, because obviously there's implications if the same definition – I mean as a comparison, if the same definition of fully vaccinated is not used for Aboriginal and non-Aboriginal children, then you could see a further disparity between coverage if you included some of the Aboriginal-specific vaccinations. So I think that's a big issue.* (Jurisdictional immunisation program manager)

In relation to assessment and reporting of the additional NIP-funded vaccines for medically at-risk children, interviewees noted that while this is a key need from a public health perspective, there is a lack of key data fields to do this using AIR alone. However, it was suggested that the integration of hospitalisation data within the MADIP data asset would enable this to occur.

> *Yeah, so my answer is, right now, it's feasible today to do it for Indigenous kids, and we should work to improving the feasibility of it for medically at-risk children, for the extra doses that they need. And that could be reasonably done, I would say within the coming one to two years, that that could start being reported on.* (Key immunisation expert)

In terms of meeting the objectives of coverage assessment and reporting, some interviewees suggested that it would be of substantial benefit, from both a public health and clinical perspective, if an interactive online platform could be developed to enable immunisation providers and consumers to access timely coverage estimates for their own area (e.g. local government area).

The jurisdictional immunisation program managers interviewed considered that the appropriateness of use of coverage targets as performance indicators for states and territories under the National Partnership on Essential Vaccines should be reassessed, given that GPs, who

are not accountable to state and territory governments, provide the vast majority of childhood vaccinations in most jurisdictions.

Prior dose assumption

Regarding use of the prior dose assumption, most stakeholders considered that while this was appropriate two decades ago when most reporting was via hard-copy forms, the need and appropriateness should be reassessed now that reporting is predominantly electronic, and mandatory.

> *You know, historically its use has been perfectly reasonable. But I think the context was very different. So I think AIR moved from being a more relaxed model to reporting being required for welfare and other support payments. So I think the strictness of reporting or the adherence to reporting has probably improved a lot since that time.* (Public health immunisation expert)

Comparison of coverage calculation methodologies used in Australia

Services Australia, under direction from the Department, calculates coverage for all children and Indigenous children, using rolling annualised estimates, combining four assessment quarters, with the Department reporting these data quarterly on its website. In contrast, NCIRS calculates coverage annually for relevant calendar year-wide birth cohorts and reports the data in its annual immunisation coverage reports. The Department reports coverage data to two decimal places whereas NCIRS reports to one decimal place.

Both Services Australia/the Department and NCIRS include the same vaccines/antigens in fully vaccinated assessment algorithms, with rotavirus vaccine not included in any of these. Both the Department and NCIRS report coverage in all children and Indigenous children for individual vaccines included in the fully vaccinated assessment algorithms. NCIRS also reports annually on coverage in all children and Indigenous children for rotavirus vaccine at the 12-month age milestone, and *Haemophilus influenzae* type b (Hib), hepatitis B, MMR, varicella and 13-valent pneumococcal conjugate vaccine (13vPCV) at the 5-year milestone. Further, NCIRS reports annually on coverage in Indigenous children for Indigenous-specific vaccines/doses – namely, two doses of hepatitis A vaccine and four doses (compared to three for non-Indigenous children) of pneumococcal vaccine, both assessed at the 30-month age milestone. While the Department does not report publicly on Indigenous-specific vaccines/doses, Services Australia provides confidential quarterly reports to jurisdictional immunisation program managers which count individuals that have received:

- one or two doses of hepatitis A vaccine by 18, 24, 30 and 36 months of age

- three or four doses of 13vPCV by age group up to 36 months
- two doses of rotavirus vaccine by 9–12 months of age.

Other differences between the Services Australia/Department and NCIRS coverage calculation methods and reporting include:

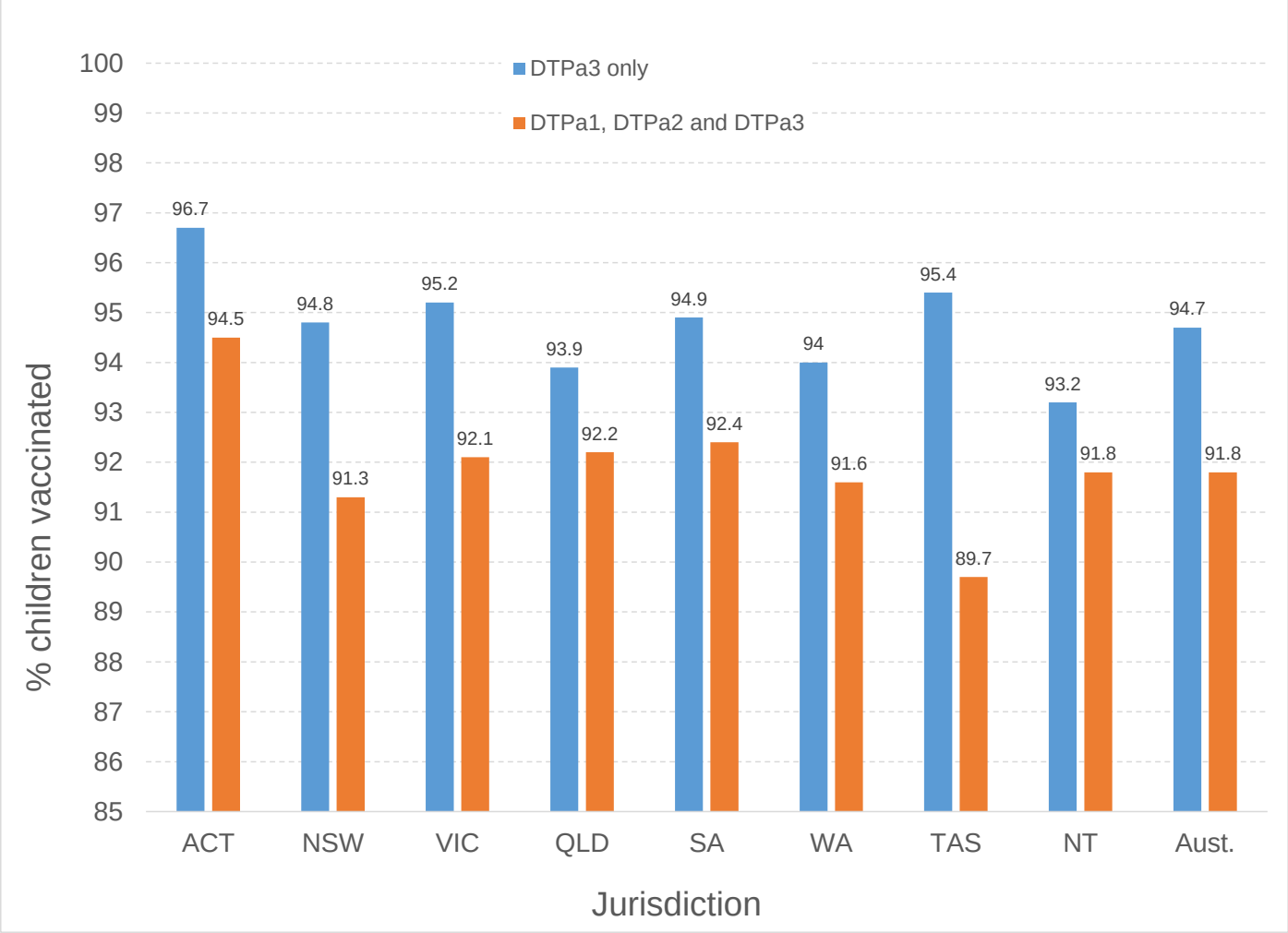
- To allow for data entry errors, NCIRS' statistical programs look for dose numbers greater than the nominal last dose – for instance, for second MMR dose coverage, NCIRS' programs look for dose 2, 3 or 4 of MMR, whereas Services Australia looks for just dose 2.
- For the purposes of ascribing area of residence for children with multiple Medicare cards, Services Australia uses the postcode associated with the Medicare card with the lowest card number, whereas NCIRS uses the postcode associated with the most recent Medicare registration date (NCIRS does not receive Medicare numbers).
- NCIRS excludes all SIN records from all calculations, whereas Services Australia includes them in its confidential reports to jurisdictional immunisation program managers on Indigenous-specific vaccines/doses.
- NCIRS calculates and reports influenza vaccination coverage by age as the proportion of persons registered on AIR in the relevant age group having at least 1 dose recorded in the relevant year, whereas Services Australia/the Department calculate/report the number of doses given in relevant age groups in the relevant year.
- Services Australia assigns the age group of influenza vaccinations to age as of 1 January of the relevant year, whereas NCIRS calculates 'age at dose' using vaccination date and date of birth.

Analysis of AIR data

Impact of prior dose assumption on vaccine coverage

Figure 1 provides an assessment of the effect of the prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine by jurisdiction for all children. Coverage is 2.9 percentage points lower at the national level without application of the assumption, ranging from 1.4 percentage points lower in the Northern Territory to 5.7 percentage points lower in Tasmania.

