

APPLIED EPIDEMIOLOGY IN THE AUSTRALIAN COVID-19 PANDEMIC

Thesis for the degree of Master of Philosophy (Applied Epidemiology)

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Originality statement

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial material which have been accepted for the award of any other degree at the Australian National University or any other educational institution, except where due acknowledgement is made in this thesis. Any contribution made to the research by others is also explicitly acknowledged. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation, or linguistic expression is acknowledged.

A handwritten signature in black ink, appearing to read 'yejin joo', with a large, stylized flourish at the end.

Ye Jin (Zoe) Joo

28 October 2022

“Whatever is true, whatever is honourable, whatever is just, whatever is pure, whatever is lovely, whatever is commendable, if there is any excellence, if there is anything worthy of praise, think about these things.”

- *Philippians 4:8*

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Abbreviations

ABS	Australian Bureau of Statistics
ANU	Australian National University
ATAGI	Australian Technical Advisory Group on Immunisation
CDNA	Communicable Diseases Network Australia
CFR	Case fatality ratio
CI	Confidence interval
COVID-19	Coronavirus disease 2019
FETP	Field Epidemiology Training Program
FluCAN	Influenza Complications Alert Network
MAE	Master of Philosophy in Applied Epidemiology
NCIRS	National Centre for Immunisation Research and Surveillance
NIP	National Immunisation Program
NNDSS	National Notifiable Diseases Surveillance System
NSC	National Surveillance Committee
PAEDS	Paediatric Active Enhanced Disease Surveillance
PHSM	Public health and social measures
PHU	Public Health Unit
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SEIFA	Socio-Economic Indexes for Areas
SES	Socio-economic status
SPRINT-SARI	Short Period Incidence Study of Severe Acute Respiratory Infection
TEPHINET	Training Programs in Epidemiology and Public Health Interventions Network
WSPHU	Western Sydney Public Health Unit

Abstract

The National Centre for Immunisation Research and Surveillance (NCIRS) plays a pivotal role in collaborative research in the policy and practice of vaccine preventable diseases at the local, national, and international levels. From February 2021 to December 2022, I undertook a field placement at NCIRS, in the Surveillance, Coverage, Evaluation and Social Sciences unit. This thesis contains details of my projects during the 22-month field placement. My projects include an evaluation of four surveillance systems on COVID-19 severity data in Australia, an investigation of a norovirus outbreak at a social event in Sydney Olympic Park, an analysis of COVID-19 notifications data in Australia from January 2020 to November 2021, and an analysis of an association between invasive meningococcal disease and socio-economic status in Australia. This thesis also describes other public health experiences during my placement. These experiences include my role as a contact tracer during the Delta outbreak at the Western Sydney Public Health Unit, my role in investigating the transmission of SARS-CoV-2 in educational settings in New South Wales and co-facilitating a pre-conference workshop at the Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET) conference. Collectively, these projects and experiences fulfil the competencies of the Master of Philosophy in Applied Epidemiology program at the Australian National University.

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Chapter 1

Introduction to field placement and summary of experience

Field placement overview

During my Master of Philosophy in Applied Epidemiology (MAE) program, I was placed at the National Centre for Immunisation Research and Surveillance (NCIRS). I had been working at NCIRS for about two years prior to the MAE in the policy team. As I became a MAE scholar, I moved into the Surveillance, Coverage, Evaluation and Social Science (SuCESS) team. There are four core programs areas at NCIRS: Knowledge translation, Research, Immunisation program support and Monitoring and Evaluation.



The SuCESS team is at the centre of both the monitoring and evaluation and research program areas at NCIRS, often taking part in projects funded by the Commonwealth Department of Health.

Kids Research at the Sydney Children's Hospitals Network provides governance and infrastructure support to NCIRS. However, the core funding for NCIRS work activities is provided by the Australian Government Department of Health and New South Wales Government. NCIRS is affiliated with The University of Sydney Children's Hospital Westmead Clinical School and School of Public Health.

MAE competencies

Evaluate a public health surveillance system

I (with Noni Winkler, MAE 2020 scholar) evaluated four surveillance systems: the National Notifiable Diseases Surveillance System (NNDSS), Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI), the Influenza Complications Alert Network (FluCAN) and the Paediatric Enhanced Active Disease Surveillance (PAEDS). As part of their operations, these systems have captured data on severe COVID-19 in Australia. A mixed-methods study with stakeholder interviews, surveys, and data review was used to assess the systems' ability to describe and characterise risk factors on clinical severity, according to the Australian National Disease Surveillance Plan for COVID-19 (version 2.0). Attributes outlined in the United States Centers for Disease Control and Prevention (CDC) Guidelines for Evaluating Public Health Surveillance Systems were used for assessment. We recommended ensuring case definitions at the national level, reserved surge capacity in hospitals and data linkage of public health and hospital systems to be prepared for future pandemics.

Investigate an acute public health event

On 2 May 2022, I was contacted by the Western Sydney Public Health Unit to investigate a gastrointestinal outbreak at social event in Sydney Olympic Park, New South Wales. As part of this investigation, I developed an online survey that was used to conduct a retrospective cohort study among attendees ($n=198$) and staff ($n=15$) at the venue. Out of 150 responses, 34% ($n=52$) reported illness. Univariate analysis demonstrated that one drink item (cosmopolitan cocktail drink) had a statistically significant ($p=0.000$) association with gastrointestinal illness and showed a moderate relative risk (2.61, 95% Confidence Interval: 1.64–4.15). However, the attributable risk percent was low (34.2%). There was a statistically significant association between table seating and illness ($p=0.018$). The duration of illness, symptom profile and spatial pattern of spread and laboratory stool specimen ($n=1$) was indicative that the gastrointestinal illness was spread person to person and most likely to be norovirus.

Analyse a public health data set

The coronavirus disease 2019 (COVID-19) pandemic has impacted the health and economy on a global scale. Australia's first case of COVID-19 was notified on 13 January 2020 and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) continues to circulate the community today. I conducted a retrospective secondary data analysis of COVID-19 using data from the National Notifiable Diseases Surveillance System, January 2020 to November 2021. I included data on when public health and social measures were implemented, vaccine coverage and variants of concern to explain the Australian story of COVID-19. In 2020, Australia was successful in controlling transmission of SARS-CoV-2 with strict public health and social measures. However, public health and social measures alone could not contain the virus in mid-2021, when the highly virulent Delta (B.1.617.2) variant impacted Australia. Strengthening surveillance as well effective use of public health and social measures and high vaccination coverage will help prepare for future variants and pandemics.

Design and conduct an epidemiological study

Invasive meningococcal disease (IMD) is a rare but serious condition. In Australia, serogroup B remains the major cause for IMD among children, and adolescents. There are many risk factors associated with IMD, including smoking and medical conditions, but little has been studied on the relationship between socio-economic status (SES) and IMD. I conducted a literature review to find any associations between SES and IMD. Then I further investigated the association between SES and IMD notifications in Australia, 2010–2020, using data from the National Notifiable Diseases Surveillance System. Using postcode of residence recorded in NNDSS, the associated socioeconomic indexes for area (SEIFA) of the index of relative socio-economic disadvantage (IRSD) decile were matched to each case. There was a significant relationship gradient for serogroup B IMD notifications by SEIFA for < 5 years. However, there was no direct association between serogroup B IMD notification and SES. Logistic regression analysis showed that the odds of an IMD notification being serogroup B in the 2–4 year age group were five-fold higher than other serogroups. We recommend that national vaccination strategies and policies to target the 2–4 year group to reduce meningococcal B disease in Australia.

Literature review

I conducted the following literature review related to invasive meningococcal disease in Chapter 5:

- Review of published literature on Scopus and PubMed on the association between socio-economic status and invasive meningococcal disease.

Manuscript for a peer-reviewed journal

I prepared the following advanced draft manuscript in Chapter 2:

- “An evaluation of four surveillance systems reporting on risk factors of COVID-19 clinical severity in Australia in 2021” for the Communicable Diseases Intelligence journal

Communication to a lay audience

I wrote a public facing summary report, “COVID-19 in schools and early childhood education and care services – the experience in NSW: 16 June to 17 September 2021” to communicate findings of the transmission of SARS-CoV-2 in schools during Term 3 in New South Wales in Chapter 6.

Conference presentations

I presented a long oral presentation (Chapter 2):

An evaluation of the Australian National Notifiable Diseases Surveillance System on COVID-19. Communicable Disease & Immunisation Conference 2022, Sydney, Australia, 20–22 June 2022.

I presented a poster and short presentation (Chapter 2):

An evaluation of the Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI) Australia on COVID-19. 11th TEPHINET Global Scientific Conference, Panama City, Panama, 4–9 September 2022.

Teaching experience

I planned and conducted the following teaching activities as presented in Chapter 7:

- Peer-to-peer teaching session: Surveillance of notifiable conditions in Australia
- Lessons from the Field: Epidemiology and immunisation policy in Australia
- Co-facilitator for pre-conference workshop at 11th TEPHINET Global Scientific Conference, Panama: “Beyond Principles: How do we use learning theories to facilitate learning experiences for field epidemiology training program trainees?”