Figure 1. Impact of prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine, by jurisdiction – all children*



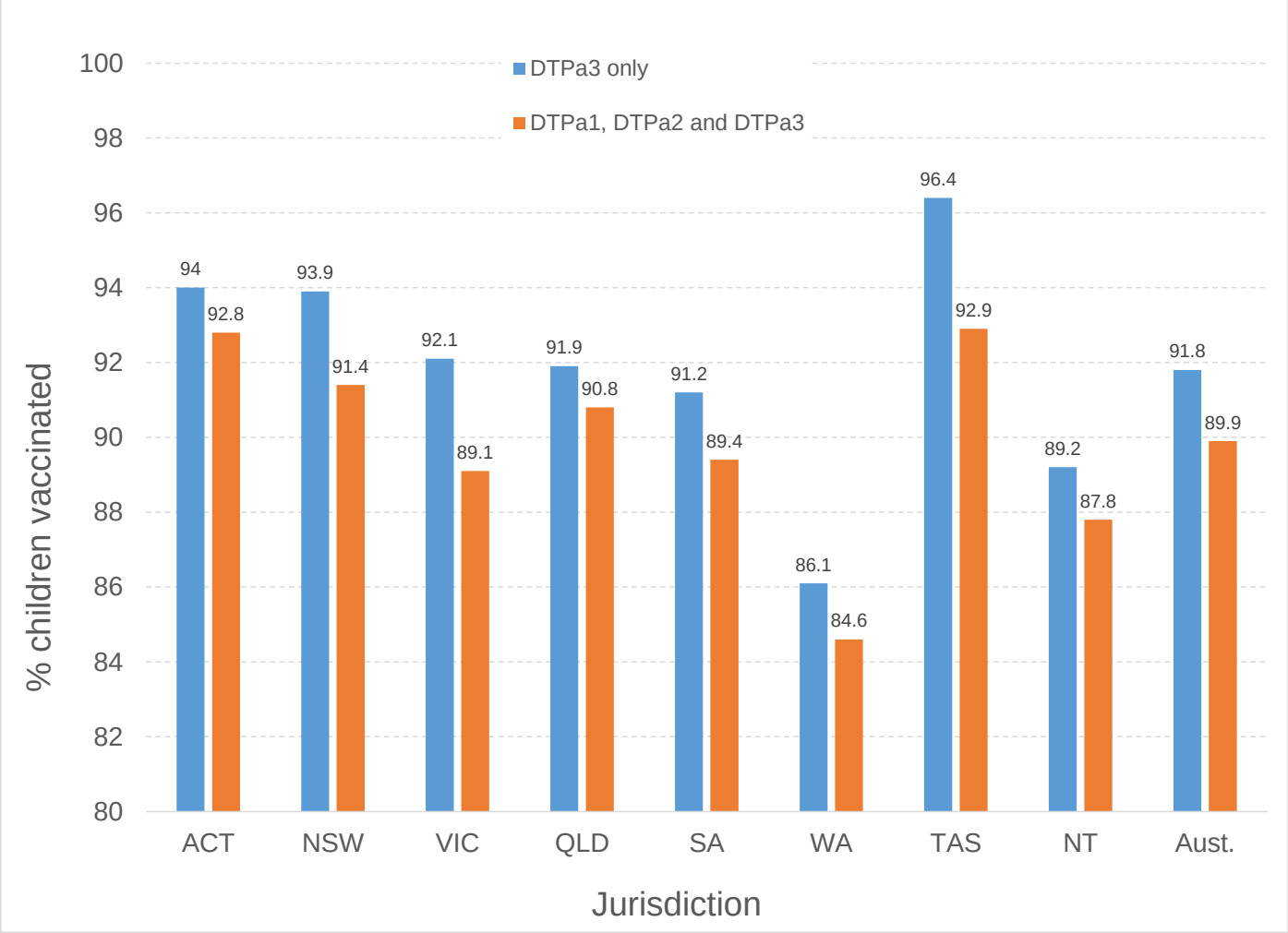
* Cohort born 1 January 2020 – 31 December 2020

DTPa = diphtheria-tetanus-acellular pertussis

Source: Australian Immunisation Register, data as at 6 February 2022

Figure 2 provides an assessment of the use of the prior dose assumption in respect of vaccine coverage estimates for the primary course of DTPa-containing vaccine by jurisdiction for Indigenous children. Coverage is 1.9 percentage points lower at the national level without application of the assumption, ranging from 1.1 percentage points lower in Queensland to 3.5 percentage points lower in Tasmania.

Figure 2. Impact of prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine, by jurisdiction – Indigenous children*



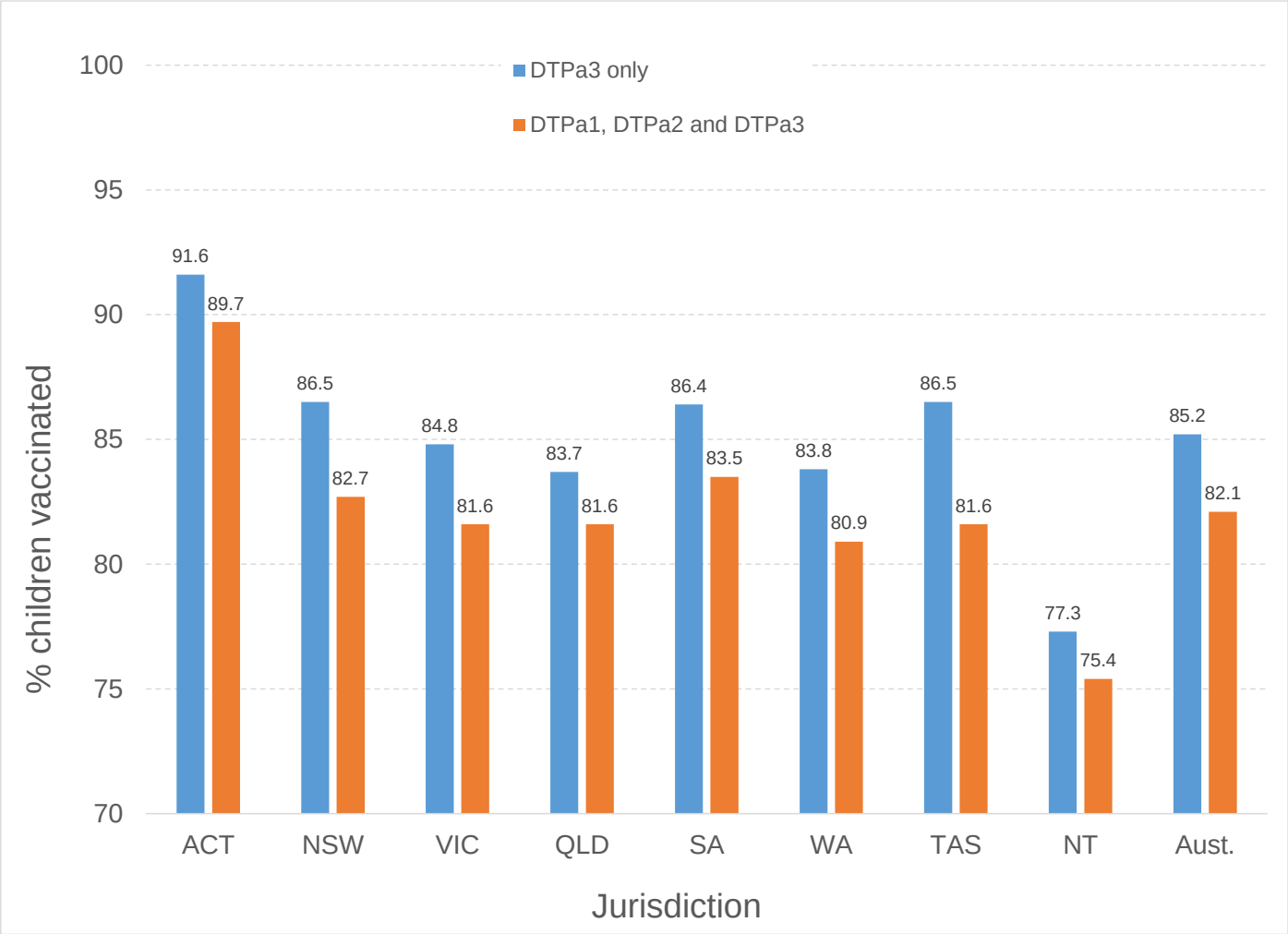
* Cohort born 1 January 2020 – 31 December 2020

DTPa = diphtheria-tetanus-acellular pertussis

Source: Australian Immunisation Register, data as at 6 February 2022

Figure 3 provides an assessment of the use of the prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine by jurisdiction for all children who were due their first 3 doses of DTPa vaccine in the first 6 months following introduction of mandatory reporting to AIR[11] (1 July 2021 to 31 December 2021). No obvious impact of mandatory reporting was seen, with coverage 3.1 percentage points lower at the national level without application of the assumption in all jurisdictions, compared to 2.9 percentage points lower in the cohort due for vaccination prior to mandatory reporting (Figure 1).

Figure 3. Impact of prior dose assumption on coverage estimates for primary course of DTPa-containing vaccine post introduction of mandatory reporting to AIR, by jurisdiction – all children*



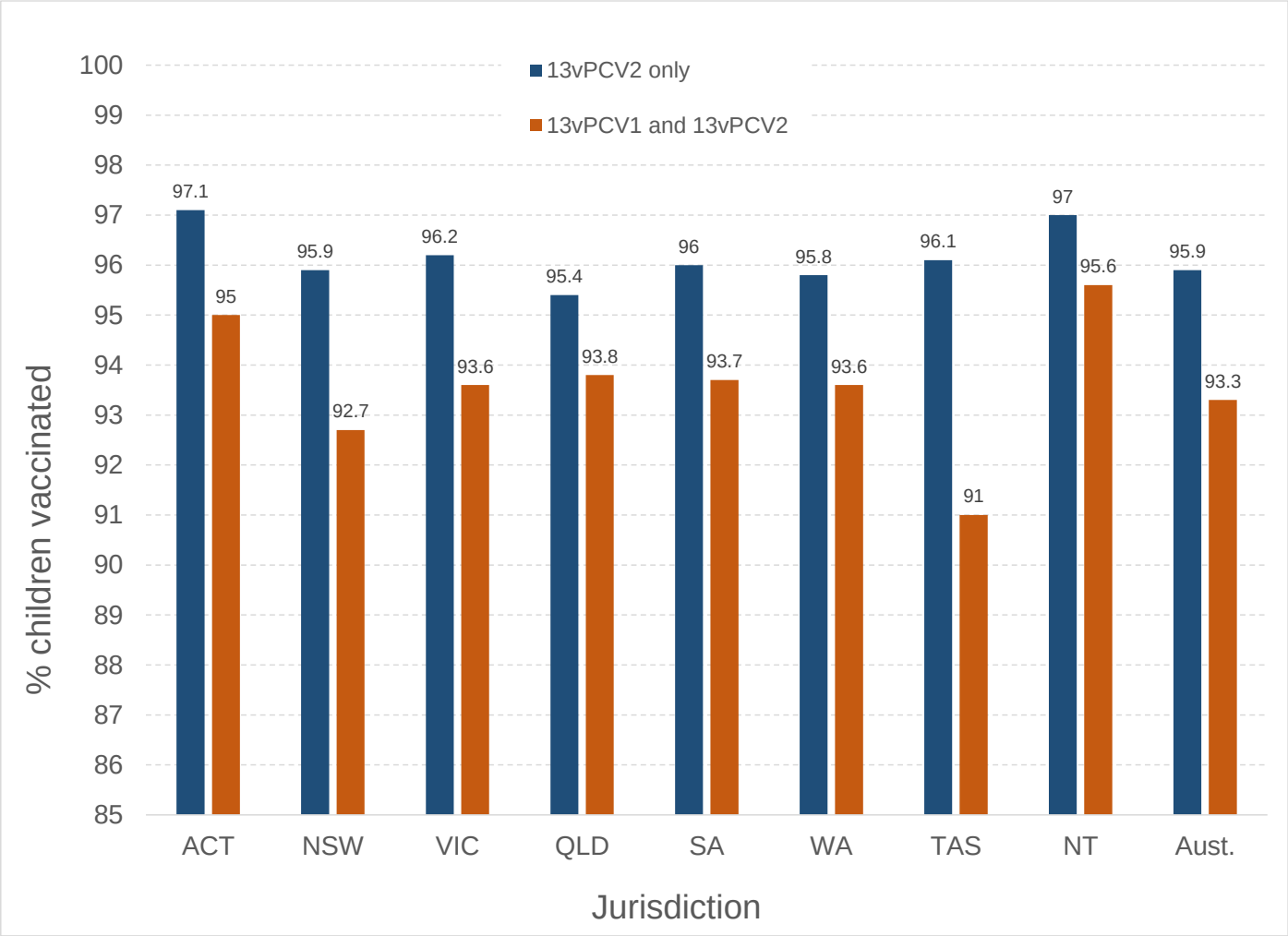
* Cohort born 1 May 2021 – 30 June 2021 (due DTPa1, DTPa2 and DTPa3 from 1 July 2021 – 31 December 2021)

DTPa = diphtheria-tetanus-acellular pertussis

Source: Australian Immunisation Register, data as at 6 February 2022

Figure 4 provides an assessment of the effect of the prior dose assumption on vaccine coverage estimates for the primary course of 13vPCV by jurisdiction for all children. Coverage at the national level was 2.6 percentage points lower without application of the assumption, ranging from 1.4 percentage points lower in the Northern Territory to 5.1 percentage points lower in Tasmania.

Figure 4. Impact of prior dose assumption on vaccine coverage estimates for the primary course of 13vPCV, by jurisdiction – all children*



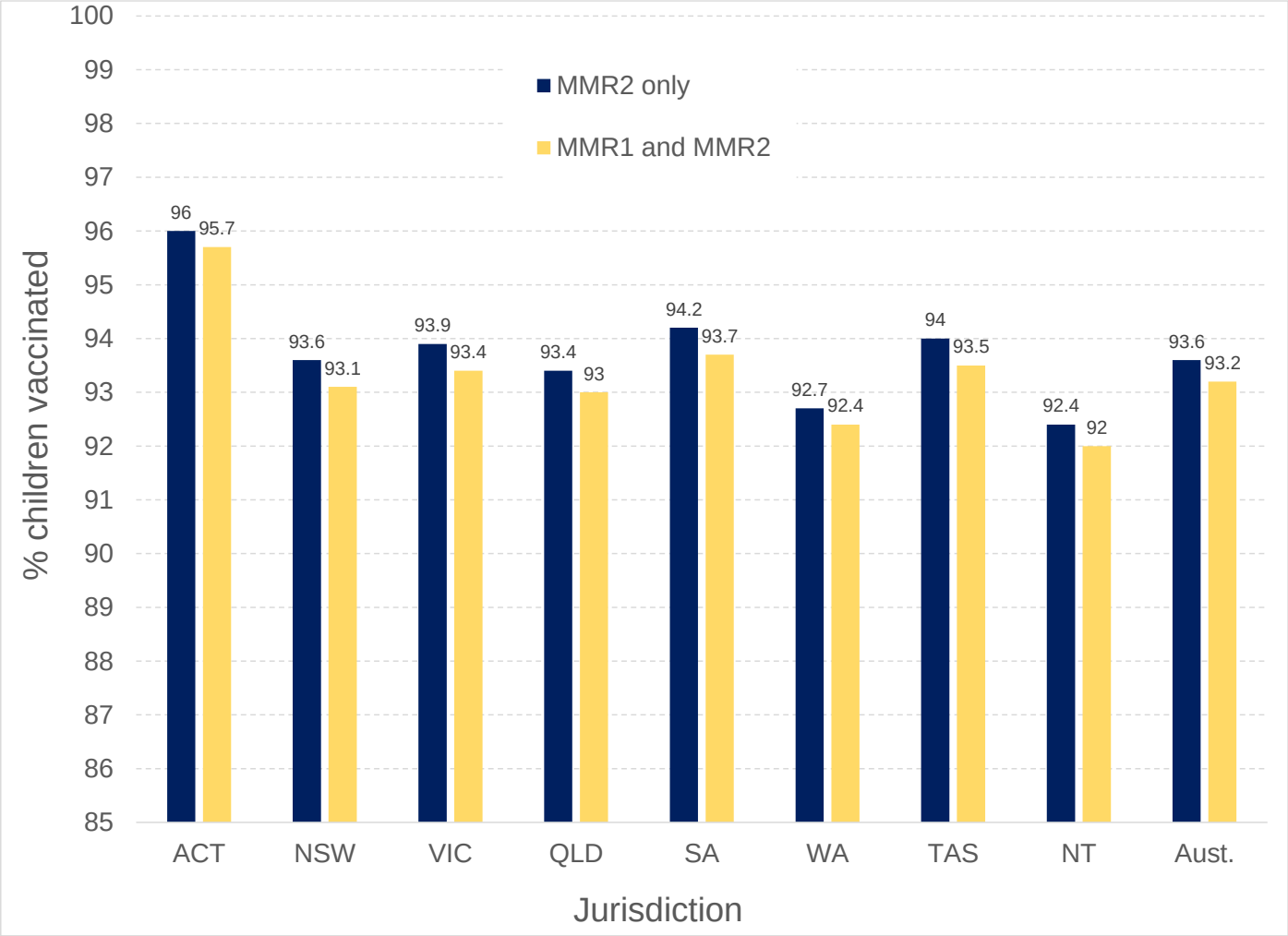
* Cohort born 1 January 2020 – 31 December 2020

13vPCV = pneumococcal conjugate vaccine

Source: Australian Immunisation Register, data as at 6 February 2022

Figure 5 provides an assessment of the effect of the prior dose assumption on 2-dose MMR vaccine coverage estimates by jurisdiction for all children. Coverage was 0.4 percentage points lower at the national level without application of the assumption, ranging from 0.3 to 0.5 percentage points by jurisdiction.