Coursework

I completed and passed the following coursework units of the MAE program:

- POPH8920 Outbreak Investigation
- POPH8917 Public Health Surveillance
- POPH8913 Analysis of Public Health Data
- POPH8915 Research Design and Methods
- POPH8914 Issues in Applied Epidemiology

Awards

- As part of the Schools SARS-CoV-2 Transmission Team, we received:
NCIRS Team of the Month award (July 2021)
Selection for the 2021 NSW Research Impact Showcase
- I received the following award for my travel to the 11th TEPHINET Global Scientific Conference, Panama:
Vice Chancellor’s Higher Degree Research Travel Grant (July 2022)

Additional field placement activities and other roles

In addition to projects related to the core requirements of the MAE, I was involved in the following activities and experiences:

- Contact tracer at the Western Sydney Public Health Unit during the Delta outbreak in New South Wales (July 2021)

- Followed-up close contacts from different educational settings for their PCR swab results for the SARS-CoV-2 transmission in schools work, NCIRS (July to December 2021)

Summary of MAE requirements

A summary of how my projects and my experiences met the core MAE competencies is presented in Table 1.

Table 1. Summary of Master of Philosophy in Applied Epidemiology projects and experiences fulfilling competencies

MAE competencies	Chapter					
	2	3	4	5	6	7
Evaluate a surveillance system	✓					
Data analysis	✓		✓	✓	✓	
Outbreak Investigation		✓			✓	
Epidemiological study				✓		
Literature review				✓		
Teaching activities						✓
Conference presentation	✓					
Lay summary					✓	
Peer review publication	✓					

Chapter 2

Evaluation of a public health surveillance system

Evaluation of four surveillance systems
reporting COVID-19 clinical severity in
Australia

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Preface

At the beginning of my placement in March 2021, I was informed that staff in the National Incident Room (NIR), now known as the National Incidence Centre (NIC) of the Commonwealth Department of Health were interested in an evaluation of how surveillance systems that capture data on coronavirus disease 2019 (COVID-19) severity met Goal 9 of the Australian National Disease Surveillance Plan for COVID-19 (version April 2021). Goal 9 of the Plan is to “describe the clinical severity of COVID-19 cases to allow prediction of health resource use and to standardise models of care, as well as characterise risk factors for serious infection to allow for targeted public health strategies”.

Initially, I felt challenged by the scope of this evaluation but knowing its importance and potential public health impact, I began to realise the great learning opportunity it presented. An evaluation of the systems would also tie in nicely with the data analysis project I had started on COVID-19 notifications using data from the National Notifiable Diseases Surveillance System (NNDSS).

In early June 2021, the subject of this evaluation resurfaced when Noni Winkler, the 2020 Master of Philosophy in Applied Epidemiology (MAE) scholar at NCIRS, was seeking an evaluation project. With the scope of this evaluation and discussions with supervisors, we decided that this would be a joint project.

Unlike typical evaluation projects undertaken by MAE scholars, this one involved four surveillance systems: the NNDSS, Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI), the Influenza Complications Alert Network (FluCAN) and Paediatric Active Enhanced Disease Surveillance (PAEDS). The aim of this evaluation was to assess the capacity of each surveillance system to describe the clinical severity of COVID-19 and characterise risk factors.

Given initial discussions with the Commonwealth Department of Health, the planned output for this evaluation, as well as a chapter in my thesis, was a report

and publication. The findings of this evaluation are presented in this chapter as a late-stage draft publication, which include an abstract and a list of references.

My role

I was the co-primary investigator in the evaluation of the four surveillance systems alongside Noni Winkler. Together we developed the study proposal and methods, presented our proposal to National Surveillance Committee (NSC) and stakeholders, developed questions for semi-structured interviews and designed surveys for data collectors and investigators. I wrote the final report to the Commonwealth Department of Health and manuscript for this evaluation. A further breakdown of roles is presented in Table 1 below.

Table 1. Roles undertaken by Zoe Joo and Noni Winkler to conduct an evaluation of four surveillance systems that capture data on COVID-19 clinical severity in Australia, June 2021 to May 2022.

	NNDSS	SPRINT-SARI	FluCAN		PAEDS
	• Led interviews • Data request • Analysis and interpretation of data	• Led interviews • Data request • Analysis and interpretation of data	• Led interviews • Data request • Survey analysis	• Final follow-up with data request • Interview analysis	• Led interviews • Data request • Analysis and interpretation of data
Zoe	✓	✓		✓	
Noni			✓		✓

Abbreviations: NNDSS= National Notifiable Diseases Surveillance System, SPRINT-SARI= Short Period Incidence Study for Severe Acute Respiratory Infections, FluCAN= The Influenza Complications Alert Network and PAEDS= Paediatric Active Enhanced Disease Surveillance

Lessons learnt

- This evaluation allowed me to understand how surveillance systems work, as well as the limitations and importance of staff and stakeholder engagement at various levels.
- I learned the lesson of patience and persistence in the process of stakeholder engagement and data requests in the midst of surging COVID-19 cases in Australia between July to November 2021. A lot of time was taken for stakeholder engagement, including sending multiple follow-up emails and making calls for surveys, interviews and requests for data.

- I learned how to use Research Electronic Data Capture (REDCap). I designed survey questions using branching logic and matrices and put a survey into production and used data for analysis.
- I also learned the importance of survey design; a carefully designed survey is necessary for maximum stakeholder participation, and quality data. Noni and I went through many iterations of surveys with feedback from various supervisors and colleagues. Although it was time consuming, we were ultimately satisfied with the results.
- Designing an evaluation for four different surveillance systems was very challenging, and perhaps foolhardy! I learnt how to see the unique and different aspects of each individual surveillance system within the broader context of the overall picture of COVID-19 surveillance.
- I also learnt how to use iMovie to create a promotional video to reach out to stakeholders for this evaluation.
- I learned the intricacies of reshaping data using Stata which required a lot of trial and error to ensure the data were set out in the correct form.
- One of the biggest lessons learnt was how to cut down the word count for my manuscript and remove unnecessary words and ideas. I learnt this the hard way after writing a lot and then spending many hours reducing my words multiple times throughout my MAE journey for this project.

Public health impact

This evaluation was conducted during the peak of the COVID-19 outbreak in Australia. During mid-June 2021 to November 2021, New South Wales (NSW) experienced its largest period of community transmission of the SARS-CoV-2 Delta (B.1.617.2) variant. During this time, COVID-19 vaccination uptake was increasing rapidly in NSW in an attempt to relieve the pressure on the public health system as well as ease restrictions of residents.

On 2 July 2021, the National Plan to transition Australia's National COVID-19 Response was released. At that time, Australia was in the "Vaccinate, Prepare and Pilot" phase which focussed on suppressing the virus for the purpose of minimising community transmission. The next phase, "Vaccination Transition

Phase” would occur when 70% of the adult population had been fully vaccinated, where the focus would then be to minimise serious illness, hospitalisation, and fatality due to of COVID-19 with low level restrictions.

This evaluation was extremely timely as Australia was in the process of achieving high vaccination coverage, but hospitalisations and intensive care unit (ICU) admissions were peaking. With a focus on minimising illness due to severe COVID-19, there was a need to understand how the surveillance systems NNDSS, SPRINT-SARI, FluCAN and PAEDS had fared so far and what could be improved or done differently moving forward.

MAE competencies addressed

- Evaluation of public health surveillance system
- Peer-review publication (advanced draft)
- Conference presentation

Acknowledgements

This evaluation would not have been possible without the participation of the NNDSS, SPRINT-SARI, FluCAN and PAEDS teams. I would like to thank everyone who participated in this evaluation, from the initial conversations, assistance with survey distribution, participation in interviews and surveys, answering all sorts of questions, providing data and documents. I thank you so much for all your help, patience, and enthusiasm despite the busy times of the pandemic. I especially would like to thank all system co-ordinators for your tireless efforts and dedication to your work.

A big thank you to my academic and field supervisors. I would like to thank Tambri Housen, my academic supervisor who was patient with me in the design of this evaluation and provided advice for sampling methods and the final write up of the report. Thank you to Amy Parry who gave me valuable advice on increasing survey participation and encouraging me to make to create video to promote the evaluation. I would like to thank my field supervisors (in no particular order), Kaitlyn Vette, Helen Quinn, Alexis Pillsbury, Stephen Lambert, Aditi Dey and

Frank Beard from NCIRS, who were entirely supportive of the long evaluation process.

Thank you, Kaitlyn, for encouraging me at the beginning of my MAE regarding the impact of this study. Thank you, Helen, for your help in the evaluation design, downloading data, connecting us to the right people and your comments. Thank you, Alexis, for listening to all my worries and struggles through this evaluation and providing me insightful comments. Thank you, Stephen for being a consistent encourager and pushing me to be a concise writer. Thank you, Frank, for all your comments throughout my writing and assisting me get through the difficult data requests. Thank you, Aditi for your suggestions on the evaluation and survey design.

I would like to extend my thanks to several colleagues at NCIRS who contributed to the survey design. Thank you to Lucy Deng, Archana Koirala and Catherine Glover for testing and providing comments on our survey questions. Thank you to Kasia Bolsewicz who supported us in the process of constructing our semi-structured interview questions with system co-ordinators. I would also like to thank Teresa Winata, a dear friend in public health who provided feedback on survey questions.

Advanced draft manuscript for publication

Title: An evaluation of four surveillance systems reporting on risk factors of COVID-19 clinical severity in Australia in 2021

Author(s) name(s): Ye Jin Joo, Noni Winkler, Frank Beard, Stephen Lambert, Helen Quinn, Aditi Dey, Alexis Pillsbury, Tambri Housen

Keywords (up to 10): COVID-19, hospitalisations, intensive care units, surveillance evaluation, mixed-methods, pandemic, emergency response

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Abstract

Background: Four existing surveillance systems, the National Notifiable Diseases Surveillance System (NNDSS), Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI), The Influenza Complications Alert Network (FluCAN) and the Paediatric Enhance Active Disease Surveillance (PAEDS) have captured data on severe COVID-19 in Australia.

Methods: We undertook a mixed-methods study with stakeholder interviews, surveys, and data review to assess the systems' ability to describe and characterise risk factors on clinical severity of COVID-19 in Australia. This ability was measured by assessing attributes (simplicity, flexibility, data quality, acceptability, sensitivity, representativeness, timeliness, and stability) outlined by the Centers for Disease Control and Prevention (CDC) *Guidelines for Evaluating Public Health Surveillance Systems*. The evaluation was conducted between July 2021 and June 2022.

Results: We interviewed 33 individuals and collected 53 survey responses that represented all jurisdictions in Australia. All systems displayed flexibility in incorporating COVID-19 surveillance into their existing system. However, inconsistencies in the collection of hospitalisation data in the NNDSS are likely to have caused misinterpretation of true counts. Increasing numbers of COVID-19 cases put pressure on hospital systems and surge capacity, causing delays in data entry and reducing data completeness in all systems. There was no immediate capacity to recruit staff to respond to increased demand within the sentinel systems.

Conclusions: The four surveillance systems evaluated collectively described and characterised risk factors on clinical severity of COVID-19 in Australia. For future pandemics, standardisation of the case definition of hospitalisation at the national level should occur. Alternative surge capacity in hospitals should be trained and prepared. Ultimately, linkage of public health and hospital systems data will strengthen existing systems and minimise duplication of efforts for future emergency responses.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged in Wuhan, China in late 2019. SARS-CoV-2 causes coronavirus disease 2019 (COVID-19) and presentation of disease ranges from asymptomatic and mild to severe cases. Severity of disease increases with the presence of comorbidities, older age, immunosuppressive conditions, and obesity.¹ Children with COVID-19 more commonly present as asymptomatic or mild infection but severe cases, such as the rare Paediatric Multisystem Inflammatory Syndrome–Temporally Associated with SARS-CoV-2 (PIMS-TS), have been reported.²⁻⁶

The Australian National Disease Surveillance Plan for COVID-19 (version 2.0, from April 2021 to May 2022) aims to characterise COVID-19 epidemiology and inform public health measures to control COVID-19 in Australia.⁷ Goal 9 of this plan describes the clinical severity of COVID-19 cases to allow prediction of health resource use and to standardise models of care, as well as characterise risk factors for serious infection to allow for targeted public health strategies (Table 1). We conducted an evaluation of how four surveillance systems, National Notifiable Diseases Surveillance System (NNDSS), Short Period Incidence Study of Severe Acute Respiratory Infections (SPRINT-SARI), Influenza Complications Alert Network (FluCAN) and Paediatric Active Enhanced Disease Surveillance (PAEDS), captured COVID-19 data on clinical severity to achieve Goal 9.

The three systems, SPRINT-SARI, FluCAN and PAEDS are sentinel systems and provide monthly reports to the Commonwealth Department of Health. Reports are used to compare with the NNDSS, the only national system, but there is no report or analysis to bring data from all systems together.

Table 1. Indicators for Goal 9 in the Australian National Disease Surveillance Plan for COVID-19 (version 2.0) from April 2021 to May 2022.

Indicators		Principal source
9.1	Number and proportion of all COVID-19 cases who have been hospitalised, admitted to Intensive Care Unit (ICU) and ventilated/received extracorporeal membrane oxygenation (ECMO), by demographics (including Aboriginal and Torres Strait Islander status, age group, sex and remoteness)	NNDSS SPRINT-SARI FluCAN PAEDS
9.2	Number of COVID-19 related deaths as a proportion of cases admitted to hospital, to ICU and those ventilated/receive ECMO, by demographics (including Aboriginal and Torres Strait Islander status, age group, sex, remoteness)	NNDSS SPRINT-SARI FluCAN PAEDS
9.3	Characteristics of COVID-19 cases who are hospitalised, admitted to ICU, ventilated/receive ECMO and who die from COVID-19 by demographics (including Aboriginal and Torres Strait Islander status, age group, sex and remoteness) and comorbidities	SPRINT-SARI FluCAN
9.4	Duration of ICU stay (for COVID-19 cases by age, sex and Aboriginal and Torres Strait Islander status)	SPRINT-SARI
9.5	Number of cases of Paediatric Inflammatory Multisystem Syndrome Temporally associated with SARS-CoV-2 (PIMS-TS) (possible and confirmed) as a count and proportion of total paediatric COVID-19 cases, by age, sex Aboriginal and Torres Strait Islander status and ICU admission and outcome status	PAEDS

Abbreviations: NNDSS=National Notifiable Diseases Surveillance System, SPRINT-SARI= Short Period Incidence Study of Severe Acute Respiratory Infections, FluCAN= The Influenza Complications Alert Network PAEDS=Paediatric Active Enhanced Disease Surveillance, ICU= Intensive Care Unit, ECMO=Extracorporeal membrane oxygenation

Methods

Study design

This evaluation had a cross-sectional mixed-methods convergent design⁸, with qualitative and quantitative phases (Figure 1). The United States (US) Centers for Disease Control and Prevention (CDC) Guidelines for Evaluating Public Health Surveillance System describes system attributes and we assessed attributes relevant to the four systems' capacity to achieve Goal 9 from July 2021 to June 2022 (Table 2).

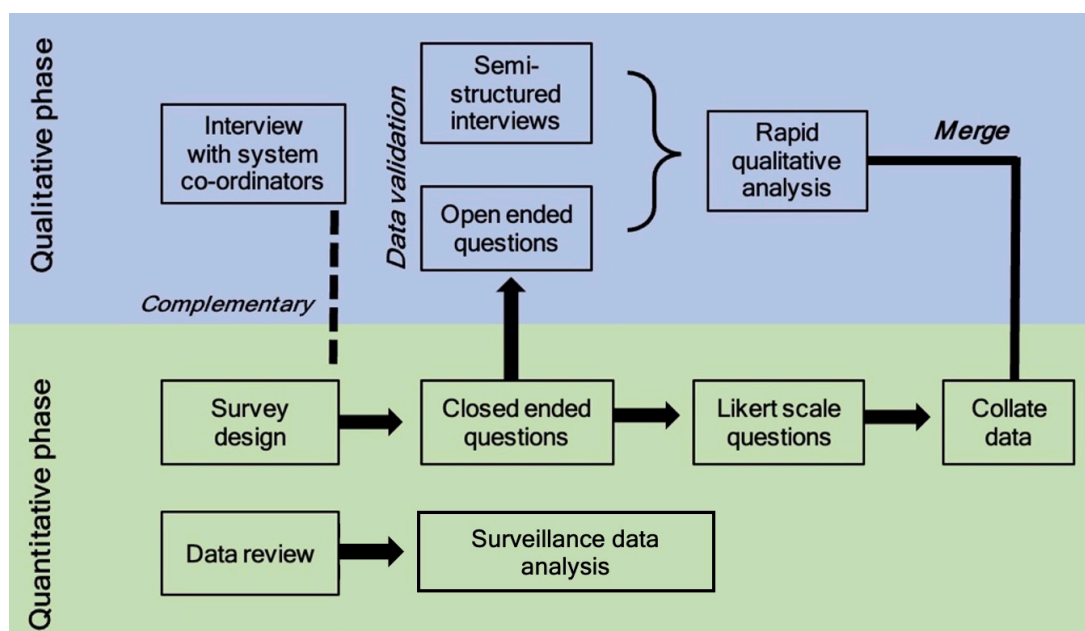


Figure 1. Mixed methods convergent design convergent design with interactive qualitative and quantitative phases for the evaluation of severe COVID-19 in four surveillance systems (National Notifiable Diseases Surveillance System, Short Period Incidence Study of Severe Acute Respiratory, The Influenza Complications Alert Network, Paediatric Active Enhanced Disease Surveillance) in Australia, 2021

Table 2. Definition of attributes outlined in the Centers for Disease Control and Prevention Guidelines for Evaluating Public Health Surveillance Systems and assessment method used for the evaluation of surveillance systems that capture data on COVID-19 severity in Australia, July 2021 to June 2022

Attribute	Definition	Method
<i>Simplicity</i>	Refers to both structure and ease of operation. Surveillance systems should be as simple as possible while meeting their objectives	• Survey • Interview
<i>Flexibility</i>	Being able to adapt to changing information needs or operating conditions with little additional time, personnel, or allocated funds	• Case report form review • Survey • Interview
<i>Data Quality</i>	Reflects the completeness and validity of the data recorded in the surveillance system	• Interview • Data analysis
<i>Acceptability</i>	Reflects the willingness of persons and organisations to participate in the surveillance system	• Interview
<i>Sensitivity</i>	The ability to detect outbreaks, including the ability to monitor changes in the number of cases over time	• Data analysis
<i>Representativeness</i>	Representative accurately describes the occurrence of a health-related events over time and its distribution in the population by place and person	• Data analysis
<i>Timeliness</i>	Reflects the speed between steps in a public health surveillance system	• Survey
<i>Stability</i>	Refers to the reliability and availability of the public health surveillance system	• Survey • Interview

Target population

Four different stakeholder groups (system co-ordinators, data collectors, investigators, and data end users) were identified in this evaluation (Table 3).