Figure 5. Impact of prior dose assumption on 2-dose MMR vaccine coverage estimates, by jurisdiction – all children*



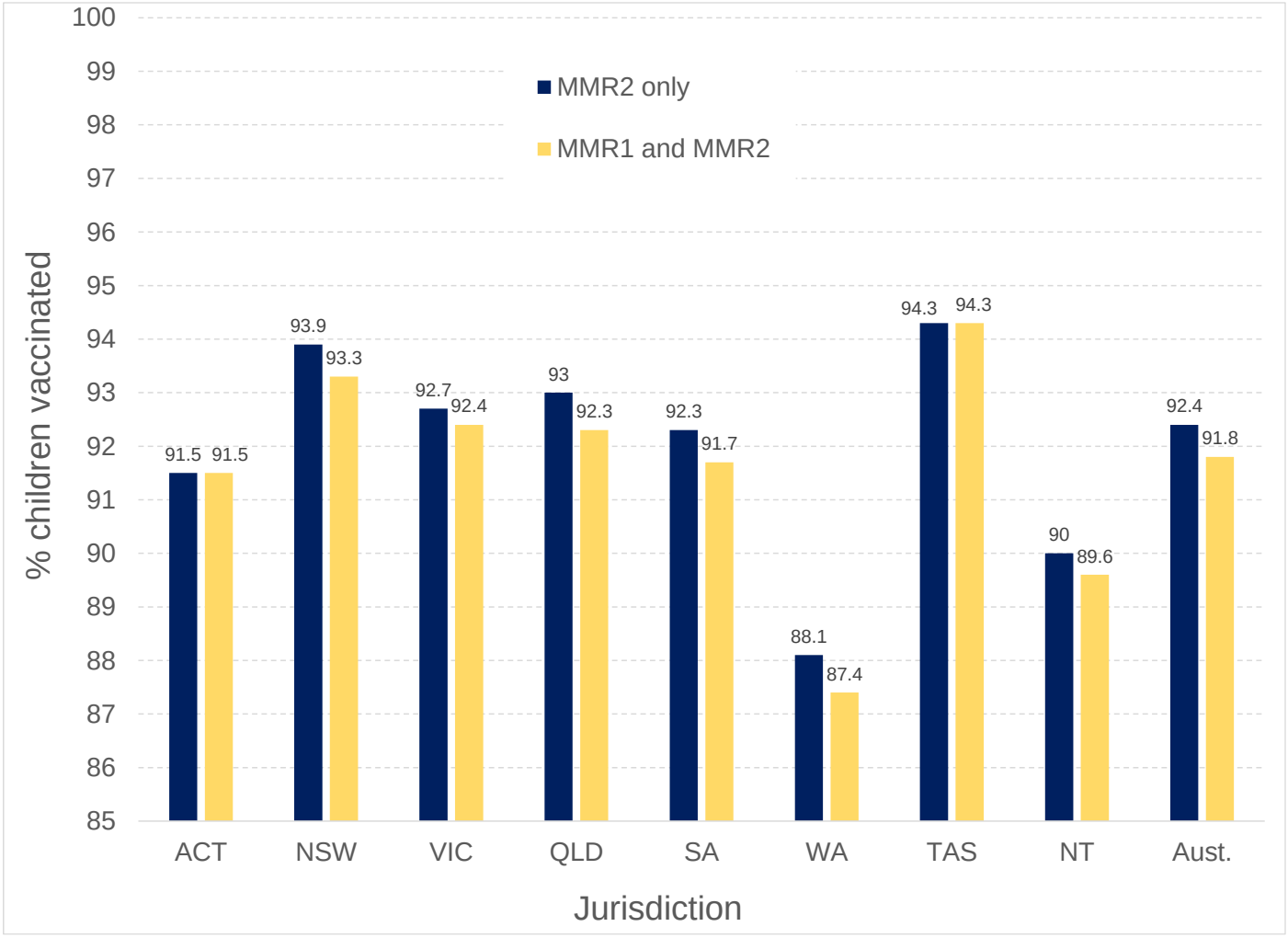
* Cohort born 1 January 2019 – 31 December 2019

MMR = measles-mumps-rubella

Source: Australian Immunisation Register, data as at 6 February 2022

Figure 6 provides an assessment of the effect of the prior dose assumption on 2-dose MMR-containing vaccine coverage estimates by jurisdiction for Indigenous children. Coverage was 0.6 percentage points lower at the national level without application of the assumption, ranging from 0.0 to 0.7 percentage points by jurisdiction.

Figure 6. Impact of prior dose assumption on 2-dose MMR-containing vaccine coverage estimates, by jurisdiction – Indigenous children*



* Cohort born 1 January 2019 – 31 December 2019

MMR = measles-mumps-rubella

Source: Australian Immunisation Register, data as at 6 February 2022

Table 2 provides a more detailed breakdown of the effect of the prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine by jurisdiction for all children. The lower coverage without application of the assumption is largely driven by children recorded as not having received the first dose, which is due at 8 weeks of age but often given at 6 weeks of age.

Table 2. Breakdown of impact of prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine, by doses missing and jurisdiction – all children*

	DTPa3 only (%)	DTPa1, DTPa2 and DTPa3 (%)	Percentage points lower than with prior dose assumption	Missing dose 1 (%)	Missing dose 2 (%)	Missing dose 1 and dose 2 (%)
ACT	96.7	94.5	2.20	1.85	0.21	0.13
NSW	94.8	91.3	3.50	3.09	0.34	0.16
VIC	95.2	92.1	3.10	2.6	0.29	0.13
QLD	93.9	92.2	1.70	1.45	0.18	0.06
SA	94.9	92.4	2.50	2.11	0.25	0.07
WA	94	91.6	2.40	2	0.28	0.11
TAS	95.4	89.7	5.70	4.99	0.43	0.31
NT	93.2	91.8	1.40	1.22	0.17	0.09
Aust.	94.7	91.8	2.90	2.44	0.28	0.12

* Cohort born 1 January 2020 – 31 December 2020

DTPa = diphtheria-tetanus-acellular pertussis -containing vaccine

Source: Australian Immunisation Register, data as at 6 February 2022

Table 3 provides a more detailed breakdown of the effect of the prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine by age at Medicare registration for all children. Coverage among children with delayed Medicare registration was disproportionately lower without use of the assumption.

Table 3. Impact of prior dose assumption on coverage estimates for the primary course of DTPa-containing vaccine by age at Medicare registration – all children*

Age at Medicare registration	N	DTPa3 only (%)	DTPa1, DTPa2 and DTPa3 (%)	Difference (percentage points)
Less than 6 weeks	194,251	96.3	94.8	1.5
6–8 weeks	30,035	95.2	91.3	3.9
8–11 weeks	25,254	93.3	86.8	6.5
12 weeks or more	39,098	87.2	80.5	6.7

* Cohort born 1 January 2020 – 31 December 2020

DTPa = diphtheria-tetanus-acellular pertussis

Source: Australian Immunisation Register, data as at 6 February 2022

Table 4 provides an assessment of the effect of the prior dose assumption on vaccine coverage estimates for the primary course of DTPa-containing vaccine by remoteness of residence for all children. Coverage without use of the assumption ranged from 1.9 percentage points lower among children in Remote areas to 2.9 percentage points lower in Major Cities.

Table 4. Impact of the prior dose assumption on coverage estimates for the primary course of DTPa-containing vaccine by remoteness of area of residence* – all children#

Remoteness	N	DTPa3 only (%)	DTPa1, DTPa2 and DTPa3 (%)	Difference (percentage points)
Major Cities	210,965	94.9	92.0	2.9
Regional	70,183	94.3	91.6	2.7
Remote	5,946	92.2	90.3	1.9

* Accessibility/Remoteness Index of Australia (ARIA++)

Cohort born 1 January 2020 – 31 December 2020

DTPa = diphtheria-tetanus-acellular pertussis

Source: Australian Immunisation Register, data as at 6 February 2022

Comparison of fully vaccinated coverage estimates at the 5-year and 2-year age milestones using different coverage calculation algorithms

Table 5 provides a comparison of fully vaccinated coverage estimates for the 5-year age milestone using different coverage calculation algorithms. As more vaccines are added to the algorithm the coverage estimate progressively decreases. However, the decrease is consistently less for Indigenous children, other than for the algorithms including rotavirus vaccine. Note that the current 5-year algorithm includes either DTPa dose 5 or DTPa dose 4 if given after 3.5 years of age. The latter criterion was included as children who were over 18 months of age in March 2016 when a fourth dose of DTPa-containing vaccine was added to the NIP schedule at 18 months of age would have been due for their fourth dose at 4 years of age (with recommendation then in place that this could be given as early as 3.5 years). However, as all children assessed at the 5-year age milestone have now been eligible for 5 doses of DTPa-containing vaccine, the reference to a fourth dose given after 3.5 years of age has been dropped from those algorithms listing all vaccines a child should have received by their fifth birthday.

Additional analyses at the 2-year age milestone show that a coverage algorithm including all vaccine doses a child should have received by their second birthday, excluding doses due at 2 and 4 months of age, would have little impact on estimated coverage compared to the current algorithm – 91.5% versus 91.8% overall and 90.2% versus 90.6% for Indigenous children (see Appendix 2).