Table 3. Stakeholder groups and their roles in four surveillance systems: National Notifiable Diseases Surveillance System, Short Period Incidence Study of Severe Acute Respiratory Infections, The Influenza Complications Alert Network, Paediatric Active Enhanced Disease Surveillance in Australia, 2021

Stakeholder group	Role description
<i>System co-ordinators</i>	Manage and co-ordinate system as well as liaise between staff and investigators
<i>Data collectors</i>	Directly enter patient data into the system
<i>Investigators</i>	Site or principal investigators who have the responsibility to conduct the study and provide input in study design
<i>Data end users</i>	Have access to data, analyse data and create national reports

Qualitative phase

Sampling

We used a purposive sampling method to target key participants. We first conducted preliminary interviews with system co-ordinators to identify key stakeholders and inform the survey design. Survey participants (data collectors and investigators) were given an option to be interviewed (except for the NNDSS where there was no survey). We aimed to interview 2–3 data collectors and at least one investigator per system from different jurisdictions. We contacted system co-ordinators for recommendations for whom to interview when survey participants could not be interviewed. Data end users were a mutual group of COVID-19 epidemiologists from the National Incidence Centre (NIC), Commonwealth Department of Health and were interviewed on all four systems.

Semi-structured interviews

Three broad areas were explored across all stakeholder group semi-structured interviews with open-ended and probing questions: 1) Successes and challenges of COVID-19 surveillance, 2) Ability to achieve Goal 9 of the national surveillance plan and 3) How the system could be improved in the future.

A rapid qualitative analysis (RQA) of the semi-structured interviews was conducted.⁹ Interviews were held via online videoconferencing applications. At commencement, all interviewees were asked for oral consent to record the interview. We (YJ and NW) made notes during the interviews, then exchanged notes and identified major themes during the post-interview debrief. Researchers re-listened to interview recordings to familiarise themselves with the data.⁹ We used deductive coding, where a matrix was already created according to surveillance attributes.¹⁰ Codes were merged and consolidated under key themes.

Interviews were conducted for NNDSS between 20 September 2021 to 9 November 2021, for SPRINT-SARI between 27 August 2021 to 19 October 2021, for FluCAN between 19 November 2021 to 10 March 2022, and for PAEDS between 27 August to 11 November 2021.

Quantitative phase

Surveys

Survey questions were presented by attribute and Likert style and included a few open-ended questions to allow for further explanation. The electronic survey was designed using the Research Electronic Data Capture (REDCap) system, hosted at the University of Sydney.^{11, 12} Surveys were open for a one-month period within September 2021 to January 2022 (depending on the system) and participants received weekly reminders via email through system co-ordinators. To increase participation, researchers created a video to promote the importance of the evaluation. Response frequencies for each question were calculated by number and percentage ($n=x/X$; %) using Microsoft Excel.

Surveillance data analysis

We looked at the data completeness of specific data fields for each surveillance system (Table 4). Line listed data from each system (from 2021) were provided and cleaned using Microsoft Excel and Stata 14.0. We also compared data on the number of ICU and ventilated cases in SPRINT-SARI with the NNDSS data to assess national representativeness.

Table 4. Data fields relating to COVID-19 severity that are captured in the NNDSS, SPRINT-SARI, FluCAN and PAEDS surveillance systems in Australia, 2021.

COVID-19 data fields	Surveillance system			
	NNDSS	SPRINT-SARI	FluCAN	PAEDS
Notification	✓			
Hospitalisations	✓		✓	✓
Length of stay		✓	✓	
Intensive Care Unit	✓	✓	✓	✓
Ventilated/ECMO	✓	✓	✓	✓
Death	✓	✓	✓	✓
Age group	✓	✓	✓	✓
Sex	✓	✓	✓	✓
Indigenous status	✓	✓	✓	✓
Remoteness	✓		✓	✓
Co-morbidities	✓	✓	✓	✓

Abbreviations: NNDSS=National Notifiable Diseases Surveillance System, SPRINT-SARI= Short Period Incidence Study of Severe Acute Respiratory Infections, FluCAN= The Influenza Complications Alert Network, PAEDS=Paediatric Active Enhanced Disease Surveillance, ECMO=Extracorporeal membrane oxygenation

Ethics and governance approvals

The Commonwealth Department of Health and the COVID-19 National Surveillance Committee approved this evaluation. Ethical approval for this study fell under the “Request for waiver of consent for use of data in research for a Master of Philosophy in Applied Epidemiology students. Protocol: 2017/909”.

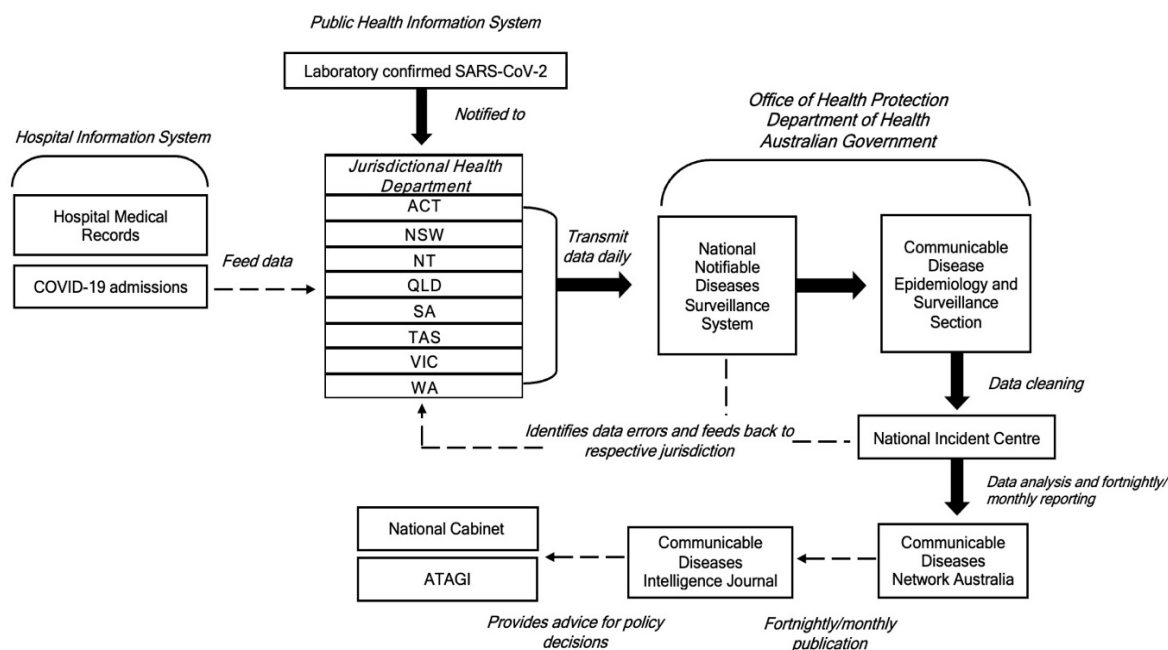
Results

We interviewed nine individuals in preliminary interviews, NNDSS (n=3), SPRINT-SARI (n=2), FluCAN (n=2) and PAEDS (n=2). Fifty-three data collectors and/or investigators from the SPRINT-SARI, FluCAN and PAEDS systems responded to our survey, with varying response rates. Out of these survey participants, we interviewed a further 15 individuals. For the NNDSS, we interviewed six individuals. We interviewed three individuals from the NIC, Commonwealth Department of Health.

NNDSS

The NNDSS co-ordinates the national surveillance of over 50 communicable diseases and on 6 February 2020 COVID-19 became a nationally notifiable disease.¹³ Each jurisdiction provides de-identified notification data to the NNDSS

daily (Figure 2). The purpose of the NNDSS is to collate data to identify national epidemiological trends, monitor risk groups and the effectiveness of control measures. For COVID-19, the use of the NNDSS expanded to capture clinical severity data.



Abbreviations: ACT= Australian Capital Territory, NSW=New South Wales, NT=Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia, ATAGI= Australian Technical Advisory Group on Immunisation

Figure 2. Flow diagram of COVID-19 notification data in the Australian National Notifiable Diseases Surveillance System, 2021

Simplicity

The NNDSS has an overall simple structure and has common data fields that all jurisdictional health departments must report on. However, COVID-19 hospitalisation data was often manually provided to jurisdictional health departments. Only New South Wales (NSW) and Victoria (VIC) experienced large surges of COVID-19 cases during the period of this evaluation. In response, NSW Health developed deterministic linkage to match COVID-19 patient data from the Patient Flow Portal (which provided details of bed management tools and hospitalisation data) to COVID-19 case identifier numbers in NSW Health's Notifiable Conditions Information Management System (NCIMS), allowing automatic feeding of hospitalisation data onto NCIMS and hence the NNDSS daily.