Table 5. Comparison of fully vaccinated coverage estimates at the 5-year age milestone using different algorithms

Algorithm description	Vaccines/antigens included	Coverage – all children (%)	Coverage – Indigenous children (%)
Current	DTPa dose 5 or DTPa dose 4 (if given after 3.5 years of age) + polio dose 4 (given as **single vaccine**)	94.3	96.6
Current + MMR dose 2	DTPa dose 5 or DTPa dose 4 (if given after 3.5 years of age) + polio dose 4 + MMR dose 2	94.2	96.5
Current + MMR dose 2 + 13vPCV dose 3	DTPa dose 5 or DTPa dose 4 (if given after 3.5 years of age) + polio dose 4 + MMR dose 2 + 13vPCV dose 3 or 4	92.4	95.4
All vaccines a child should have received by their fifth birthday excluding rotavirus vaccine (using prior dose assumption)	DTPa dose 5 + polio dose 4 + MMR dose 2 + varicella dose 1 + 13vPCV dose 3 or 4 + Hib dose 4 + Hep B dose 3 + Men C dose 1	91.1	94.6
All vaccines a child should have received by their fifth birthday including rotavirus vaccine (using prior dose assumption)	DTPa dose 5 + polio dose 4 + MMR dose 2 + varicella dose 1 + 13vPCV dose 3 or 4 + Hib dose 4 + Hep B dose 3 + Men C dose 1 + rotavirus dose 2	86.9	86.4
*All vaccine **doses** a child should have received by their fifth birthday excluding rotavirus vaccines (i.e. **not** using prior dose assumption)*	DTPa doses 1–5 + polio doses 1–4 + MMR doses 1–2 + varicella dose 1 + 13vPCV doses 1–3 or 1–4 + Hib doses 1–4 + Hep B doses 1–3 + Men C dose 1	86.0	91.5
*All vaccine **doses** a child should have received by their fifth birthday including rotavirus vaccines (i.e. **not** using prior dose assumption)*	DTPa doses 1–5 + polio doses 1–4 + MMR doses 1–2 + varicella dose 1 + 13vPCV doses 1–3 or 1–4 + Hib doses 1–4 + Hep B doses 1–3 + Men C dose 1 + rotavirus doses 1–2	83.1	84.0
*All vaccine **doses** a child should have received by their fifth birthday, excluding doses due at 2 and 4 months of age (i.e. **limiting** prior dose assumption to doses due at 2 and 4 months)*	DTPa doses 3–5 + polio doses 3–4 + MMR doses 1–2 + varicella dose 1 + 13vPCV dose 3 or 4 + Hib doses 3–4 + Hep B dose 3 + Men C dose 1	90.1	93.7

DTPa = diphtheria-tetanus-acellular pertussis
MMR = measles-mumps-rubella
13vPCV = pneumococcal conjugate vaccine
Hib = *Haemophilus influenzae* type b
Hep B = hepatitis B
Men C = meningococcal C

Source: Australian Immunisation Register, data as at 30 January 2022

Lag period analysis

Table 6 shows vaccination coverage estimates in children by age assessment milestone, vaccine/antigen and Indigenous status, using AIR data as at 31 March 2021 compared to AIR data as at 31 January 2021 to assess whether using a shorter lag period between the end of the due date for completion of each milestone (the assessment date) and the date of the AIR data used for analysis leads to any changes in vaccination coverage. For all vaccines/antigens and all three age milestones there was minimal difference in coverage when using a shorter 1-month lag compared with using the current standard 3-month lag period. This was the case for both all children and Indigenous children.

Table 6. Vaccination coverage estimates (%) in children by age assessment milestone, vaccine/antigen and Indigenous status, using AIR data as at 31 March 2021 compared to data as at 31 January 2021

Vaccine/antigen	Age milestone	Data as at 31 March 2021 (3-month lag)		Data as at 31 January 2021 (1-month lag)	
		All children	Indigenous	All children	Indigenous
Fully vaccinated	12 months†	94.8	93.1	94.7	92.9
	24 months‡	92.1	91.2	92.1	91.2
	60 months§	94.8	97.0	94.9	97.0
Diphtheria-tetanus-acellular pertussis	12 months† (Dose 3)	95.3	93.3	95.2	93.1
	24 months‡ (Dose 4)	93.5	92.5	93.6	92.6
	60 months§ (Dose 4 or 5)	96.7	98.5	96.8	98.5
Polio	12 months† (Dose 3)	95.3	93.3	95.1	93.1
	24 months‡ (Dose 3)	96.6	97.3	96.6	97.4
	60 months§ (Dose 4)	94.9	97.0	94.9	97.0
Haemophilus influenzae type b	12 months† (Dose 3)	95.2	93.2	95.1	93.1
	24 months‡ (Dose 4)	94.3	94.6	94.3	94.6
	60 months§ (Dose 4)	96.7	98.8	96.7	98.8
Hepatitis B	12 months† (Dose 3)	95.1	93.2	95.0	93.1
	24 months‡ (Dose 3)	96.4	97.3	96.4	97.3
	60 months§ (Dose 3)	96.6	98.8	96.7	98.8
Measles-mumps-rubella	12 months	N/A	N/A	N/A	N/A
	24 months‡ (Dose 1)	95.8	96.9	95.8	96.9
	24 months‡ (Dose 2)	94.0	93.9	94.0	93.9
	60 months§ (Dose 2)	96.8	98.8	96.9	98.8
Varicella	12 months	N/A	N/A	N/A	N/A
	24 months‡ (Dose 1)	94.0	93.6	94.0	93.6
	60 months§ (Dose 1)	96.8	98.8	96.8	98.8
Meningococcal ACWY vaccine	12 months	N/A	N/A	N/A	N/A
	24 months‡ (Dose 1)	95.0	96.5	95.1	96.5
	60 months§ (Dose 1)	N/A	N/A	N/A	N/A
13-valent pneumococcal conjugate vaccine	12 months† (Dose 2 or 3)	96.5	96.7	96.5	96.7
	24 months‡ (Dose 3)	95.6	96.8	95.6	96.9
	60 months§ (Dose 3)	95.2	97.4	95.2	97.4
Rotavirus vaccine	12 months† (Dose 2)	92.5	87.6	92.4	87.6
	24 months	N/A	N/A	N/A	N/A
	60 months	N/A	N/A	N/A	N/A

Coverage estimates in this table are calculated using 12-month-wide cohorts and may differ slightly from estimates published elsewhere using rolling annualised cohorts.

† Cohort born 1 January 2019 – 31 December 2019 (2020 estimate)

‡ Cohort born 1 January 2018 – 31 December 2018 (2020 estimate)

§ Cohort born 1 January 2015 – 31 December 2015 (2020 estimate)

N/A Not applicable (vaccine either not given prior to this milestone, or contraindicated after previous milestone)

Source: Australian Immunisation Register, data as at 31 March 2021 for 3-month lag data and 31 January 2021 for 1-month lag data.

Analysis of MADIP data

NCIRS has worked with HERD to use MADIP data to better define some medically at-risk population groups in order to assess COVID-19 vaccine uptake. Linked Medicare Benefits Schedule (MBS) and Pharmaceutical Benefit Scheme (PBS) data can be used as proxy measures to define select specific medical risk groups. Examples are MBS item numbers for pregnancy ultrasound as a proxy for pregnancy at a particular gestation, and PBS item numbers for particular pharmaceutical preparations as a proxy for having diabetes. However, for the majority of medically at-risk childhood populations defined in the Australian Immunisation Handbook,[19] no proxy items are available (e.g. childhood haematological cancers, congenital heart disease) or greater precision in defining the population is required (e.g. severe asthma is usually defined as asthma requiring hospitalisation). The MADIP data asset does not as yet include International Classification of Diseases, Tenth Revision (ICD-10) coded hospital discharge data.

Hence, while MADIP data may provide an indication of some medically at-risk children – for example, those with diabetes – the overall ascertainment of this population will be incomplete, with some relevant conditions not captured at all. Also, as many of these medically at-risk conditions are rare in children, misclassification of the population at risk may lead to a lack of representativeness and inaccuracies in regular coverage reporting. Therefore, to fully enable assessment of coverage in the childhood medically at-risk groups defined for relevant NIP vaccines using MADIP data, integration of timely hospitalisation (ICD-10 coded hospital discharge) data is required in addition to the datasets already linked. There are established ICD-10 codes for many of these conditions; they have been used in previous work to define such groups, and would be useful if needed for international comparisons. There is ongoing work using MADIP data linked to the National Integrated Health Services Information (NIHSI) Analysis Asset. The NIHSI data asset includes some ICD-10 coded hospitalisation data but these data are not current and are being used primarily for the purposes of examining the validity of MBS and PBS codes used to define some medically at-risk groups.{Australian Government Department of Health, 2020 #19;Australian Government Department of Health, 2022 #20;Australian Government Australian Institute of Health & Welfare, 2005 #21;Jayasinghe, 2019 #22} It is expected that any national linkage to ICD-10 coded hospital discharge data would be subject to some delays, given national data is collated from eight state and territory databases and there is typically many months delay in data transmission and collation for the whole Australian population. However, such reporting is still warranted to ensure program objectives are achieved, in terms of uptake in medically at-risk populations under the NIP.

Discussion

The underlying coverage assessment and reporting methodologies used in Australia have remained largely unchanged over the past 25 years, with relatively minor adjustments to account for inclusion/removal of vaccines from the NIP. While this continuity and consistency has its benefits, issues with some of the methodological settings have arisen. The rationale for some of the methodological decisions made over two decades ago is unclear, particularly in relation to the 5-year fully vaccinated assessment algorithm, which was introduced in 2002 and has always assessed only the booster doses of vaccines due at 4 years of age (initially 5 years), unlike the 1- and 2-year algorithms which have since inception assessed most of the vaccines that should have been received by the relevant age. The limited scope of the 5-year assessment algorithm has become increasingly problematic as the NIP schedule has evolved over time. While new vaccines, including meningococcal, pneumococcal and varicella, have been added to the NIP schedule and to the 1- and/or 2-year assessment algorithms, the 5-year fully vaccinated algorithm has included only the single vaccine now due at 4 years of age since the second dose of MMR-containing vaccine was moved from 4 years to 18 months in 2013. After a quarter of a century with little change in methodological settings, we considered it appropriate to undertake a thorough review, with consideration of public health rationale and objectives and comparison to approaches taken overseas.

Fully vaccinated coverage algorithms and assessment milestones

Our review of coverage assessment and reporting methodologies in selected countries with comparable immunisation information systems and schedules identified considerable variation. Only two of the six other countries reviewed also assess fully vaccinated coverage (New Zealand, at multiple age milestones, and the Netherlands, at the 2-year age milestone only), with the remainder assessing coverage for individual vaccines only. However, fully vaccinated coverage assessment and reporting has been in place for 25 years in Australia and the key stakeholders we interviewed were all highly supportive of its usefulness from a public health perspective. Similarly, while assessment age milestones varied between the countries reviewed there was strong stakeholder support for maintaining the current 1-, 2- and 5-year age milestones in Australia. Some interviewees also recommended that an 18-month age milestone be added to allow assessment of MMR coverage six months after it is due at 12 months of age, in the context of concerns about maintaining measles elimination. In relation to fully vaccinated assessment algorithms, most stakeholders interviewed were supportive of a consistent and more transparent approach, with all vaccines/antigens (except rotavirus, due to its strict upper age limits) that should have been received by each age milestone included. This would particularly address the major identified shortcomings with the current 5-year fully vaccinated algorithm.

Data lag periods and immediacy of reporting

The key stakeholders we interviewed highlighted the importance of optimising the immediacy of data reporting, but acknowledged the tension between assessment of timely vaccination versus actual coverage achieved. Most interviewees were supportive of continued use, in primary routine coverage reporting, of an assessment date encompassing vaccinations received up to 6 months after the last scheduled vaccine due at the 1- and 2-year age milestones, and 12 months after at the 5-year age milestone. Most also supported the need for supplementary secondary analyses of timely vaccination. Of note, our data showed minimal difference in coverage estimates when using a shorter 1-month lag between the assessment date and the extraction date (when AIR data used for analysis are extracted) than with the current standard 3-month lag period. This 3-month lag period was originally introduced when reporting to the ACIR was mainly paper based.[1] However, now that over 96% of vaccination encounters are notified to AIR electronically,[7] delayed notification to AIR is not a significant issue, and using a 1-month data extraction lag would improve immediacy of coverage data without loss of accuracy. Some interviewees also suggested that an interactive online platform be developed to allow providers and consumers timely access to coverage estimates for their own area (e.g. local government area).

Prior dose assumption

Interviewees were also supportive of reassessment of the appropriateness of the prior dose assumption in light of technological (predominance of electronic reporting) and other (mandatory reporting) changes since instituted. In our review of comparable countries we could find no evidence of any others using a similar assumption. This assumption was introduced when reporting of vaccination coverage from the ACIR first commenced in 1998, because delays in Medicare registration were considered likely to affect recording of vaccine doses due at 2 and 4 months of age, and delays in reporting to the ACIR were more common in general due to the paper-based system.[10] The assumption was last validated in the Australian context in 2001 using a telephone survey of parents of children recorded as having received the third dose of DTPa-containing vaccine but not the first and/or second dose, with 97% assessed as definitely fully vaccinated based on a parent reading from a provider-completed written vaccination record.[10] The use of the prior dose assumption was estimated to increase fully vaccinated coverage at the 1-year milestone by seven percentage points. Our analysis of AIR data showed use of the assumption had less than half a percentage point impact on estimates of 2-dose MMR coverage, but around three percentage points on vaccines/antigens with doses due at 2, 4 and/or 6 months of age (DTPa and 13vPCV). On further analysis in relation to DTPa this was largely driven by

children recorded as not having received the first dose, due at 8 weeks but often given at 6 weeks of age, with impact of the prior dose assumption disproportionately greater in children with delayed Medicare registration (fourfold higher in those registered 12 or more weeks after birth compared to less than 6 weeks after birth). This could be due to a combination of: underreporting to AIR of vaccinations in infants not yet registered with Medicare, including in those born overseas; and incomplete reassignment of vaccinations in infants initially assigned SINs in AIR to their PIN-associated record once Medicare-registered. We found no difference in data for the 6-month period following introduction of mandatory reporting on 1 July 2021. Until these issues around incomplete capture of vaccinations in young infants with delayed Medicare registration are resolved, continued use of the prior dose assumption seems appropriate for vaccine series due at 2, 4 and/or 6 months of age, but there seems little rationale for continued use for vaccine series due in children aged 1 year or over.[20]

Additional vaccine doses in Indigenous and medically at-risk children

Our interviewees strongly supported regular assessment of fully vaccinated coverage in Indigenous and medically at-risk children, incorporating the additional vaccines/vaccine doses funded under the NIP for these groups. However, most recommended that Indigenous fully vaccinated coverage should primarily be assessed using the standard algorithm (comparing 'apples with apples'), with secondary analysis to include Indigenous-specific vaccines in the algorithm – namely, meningococcal B (all jurisdictions) and hepatitis A/extra dose of 13vPCV (Queensland, NT, SA, WA only) – at relevant milestones. Very limited information on medical conditions is currently captured in AIR. Our exploratory analyses showed that coverage assessment in medically at-risk children using current MADIP data would generally be very incomplete. However, if hospitalisation data could also be integrated into the MADIP data, more robust coverage estimates would be achievable.

Other methodological considerations

Vaccination activity may vary throughout the year – for example, in relation to school holidays and school enrolment timing. Seasonal adjustment is used in assessment and reporting of data in a range of other settings, although methodologies are often conceptually complex. It is recommended that the Department engage with suitable experts to consider the extent to which seasonality exists within AIR data, and potential appropriate strategies to account for this, being mindful of the need to communicate any such approaches simply to broad audiences.

Consistency of coverage assessment and reporting in Australia

AIR data on vaccination coverage in Australia are primarily analysed and reported by Services Australia/the Department and NCIRS. We identified several differences in the methodologies used by Services Australia and NCIRS, which could potentially contribute to the discrepancies that have been observed previously in coverage estimates reported by the Department and NCIRS. While relatively minor (generally less than 1 percentage point), such inconsistencies are not optimal in terms of maintaining public and provider confidence. Ongoing discussions between the three agencies are advisable to ensure consistent methodological approaches. The agencies should also consider strategies that would promote consistency of analysis and reporting among other key stakeholders such as state and territory health department staff.

Appropriate level of precision in reporting of vaccination coverage data

Precision relates to the number of decimal places (digits to the right of the decimal point) and significant figures (number of all digits). Excessive precision in data reporting should be avoided as it tends to overcomplicate and obscure messaging associated with the data.[21] NCIRS reports all vaccination coverage data using a single decimal place, whereas Services Australia and the Department report using two decimal places. Of the six other comparable countries reviewed, all report to either one decimal place (NZ, UK, Ireland, Netherlands) or none (Denmark). Given inherent limitations in the data, including some level of underreporting[22] and data fluctuation, use of a single decimal place is the appropriate level of precision for reporting of most Australian vaccination coverage estimates. Appropriate level of precision also needs to be considered in relation to cohort size. For example, in relation to Aboriginal and Torres Strait Islander children, the size of the cohorts at national level for which vaccination coverage is assessed at the 1-, 2- and 5-year age milestones is approximately 20,000. A change in coverage of 0.01% would therefore equate to uptake in approximately two children, making use of two decimal places unhelpful and inappropriate. For cohorts with a particularly small population size (e.g. less than 100), it may be preferable to report using no decimal place, as a change in coverage of less than one percentage point would imply/reflect uptake of vaccination by a fraction of a single individual, which is obviously not possible.

Handling and communicating changes in coverage assessment and reporting methodology

A coverage assessment algorithm at the 5-year age milestone including all vaccines/antigens that should have been received by that age (except rotavirus, and with continued use of prior dose assumption for infant vaccine series) would result in fully vaccinated coverage 4.2 percentage points lower than the current algorithm for children overall (90.1% versus 94.3%) and 2.9 percentage points lower for Indigenous children (93.7% versus 96.6%). A similarly amended 2-year age milestone algorithm would result in less than half a percentage point difference, due to

more minor changes involved, with no change needed to the 1-year algorithm. A potential perception of a ‘drop’ in fully vaccinated coverage due to new algorithms, particularly at the 5-year mark, could create undue concern and communications issues. To maximise the public health usefulness of both new and old benchmarks, parallel reporting using both new and old algorithms would be advisable for a potentially extended period until the new algorithms are well established with appropriate trend data. A strategy would also be needed to clearly communicate rationale and address any concerns of the public and other key stakeholders when new methodologies indicate lower than previously reported coverage.