VIC used an existing system, the Victorian Healthcare Associated Infection Surveillance System (VICNISS), to feed patient data to the VIC Department of Health. Other jurisdictions did not have mechanisms in place to automatically feed hospitalisation data to the NNDSS.

Flexibility

The NNDSS and the Communicable Diseases Network Australia (CDNA) demonstrated flexibility by including COVID-19 as a national notifiable disease. The CDNA was quick to create the first COVID-19 case definition on 23 January 2020, after the first COVID-19 notification occurred on 13 January 2020.¹⁴ The NNDSS also demonstrated system flexibility by including the following enhanced data fields: “intensive care unit (ICU)”, “ventilated” and “co-morbidities”. However, standardising the definition of “hospitalisation” was a challenge.

There were lots of issues on recording hospitalisation in the NNDSS, it depends on how the states follow and this is an issue. (Epidemiologist)

Data quality

The NNDSS demonstrated high data completeness during non-peak times (May to June 2021) of the Delta outbreak (Table 6). However, an analysis by jurisdiction showed poorer completeness for Indigenous status, hospitalised, and comorbidities during the peak (September to October 2021). Only jurisdictions that showed a decline over 10% during the peak are reported (Table 7).

Table 6. Completeness of data fields in the National Notifiable Diseases Surveillance System for COVID-19 during peak and non-peak times of the Delta outbreak in Australia, 2021.

Data fields	Data completeness at two time periods	
	Non-peak (N=934) May to June 2021	Peak (N=115,579) September to October 2021
Sex	99.8%	99.6%
Indigenous status	95.3%	78.3%
Hospitalised	89.6%	77.5%
Comorbidities	74.9%	72.9%
Died	74.4%	73.2%

Table 7. Completeness of selected data fields in selected jurisdictions with a reduction in completion in the National Notifiable Diseases Surveillance System for COVID-19 during non-peak and peak times of the Delta outbreak in Australia, 2021

State	Data field	Data completeness at two time periods	
		Non-peak (N=934) May to June 2021	Peak (N=115,579) September to October 2021
New South Wales	Indigenous status	96.9%	88.5%
	Hospitalised	86.6%	43.4%
	Comorbidities	76.7%	30.4%
South Australia	Indigenous status	93.2%	76.3%
Victoria	Indigenous status	95.7%	71.3%

SPRINT-SARI

SPRINT-SARI is a global observational study of patients in hospitals and ICUs with severe acute respiratory infection and was established for pandemic preparedness. SPRINT-SARI Australia was activated with COVID-19 and data collection sites expanded from 15 to 79 sites (Figure 3). SPRINT-SARI Australia sites cover 96% of ICU beds in Australia.

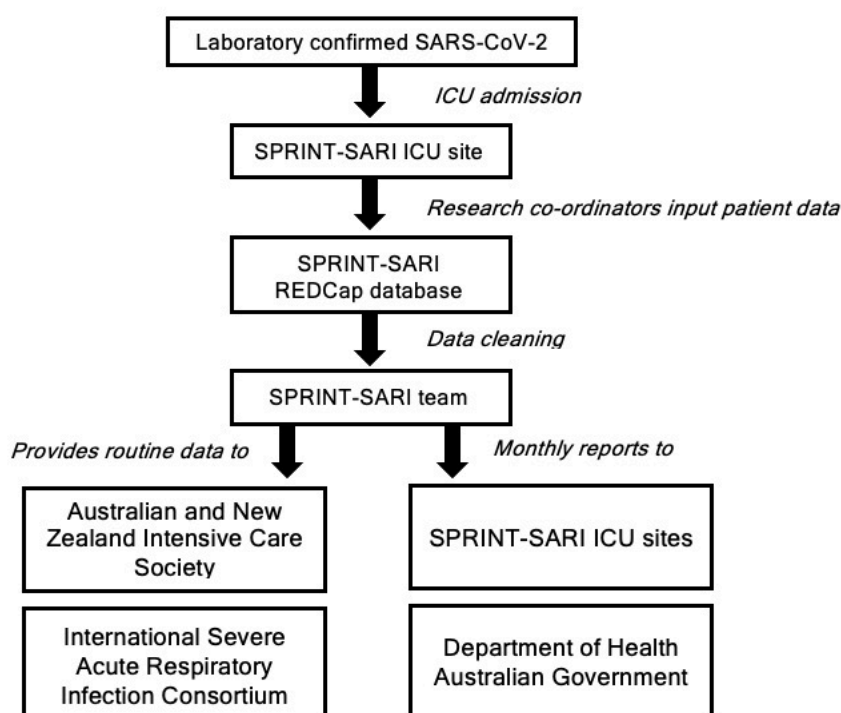


Figure 3. Flow diagram of COVID-19 data in Short Period Incidence Study for Severe Acute Respiratory Infections (SPRINT-SARI) Australia, 2021

Simplicity

SPRINT-SARI is a system that relies on research co-ordinators (RCs) to manually collect and input patient data onto REDCap, an electronic database. Survey results showed that 80% (20/25) of RCs agreed that SPRINT-SARI was a simple system and 88% (22/25) agreed that it was easy to apply the COVID-19 case definition.

In interviews, both RCs and investigators commented how the amount of data collected using the case reporting form (CRF) was extensive and burdensome for data collectors. To account for this, the amount of data collected was reduced.

*After decreasing data load on the CRF, it has been simple.
(Research co-ordinator)*

Flexibility

Survey results showed that 60% (15/25) of RCs agreed that incorporation of COVID-19 into SPRINT-SARI was easy. However, a few RCs commented that challenges with obtaining research governance delayed collection of data.

Among RCs that reported experiencing a surge, 67% (16/21) stated there were not enough staff to cope with higher workload. RCs were also deployed into clinical roles, making it difficult for them to fulfil their SPRINT-SARI research roles. Funding for SPRINT-SARI had already been allocated per site, and additional staff could not be recruited.

Three out of seven investigators reported that SPRINT-SARI is not well resourced in terms of funding, staffing, governance, and ethics for the future. Two investigators stated that SPRINT-SARI is well prepared for future COVID-19 surges and/or concurrent flu seasons.

Timeliness

The main issue associated with timeliness of SPRINT-SARI was data entry. The ability to enter data within 24 hours reduced during peak times (Figure 4).

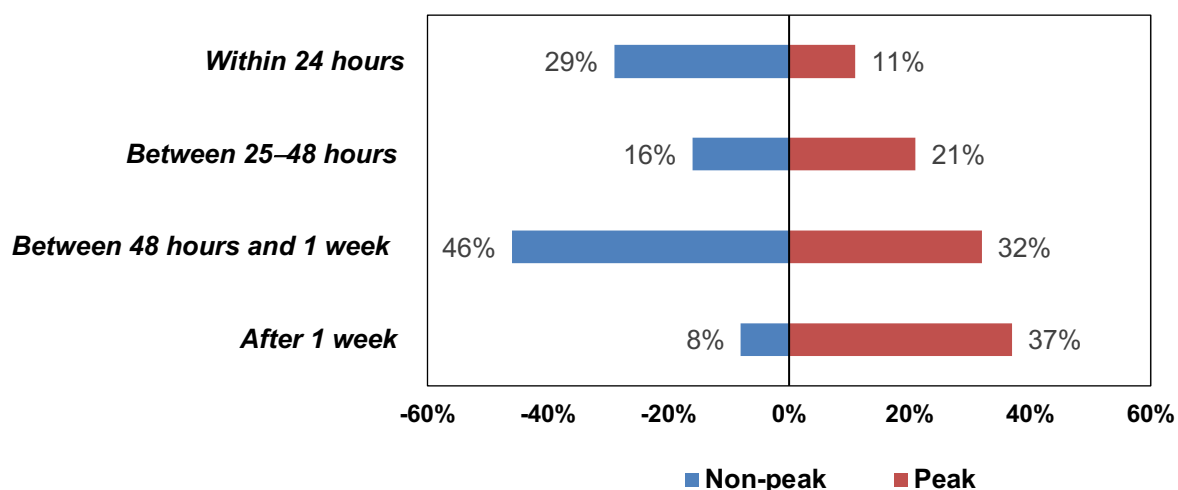


Figure 4. Timeliness of data entry in non-peak and peak times of the COVID-19 pandemic in Short Period Incidence Study for Severe Acute Respiratory Infections (SPRINT-SARI),

Data quality and representativeness

Overall SPRINT-SARI had 100% data completeness for demographic data fields during non-peak times (Table 8). Even during the peak, completeness was high for data fields including clinical information. SPRINT-SARI had the most comprehensive CRF, with data fields capturing clinical complications. However, SPRINT-SARI did not collect data on postcode. SPRINT-SARI data contained higher numbers of ICU and ventilated cases than the NNDSS (Figure 5). But the overall pattern and numbers were similar, even during peak times.

Table 8. Completeness of data fields in Short Period Incidence Study of Severe Acute Respiratory Infections (SPRINT-SARI) for COVID-19 during peak and non-peak times of the Delta outbreak in Australia, 2021.