Conclusions

The underlying coverage assessment and reporting methodologies used in Australia have remained largely unchanged over the past 25 years. While this continuity and consistency has its benefits, our findings show that some of these methodologies are no longer optimally fit for purpose from a public health perspective. A refresh of methodological settings is therefore warranted, in line with the recommendations presented in this report. Further consultation with key stakeholders would be of benefit to refine and operationalise these recommendations.

Appendices

Appendix 1. Review of immunisation coverage analysis and reporting methodologies in Australia and selected countries with similar immunisation systems and schedules

Country with Immunisation Information Systems (IIS)	Age milestones assessed	Report fully vaccinated coverage	Vaccine type and dose assessed for each milestone	Specific features of coverage methodology and reporting of estimates	At risk groups
Australia	12 months	Yes	3rd dose of DTPa (given at 6 months) 3rd dose of polio (given at 6 months) 3rd dose of Hep B (given at 6 months) 3rd dose of Hib (given at 6 months) 2nd or 3rd dose of 13vPCV (given at 4 or 6 months)	Cohort method used.[12] The Department publishes on its website rolling annualised coverage estimates, calculated quarterly using AIR data, for individual vaccines and for fully vaccinated at 12, 24 and 60 months, using the prior dose assumption for all age milestones and all vaccines. NCIRS publishes similar coverage estimates, but calculated annually, in its annual coverage reports.	The Department publishes rolling annualised coverage estimates for Indigenous children on its website, for individual vaccines and for fully vaccinated at 12, 24 and 60 months. NCIRS publishes similar coverage estimates, but calculated annually, in its annual coverage reports, along with coverage of hepatitis A vaccine and the fourth dose of 13vPCV, for Indigenous children in Queensland, SA, NT and WA only.
	24 months	Yes	4th dose of DTPa (given at 18 months) 3rd dose of polio (given at 6 months) 3rd dose of Hep B (given at 6 months) 4th dose of Hib (given at 12 or 18 months) 1st dose of Men ACWY (given at 12 months) 1st dose of varicella (given at 18 months) 2nd dose of MMR (given at 18 months) 3rd dose of 13vPCV (given at 6 or 12 months)		

	60 months	Yes	4th or 5th dose of DTPa (given at 48 months) 4th dose of polio (given at 48 months)		
New Zealand	6 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 2 doses of 10-valent pneumococcal (given at 6 weeks and 5 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months)	Cohort method used.[13] Immunisation coverage is calculated quarterly using National Immunisation Register (NIR) data for children who turned the milestone age during a 3-month or 12-month reporting period and who have completed their age-appropriate immunisations. 'Fully vaccinated for age' – the number of eligible children who have completed all of their age-appropriate immunisations by the time they turned the milestone age. Detailed immunisation coverage data for New Zealand and for each of the 20 district health boards provided.	Milestone age data are also provided by ethnicity and level of deprivation for 3-month and 12-month reporting periods. Ethnic groups reported on are: Māori, Pacific, Asian, New Zealand European and Other (includes European, African, Middle Eastern, Latin American/Hispanic).
	8 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 2 doses of 10-valent pneumococcal (given at 6 weeks and 5 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months)		
	12 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 2 doses of 10-valent pneumococcal (given at 6 weeks and 5 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months)		
	18 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 3 doses of 10-valent pneumococcal (given at 6 weeks, 5 months and 12 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months) 2 doses of MMR (given at 12 months and 15 months) 4 doses of Hib (given at 6 weeks, 3 months, 5 months and 15 months) 1 dose of varicella (given at 15 months)		
	24 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months)		

		3 doses of 10-valent pneumococcal (given at 6 weeks, 5 months and 12 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months) 2 doses of MMR (given at 12 months and 15 months) 4 doses of Hib (given at 6 weeks, 3 months, 5 months and 15 months) 1 dose of varicella (given at 15 months)		
54 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 3 doses of 10-valent pneumococcal (given at 6 weeks, 5 months and 12 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months) 2 doses of MMR (given at 12 months and 15 months) 4 doses of Hib (given at 6 weeks, 3 months, 5 months and 15 months) 1 dose of varicella (given at 15 months) 1 dose of booster DTPa and polio (given in a combination vaccine at 4 years)		
60 months	Yes	2 doses of rotavirus (given at 6 weeks and 3 months) 3 doses of 10-valent pneumococcal (given at 6 weeks, 5 months and 12 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 6 weeks, 3 months and 5 months) 2 doses of MMR (given at 12 months and 15 months) 4 doses of Hib (given at 6 weeks, 3 months, 5 months and 15 months) 1 dose of varicella (given at 15 months) 1 dose of booster DTPa and polio (given in a combination vaccine at 4 years)		

Norway	24 months	No	2 doses of rotavirus (given at 6 weeks and 3 months) 3 doses of DTPa, Hep B, polio, and Hib (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 3 months, 5 months and 12 months) 3 doses of 13-valent pneumococcal (given at 3 months, 5 months and 12 months) 1 dose of MMR (given at 15 months)	Cohort method used.[17] Norway does not report any fully vaccinated coverage estimates based on specific coverage algorithms. It reports on coverage estimates for individual vaccines/doses.	
	9 years	No	1 dose of booster DTPa and polio (given in a combination vaccine at 7 years) 2 doses of MMR (given at 15 months and 11 years)		
UK	12 months	No	3 doses of DTPa-polio/Hib/Hep B (given at 2, 3 and 4 months) 2 doses of rotavirus (given at 2 and 3 months) 2 doses of Men B (given at 2 and 4 months) 1 dose of PCV (given at 3 months)	Cohort method used.[14] The UK does not report any fully vaccinated coverage estimates based on specific coverage algorithms. It reports on coverage estimates for individual vaccines/doses.	
	24 months	No	3 doses of DTPa-polio/Hib/Hep B (given at 2, 3 and 4 months) 1 dose of MMR (given at 12–13 months) 2 doses of PCV (given at 3 months and 12–13 months) 3 doses of Men B (given at 2, 4 and 12–13 months) 1 (or 4) dose of Hib/Men C (booster) (given at 12–13 months)		
	60 months	No	3 doses of DTPa-polio/Hib/Hep B (given at 2, 3 and 4 months) 1 dose of MMR (given at 12–13 months) 2 doses of MMR (given at 12–13 months and 3 years and 4 months) 1 (or 4) dose of Hib/Men C booster (given at 12–13 months) 1 (or 4) doses of DTPa-polio booster (given at 3 years and 4 months)		
Ireland	12 months	No	3 doses of DTPa (given at 2, 4 and 6 months)	Since 2000, the Health Protection Surveillance Centre collates data	

			3 doses of polio (given at 2, 4 and 6 months) 3 doses of Hep B (given at 2, 4 and 6 months) 3 doses of Hib (given at 2, 4 and 6 months) 2 doses of PCV (given at 2 and 6 months) 1 dose of Men C (given at 6 months) 2 doses of rotavirus (given at 2 and 4 months) 2 doses of Men B (given at 2 and 4 months)	and reports on the uptake of vaccines provided through the childhood vaccination program. Cohort method used.[15] Fully vaccinated estimates at 12 months and 24 months of age are not reported on.	
	24 months	No	3 doses of DTPa (given at 2, 4 and 6 months) 3 doses of polio (given at 2, 4 and 6 months) 3 doses of Hep B (given at 2, 4 and 6 months) 4 doses of Hib (given at 2, 4, 6 and 13 months) 3 doses of PCV (given at 2, 6 and 13 months) 2 doses of Men C (given at 6 and 13 months) 2 doses of rotavirus (given at 2 and 4 months) 3 doses of Men B (given at 2, 4 and 12 months) 1 dose of MMR (given at 12 months)		
Netherlands	24 months	Yes	3 doses of DTPa, Hep B, polio, and Hib antigens (usually given together in a hexavalent combination vaccine (Infanrix hexa) (given at 3 months, 5 months and 11 months) 3 doses of PCV (given at 3 months, 5 months and 11 months) 1 dose of MMR (given at 14 months) 1 dose of Men ACWY (given at 14 months)	Fully vaccinated coverage calculated and reported on at 2 years of age. Cohort method used.[18]	
	60 months	No	4 doses of DTPa and polio (given in a combination vaccine at 4 years)		