Data fields	Data completeness	
	Non-peak (N=13) May to June 2021	Peak (N=1,678) September to October 2021
Age group		100%
Sex		100%
Indigenous status		100%
Length of stay	100%	95.1%
Comorbidities	100%	87.9%
Ventilated/extracorporeal membrane oxygenation	100%	92%
Hospital outcome	100%	93.9%

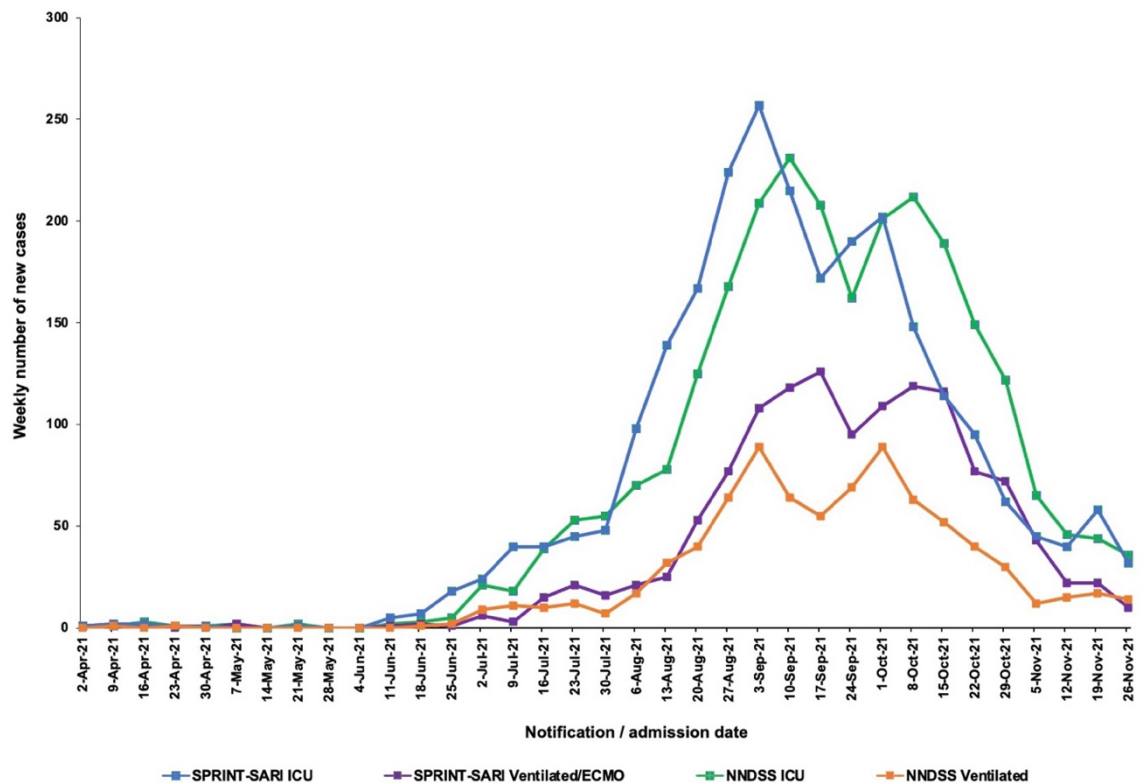


Figure 5. Epidemiological curve of new weekly Intensive Care Unit (ICU) admissions and number of ventilated cases/extracorporeal membrane oxygenation (ECMO) in the National Notifiable Diseases Surveillance System and the Short Period Incidence Study for Severe Acute Respiratory Infections (SPRINT-SARI), April to November 2021, Australia.

FluCAN

FluCAN was established as a response to a lack of clinical data available during the 2009 H1N1 influenza pandemic. FluCAN collects influenza data from 22 hospitals (including major hospitals) across all states and territories in Australia and includes 14% of national hospital bed capacity. FluCAN is a sentinel surveillance system and incorporated COVID-19 surveillance in 2020 (Figure 6).

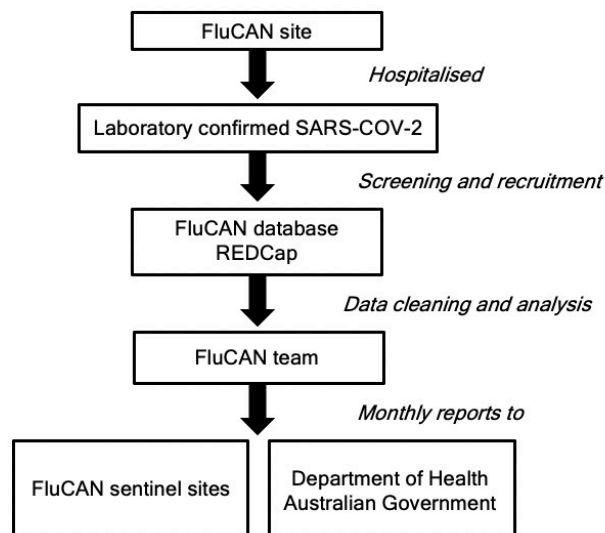


Figure 6. Flow diagram of COVID-19 data in the Influenza Complications Alert Network (FluCAN), Australia 2021

Simplicity

All survey participants, including RCs and investigators (11/11) agreed that FluCAN was a simple system for collecting data on COVID-19 hospitalisations and 82% (9/11) agreed that the COVID-19 case definition was easy to apply. Most RCs commented that the data were generally easy and quick to find in medical records and that REDCap was a user-friendly interface.

*It's easy to follow-up hospital admissions by the positive COVID-19 PCR and access hospital records.
(System co-ordinator)*

Flexibility

Among RCs and investigators surveyed, 82% (9/11) agreed that incorporating COVID-19 surveillance was easy. However, 71% (5/7) who experienced a peak, stated that there were not enough staff to cope with higher surveillance burden.

There were mixed opinions on how well FluCAN was resourced in terms of managing a surge in COVID-19 caseload. Survey results showed 27% (3/11) agreed, 36% (4/11) disagreed and 36% (4/11) were unsure. FluCAN staff that experienced high surges of COVID-19 in their jurisdiction tended to disagree.

Funding is a little unstable, it does create some uncertainty for sites that try to hire staff, they don't know

how long they can hire for. Having support to have staff available all year round will be helpful. (Investigator)

Data quality

Survey results showed that 91% (10/11) agreed that data collected by FluCAN was of high quality. The completeness of data in FluCAN was high throughout 2021, except during the peak of the Delta outbreak, where completeness of length of hospital stays and hospital outcome was reduced (Table 9).

Table 9. Completeness of data fields in the Influenza Complications Alert Network (FluCAN) for COVID-19 during peak and non-peak times of the Delta outbreak in Australia, 2021.

Data fields	Data completeness	
	Non-peak (N=16) May to June 2021	Peak (N=1,333) September to October 2021
Age group		100%
Sex		100%
Indigenous	100%	99.2%
Length of Stay	99.8%	56.7%
ICU	100%	99.8%
Ventilated/Extracorporeal membrane oxygenation	100%	99.7%
Hospital outcome	93.8%	59.3%

Timeliness

The major challenge for FluCAN was the delay in entering data during peak times (Figure 7). No staff surveyed entered data within 24 hours of admission during the peak.

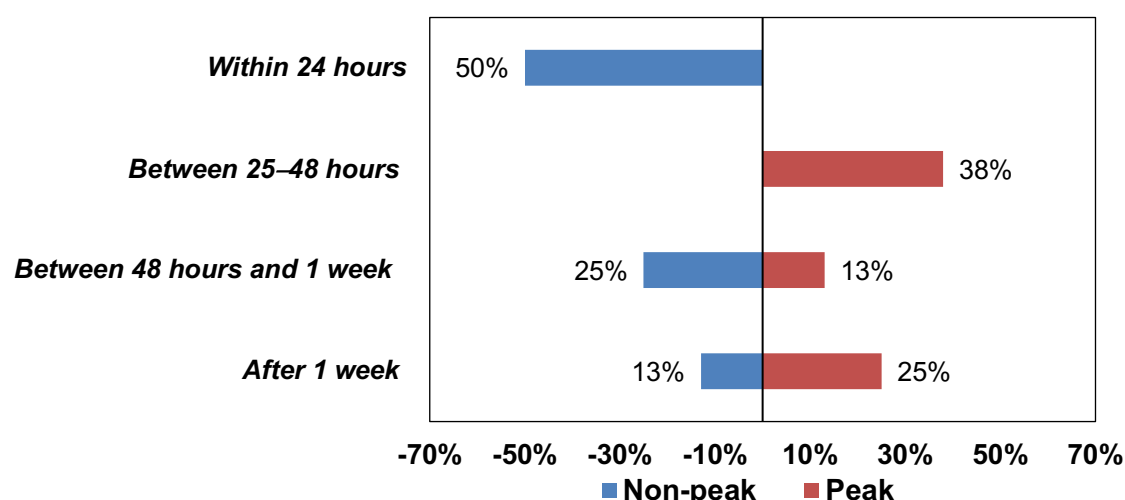


Figure 7. Timeliness of data entry of patient admission in non-peak and peak times of the COVID-19 pandemic in the Influenza Complications Alert Network (FluCAN), 2021

PAEDS

PAEDS is a surveillance system that collects data on hospitalised paediatric cases, including COVID-19 and PIMS-TS from mid-2020, with retrospective case recruitment from 1 January 2020. PAEDS had been collecting data on all inpatient paediatric COVID-19 patients (admissions for social, policy, and medical reasons), emergency department presentations, hospital in the home patients and ICU admissions (Figure 8).

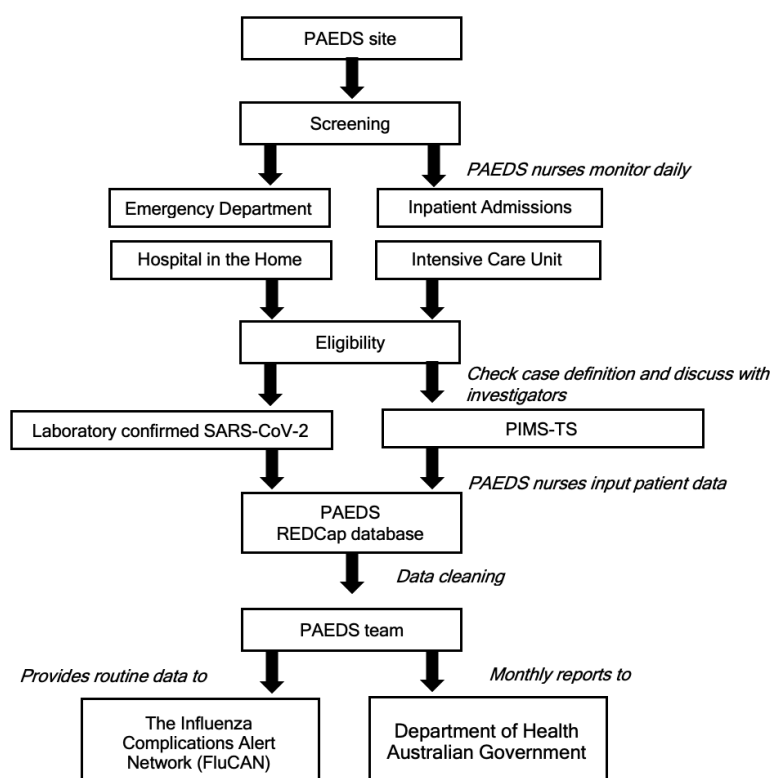


Figure 8. Flow diagram of COVID-19 data in the Paediatric Active Enhanced Disease Surveillance (PAEDS) in Australia, 2021

Simplicity

Survey results showed that 100% (6/6) of PAEDS nurses agreed that PAEDS was a simple system and 83% (5/6) agreed that it was easy to apply the COVID-19 case definition. But some sites used old methods of data collection that were not simple.

A lot of the workflows in PAEDS are quite archaic, we need to physically walk into the ICU and look at the stickers in the admissions book and there are far better ways of doing that. (PAEDS co-ordinator)

Half of PAEDS nurses surveyed (3/6) entered data for PIMS-TS patients. Of these nurses, 67% (2/3) strongly agreed that PAEDS was a simple system to collect data on PIMS-TS.

Flexibility

Survey results showed that 67% (4/6) of PAEDS nurses and 75% (3/4) of PAEDS investigators agreed that incorporating COVID-19 surveillance was easy.

*Having the established PAEDS program of research made it swifter, in terms of getting a protocol up, a study-arm up and conducting the actual surveillance.
(Investigator)*

Survey results showed that two out of six PAEDS nurses experienced high surges and strongly disagreed that there enough staff to cope.

*There absolutely hasn't been enough staff to cope. I am spending most of my time on COVID recruitment alone. It has been stressful.
(PAEDS nurse)*

Survey results showed that 50% (2/4) of PAEDS investigators agreed that PAEDS was well prepared for a surge in COVID-19 cases and/or a concurrent flu season, but the other 50% disagreed.

*If COVID-19 were to settle into a concurrent seasonality with flu, we would have to rethink the scale of surge capacity.
(Investigator)*

Data quality

All survey participants agreed PAEDS data were of high quality. Data analysis showed that PAEDS had high data completeness for age group, sex, ventilated/ECMO and death data fields before and during the peak of the Delta outbreak (Table 10). However, Indigenous status, remoteness (postcode) and ICU fields were poorly completed during peak times.

Table 10. Completeness of data fields in Paediatric Active Enhanced Disease Surveillance for COVID-19 during peak and non-peak times of the Delta outbreak in Australia, 2021.

Data fields	Data completeness	
	Non-peak (N=34) May to June 2021	Peak (N=2,320) September to October 2021
Age group	100%	
Sex	100%	79.2%
Indigenous	97.1%	43.2%
Remoteness	91.2%	48.1%
ICU	70.6%	46.5%
Ventilated/Extracorporeal membrane oxygenation	100%	99.7%
Death	100%	100%

Timeliness

All PAEDS nurses (6/6) reported that they could enter at least minimum case data within 48 hours of admission in non-peak times. Three out of four participants from NSW reported data entry was delayed from within 48 hours to 1 week after admission during peak times.

Key Findings

The following key findings emerged from the evaluation:

1. Surveys, interviews, and data review demonstrated that each system met the indicators of Goal 9 in the Australian National Disease Surveillance Plan for COVID-19.
2. All systems displayed simplicity and flexibility by rapidly incorporating COVID-19 surveillance.
3. There was no standardisation of the definition of “hospitalisation” across jurisdictions in the NNDSS.
4. High COVID-19 case load put pressure on hospital systems and surge capacity, causing delays in data entry and poor data completeness across all four systems.
5. Amongst sentinel systems, there was no immediate capacity to recruit staff to respond to the system with increasing hospitalisations and research staff being redeployed to clinical roles.

Summary of system evaluation by attribute

Overall, all four systems were useful and met the indicators of Goal 9 of the Australian National Disease Surveillance Plan for COVID-19 (version 2.0). Even during peak times of the pandemic, no system failed to provide key data on counts of COVID-19 cases, hospitalisations, ICU admissions, deaths, demographic information, and length of ICU stay. All systems demonstrated simplicity, flexibility, data quality and timeliness to at least a moderate level (Table 11). All systems were flexible in incorporating COVID-19 surveillance. The challenges included working under higher disease burden, with a fixed number of staff and resources.

Table 11. Performance of four Australian COVID-19 surveillance systems by four attributes outlined in the Centres for Disease Control and Prevention Guidelines for Evaluating Public Health

Attribute	System							
	NNDSS		SPRINT-SARI		FluCAN		PAEDS	
Simplicity	✓		✓		✓		✓	
Flexibility	✓		✓		✓		✓	
Data quality	Non-peak ✓	Peak ✓	Non-peak ✓	Peak ✓	Non-peak ✓	Peak ✓	Non-peak ✓	Peak ✓
Timeliness	Not assessed		Non-peak ✓	Peak ✓	Non-peak ✓	Peak ✓	Non-peak ✓	Peak ✓

Key: level of demonstration of attribute

✓ = High ✓ = Medium ✓ = Low

Abbreviations: NNDSS=National Notifiable Diseases Surveillance System, SPRINT-SARI=Short Period Incidence Study of Severe Acute Respiratory Infections, FluCAN= The Influenza Complications Alert Network and PAEDS=Paediatric Active Enhanced Disease Surveillance

Discussion

The four systems complemented one another in collecting data required to meet the indicators of Goal 9 in the Australian National Disease Surveillance Plan for COVID-19 (version 2.0). Each system used its strengths to report data at different levels of granularity for understanding severe disease. The systems collectively described risk factors and the severity of disease among COVID-19 patients in Australia.

System users reported experiencing surge pressure, leading to delays in data collection, and poorer data completeness. Although the number of data fields collected were reduced to cope with high case load, systems were unable to obtain additional capacity or human resources, restricting capacity to address issues in a timely manner.

The four systems were not linked; linking data across systems could have led to greater efficiency and provided a means for assessing data quality and validity. Consultation with system users, hospital research units and the NIC, Commonwealth Department of Health, could have led to recommendations to improve the performance of each system as the pandemic evolved.

This is the first time all four systems were evaluated simultaneously. It's also the first evaluation on COVID-19 severity using the US Guidelines for Evaluating Public Health Surveillance Systems for the NNDSS, SPRINT-SARI, FluCAN and PAEDS. Australia's NNDSS was first and last evaluated in 2004 and demonstrated that the NNDSS was structurally simple but found to be inflexible to changing needs and lacked timeliness.¹⁵ In this evaluation, the NNDSS was found to be more flexible in adapting to the changing pandemic by creating enhanced fields, such as ICU, ventilated and co-morbidities. The PAEDS system has also been evaluated and reported the need for electronic portable data collection tools, ensuring long-term funding and timely reporting.¹⁶

A similar evaluation using the US CDC Guidelines for Evaluating Public Health Surveillance Systems was conducted on enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria, Australia (in March to June 2020).¹⁷ The surveillance system was successful in aiming to reduce the pressures of workforce capacity and increase situational awareness of hospitalised patients.¹⁷ For the case of the a greater influx of COVID-19 admissions, plans to scale up the system and to maintain stakeholder acceptability are key.¹⁷ Eleven surveillance hospital sites with COVID-19 patients in nine European countries (conducted in October and December 2021) used a very similar method to our evaluation to identify whether the surveillance system met its objectives and identified future improvements.¹⁸ Similarly to our

evaluation, the European evaluation reported standardisation between different region and countries was required as well as monitoring for outbreaks to ensure the sustainability of the surveillance system.¹⁸ Strengthening electronic platforms and automating data flow to reduce burden for clinical staff were also suggested.