	10 years	No	1 dose of DT-polio (given at 9 years) 2 doses of MMR (given at 14 months and 9 years)		
Denmark	12 months	No	2 doses of DTPa, polio, and Hib antigens (usually given together in a pentavalent combination vaccine (Pentavac) (given at 3 months and 5 months) 2 doses of PCV (given at 3 months and 5 months)	Cohort method used.[16] Denmark does not report any fully vaccinated coverage estimates based on specific coverage algorithms. It reports on coverage estimates for individual vaccines/doses.	
	24 months	No	3 doses of DTPa, polio, and Hib antigens (usually given together in a pentavalent combination vaccine (Pentavac) (given at 12 months) 3 doses of PCV (given at 12 months) 1 dose of MMR (given at 15 months)		
	60 months	No	2 doses of MMR (given at 4 years) 4 doses of DTPa, polio, Hib (given at 5 years)		

DTPa = diphtheria-tetanus-acellular pertussis

Hep B = hepatitis B

Hib = *Haemophilus influenzae* type b 13vPCV = 13-valent pneumococcal conjugate vaccine

MMR = measles-mumps-rubella

Men C = meningococcal C

Men B = meningococcal B

Men ACWY = meningococcal ACWY vaccine

DTPa-polio = diphtheria-tetanus-acellular pertussis with inactivated polio vaccine

PCV = pneumococcal conjugate vaccine

Appendix 2. Comparison of fully vaccinated coverage estimates at the 2-year age milestone using different algorithms

Algorithm description	Vaccines/antigens included	Coverage – all children (%)	Coverage – Indigenous children (%)
Current	DTPa dose 4 + polio dose 3 + MMR dose 2 + varicella dose 1 + 13vPCV dose 3 or dose 4 + Hib dose 4 + Hep B dose 3 + Men C dose 1	91.8	90.6
All vaccine doses a child should have received by their fifth birthday including rotavirus vaccines (not using prior dose assumption)	DTPa doses 1–4 + polio doses 1–3 + MMR doses 1–2 + varicella dose 1 + 13vPCV doses 1-3 or 1–4 + Hib doses 1–4 + Hep B doses 1–3 + Men C dose 1 + rotavirus doses 1–2	85.3	81.5
All vaccine doses a child should have received by their fifth birthday excluding rotavirus vaccines (not using prior dose assumption)	DTPa doses 1–4 + polio doses 1–3 + MMR doses 1–2 + varicella dose 1 + 13vPCV doses 1–3 or 1–4 + Hib doses 1–4 + Hep B doses 1–3 + Men C dose 1	88.6	88.7
All vaccine doses a child should have received by their second birthday, excluding doses due at 2 and 4 months of age (i.e. limiting prior dose assumption to doses due at 2 and 4 months)	DTPa doses 3–4 + polio dose 3 + MMR doses 1–2 + varicella dose 1 + 13vPCV dose 3 or 4 + Hib doses 3–4 + Hep B dose 3 + Men C dose 1	91.5	90.2

DTPa = diphtheria-tetanus-acellular pertussis

MMR = measles-mumps-rubella

13vPCV = pneumococcal conjugate vaccine

Hib = *Haemophilus influenzae* type b

Hep B = hepatitis B

Men C = meningococcal C

Source: Australian Immunisation Register, data as at 30 January 2022

References

1. Hull BP, McIntyre PB, Heath TC, Sayer GP. Measuring immunisation coverage in Australia. A review of the Australian Childhood Immunisation Register. Aust Fam Physician. 1999; 28:55-60.

2. Hull BP, Deeks SL, McIntyre PB. The Australian Childhood Immunisation Register-A model for universal immunisation registers? Vaccine. 2009; 27:5054-60.

3. Kabir A, Newall AT, Randall D, Menzies R, Sheridan S, Jayasinghe S, et al. Estimating pneumococcal vaccine coverage among Australian Indigenous children and children with medically at-risk conditions using record linkage. Vaccine. 2021; 39:1727-35.

4. O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. Communicable Diseases Intelligence. 1998; 22:36-7.

5. Hull B, Deeks S, Menzies R, McIntyre P. Immunisation coverage annual report, 2007. Commun Dis Intell Q Rep. 2009; 33:170-87.

6. Hull BP, Mahajan D, Dey A, Menzies RI, McIntyre PB. Immunisation coverage annual report, 2008. Commun Dis Intell Q Rep. 2010; 34:241-58.

7. National Centre For Immunisation Research and Surveillance. Annual Immunisation Coverage Report 2020. Sydney: National Centre For Immunisation Research and Surveillance; 2021 [updated 29/11/2021; cited 2022 25/03/2022]; Available from: https://www.ncirs.org.au/sites/default/files/2021-11/NCIRS%20Annual%20Immunisation%20Coverage%20report%202020.pdf.

8. National Centre For Immunisation Research and Surveillance. Research report 1: Coverage at the 2-year and 5-year age milestones. Sydney: National Centre For Immunisation Research and Surveillance; 2020 [updated 15/07/2020; cited 2022 16/03/2022]; Available from: https://ncirs.org.au/sites/default/files/2020-07/Coverage%20at%20the%202-year%20age%20milestone_FINAL_15%20July%202020.pdf.

9. Australian National Audit Office. Improving Immunisation Coverage. Canberra: Australian National Audit Office; 2021 [updated 22/09/2021; cited 2022 16/03/2022]; Available from: https://www.anao.gov.au/work/performance-audit/improving-immunisation-coverage.

10. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Estimating immunisation coverage: is the 'third dose assumption' still valid? Commun Dis Intell Q Rep. 2003; 27:357-61.

11. Australian Government Department of Health. Mandatory reporting of National Immunisation Program vaccines to the Australian Immunisation Register began on 1 July 2021. Canberra: Australian Government Department of Health; 2021 [updated 08/07/2021; cited 2022 23/03/2022]; Available from: https://www.health.gov.au/news/mandatory-reporting-of-national-immunisation-program-vaccines-to-the-australian-immunisation-register-began-on-1-july-2021.

12. Hull B, Hendry A, Dey A, Macartney K, Beard F. Immunisation Coverage Annual Report 2019. Commun Dis Intell (2018). 2021; 45.

13. New Zealand Ministry of Health. National and regional immunisation data. New Zealand: New Zealand Ministry of Health; 2022 [updated 29/05/2023; cited 2023 06/06/2023]; Available from: https://www.health.govt.nz/our-work/preventative-health-wellness/immunisation/immunisation-coverage/national-and-regional-immunisation-data.

14. UK Health Security Agency. Vaccine uptake guidance and the latest coverage data - Cover of vaccination evaluated rapidly (COVER) programme UK: UK Health Security Agency; 2022 [updated 22/02/2022; cited 2022 17/03/2022]; Available from: https://www.gov.uk/government/collections/vaccine-uptake#cover-of-vaccination-evaluated-rapidly-programme.

15. Health Protection Surveillance Centre. Immunisation uptake statistics at 12 and 24 months of age. Ireland: Health Protection Surveillance Centre; 2022 [updated 10/02/2022; cited 2022 17/03/2022];

Available from: https://www.hpsc.ie/a-z/vaccinepreventable/vaccination/immunisationuptakestatistics/immunisationuptakestatisticsat12and24monthsofage/.

16. Danish Health Authority. The Danish childhood immunization programme 2018 - English summary. Denmark: Danish Health Authority; 2018 [updated 2018; cited 2022 17/03/2022]; Available from: https://www.sst.dk/-/media/Udgivelser/2019/B%C3%B8rnevaccinationsprogrammet-%C3%A5rsrapport/The-Danish-childhood-vaccination-programme-2018-summary-in-english.ashx?la=da&hash=34B538452F61AC10A87441E1D20D3E9E4D8CE955.

17. The Norwegian Institute of Public Health. High vaccine uptake in the childhood immunisation programme. Norway: The Norwegian Institute of Public Health; 2022 [updated 07/04/2022; cited 2023 06/06/2023]; Available from: https://www.fhi.no/en/news/2022/high-vaccine-uptake-in-the-childhood-immunisation-programme/.

18. National Institute for Public Health and the Environment. Immunisation coverage and annual report - National Immunisation Programme in the Netherlands 2019. The Netherlands: National Institute for Public Health and the Environment; 2020 [updated 2020; cited 2022 17/03/2022]; Available from: https://www.rivm.nl/bibliotheek/rapporten/2020-0011.pdf.

19. Australian Technical Advisory Group on Immunisation (ATAGI). Australian Immunisation Handbook. Canberra: Australian Government Department of Health; 2018; Available from: https://immunisationhandbook.health.gov.au.

20. Australian Government Department of Health. No Jab, No Pay –New Immunisation Requirements for Family Assistance Payments. Canberra2019 [updated 19 November 2018; cited 2019 08/11/2019]; Available from: https://www.health.gov.au/sites/default/files/no-jab-no-pay-new-requirements-fact-sheet.pdf.

21. Cole TJ. Too many digits: the presentation of numerical data. Arch Dis Child. 2015; 100:608-9.

22. Dalton LM, K.; Beard, F.; Dey, A.; Hull, B. P.; McIntyre, P. B.; Macartney, K. Australian Immunisation Register Data Transfer Study - Stage 2 Final Report Sydney: National Centre for Immunisation Research and Surveillance; 2018 [updated 01/08/2018; cited 2022 12/05/2022]; Available from: https://www.ncirs.org.au/sites/default/files/2018-12/2018%20AIR%20data%20tranfer%20report_FINAL_0.pdf.