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The strengths and limitations of this evaluation should be considered in the interpretation of findings and recommendations. This evaluation was conducted during the emergency response of the Delta outbreak which may have reduced stakeholder participation, although relevant hospitals and surveillance system staff from all eight jurisdictions were represented. This evaluation only captured information in the second half of 2021 and findings may not apply to future emerging SARS-CoV-2 variants.

Key Recommendations

To improve the operations and flow of data in surveillance systems:

1. Strengthen and link public health and hospitalisation information systems at the jurisdictional level for easy data flow.
2. Explore a national research governance mechanism (complementing the current National Mutual Acceptance for research ethics) to respond to pandemics immediately at a national level.
3. Improve standardisation of the hospitalisation case definition across jurisdictions for national consistency.

For sustainability and preparedness of future pandemics in Australia:

1. Create an alternative hospital surge capacity (research and medical staff) that are trained and ready for emergency response.
2. Create a contingency research protocol for sentinel surveillance systems to sample a portion of hospitalised cases, to effectively collect information when case numbers escalate.
3. Provide more incentives (research and funding) and advocate for research roles.

4. Ensure long-term stable funding for sentinel systems to be able to adequately plan for staff resourcing and respond to high case load.

Conclusion

The NNDSS, SPRINT-SARI, FluCAN and PAEDS surveillance systems have been essential in describing risk factors for COVID-19 clinical severity in Australia since 2020. The main issues identified during this evaluation included intense staffing and capacity pressures during surges in case numbers, a need to advocate for research roles, and a lack of system integration. Key recommendations included the need to make systems more efficient and future proof at the operational as well as the state and government levels.

Acknowledgement (optional):

We would like to express thanks and appreciation to the NNDSS, SPRINT-SARI, FluCAN and PAEDS system co-ordinators, investigators and data collectors who have contributed to the evaluation (initial consultation, survey participation and interviews) and to the pandemic response since 2020.

References

1. Hu B, Guo H, Zhou P, Shi ZL. Characteristics of SARS-CoV-2 and COVID-19. *Nat Rev Microbiol*. 2021;19(3):141-54.
2. Bhopal SS, Bagaria J, Olabi B, Bhopal R. Children and young people remain at low risk of COVID-19 mortality. *The Lancet Child & Adolescent Health*. 2021;5(5):e12-e3.
3. Smith C, Odd D, Harwood R, Ward J, Linney M, Clark M, et al. Deaths in Children and Young People in England following SARS-CoV-2 infection during the first pandemic year: a national study using linked mandatory child death reporting data. 2021.
4. Ward JL, Harwood R, Smith C, Kenny S, Clark M, Davis PJ, et al. Risk factors for intensive care admission and death amongst children and young people admitted to hospital with COVID-19 and PIMS-TS in England during the first pandemic year. *medRxiv*. 2021.
5. Whittaker E, Bamford A, Kenny J, Kaforou M, Jones CE, Shah P, et al. Clinical Characteristics of 58 Children With a Pediatric Inflammatory Multisystem Syndrome Temporally Associated With SARS-CoV-2. *JAMA*. 2020;324(3):259-69.
6. World Health Organization. Multisystem inflammatory syndrome in children and adolescents with COVID-19 2020 [cited 2021 12 July]. Available from: <https://www.who.int/publications/i/item/multisystem-inflammatory-syndrome-in-children-and-adolescents-with-covid-19>
7. Communicable Diseases Network Australia. Australian national disease surveillance plan for COVID-19 Version 2.0. 2021. Available from: <https://www.health.gov.au/resources/publications/australian-national-disease-surveillance-plan-for-covid-19>
8. Creswell JW, & Plano Clark, V. L. Designing and conducting mixed methods research: SAGE Publications; 2017.
9. Gale RC, Wu J, Erhardt T, Bounthavong M, Reardon CM, Damschroder LJ, et al. Comparison of rapid vs in-depth qualitative analytic methods from a process evaluation of academic detailing in the Veterans Health Administration. *Implement Sci*. 2019;14(1):11.
10. Taylor B, Henshall C, Kenyon S, Litchfield I, Greenfield S. Can rapid approaches to qualitative analysis deliver timely, valid findings to clinical leaders? A mixed methods study comparing rapid and thematic analysis. *BMJ Open*. 2018;8(10):e019993.
11. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
12. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-81.
13. Federal Register of Legislation. National Health Security (National Notifiable Disease List) Amendment Instrument 2020 2020 [cited 28 June 2022]. Available from: <https://www.legislation.gov.au/Details/F2020L00111>
14. National Incident Room Surveillance Team. 2019-nCoV acute respiratory disease, Australia: Epidemiology Report 1 (Reporting week 26 January - 1 February 2020). *Commun Dis Intell* (2018). 2020;44.

15. Miller M, Roche P, Spencer J, Deeble. Evaluation of Australia's National Notifiable Disease Surveillance System. *Commun Dis Intell.* 2004;28(3)
16. Maguire JE. Infectious Disease Epidemiology in the Asia-Pacific Region [A thesis submitted for the degree of Master of Philosophy in Applied Epidemiology of The Australian National University]; 2018. <https://openresearch-repository.anu.edu.au/bitstream/1885/164111/1/Maguire%20Thesis.pdf>
17. Curtis SJ, Cutcher Z, Brett JA, Burrell S, Richard MJ, Daneeta H, Gang RF, Lau CL, Rowe SL. An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria. *Commun Dis Intell.* 2020;44.
18. Young JJ, Mutch H, Rose, AMC, Evans JMM, European COVID-19 Hospital Evaluation Writing Group. Enhanced surveillance of hospitalised COVID-19 patients in Europe: an evaluation of the I-MOVE-COVID-19 surveillance network. *European Journal of Public Health.* 2023;34(1): 181–189.

Conference presentations

At the Communicable Diseases & Immunisation Conference, International Conference Centre, Sydney, Australia, 20–22 June 2022, I presented a long 10-minute oral presentation on the NNDSS part of the evaluation (Appendix A).

At the 11th Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET) Global Scientific Conference, Panama, 4–9 September 2022, my abstract on the evaluation of SPRINT-SARI (Appendix B) was accepted for a poster presentation (Appendix C), which included a five-minute oral presentation.

Appendix A – CDIC presentation slides

An evaluation of the Australian National Notifiable Diseases Surveillance System on COVID-19

Ye Jin (Zoe) Joo
Master of Philosophy in
Applied Epidemiology (MAE) scholar



Australian
National
University



Acknowledgement of Country



Overview



- 1) Surveillance system and it's relevance
- 2) The aim of the evaluation and methods
- 3) Major findings
- 4) Recommendations for next steps

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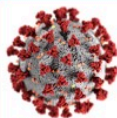
National Notifiable Diseases Surveillance System



National Notifiable Diseases Surveillance System
Established in 1990

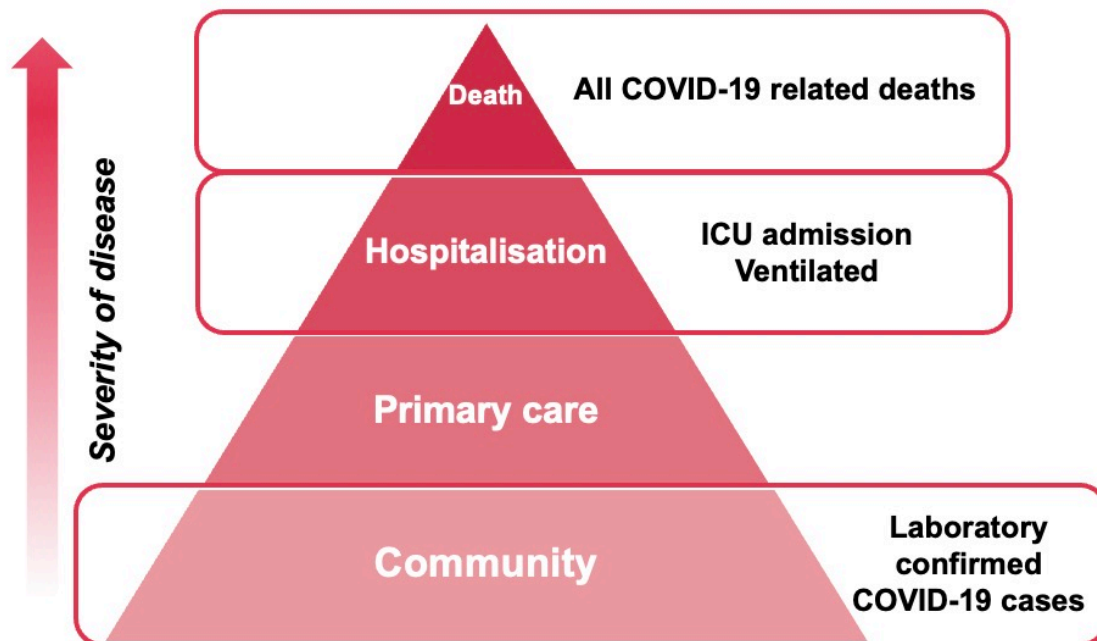
Co-ordinates surveillance > 50 communicable diseases

Each jurisdiction provides de-identified data



COVID-19 became a notifiable disease on 06 February 2020

COVID-19 Surveillance



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National Surveillance Plan



Australian National Disease Surveillance Plan for COVID-19 Version 2.0, April 2021

Contents

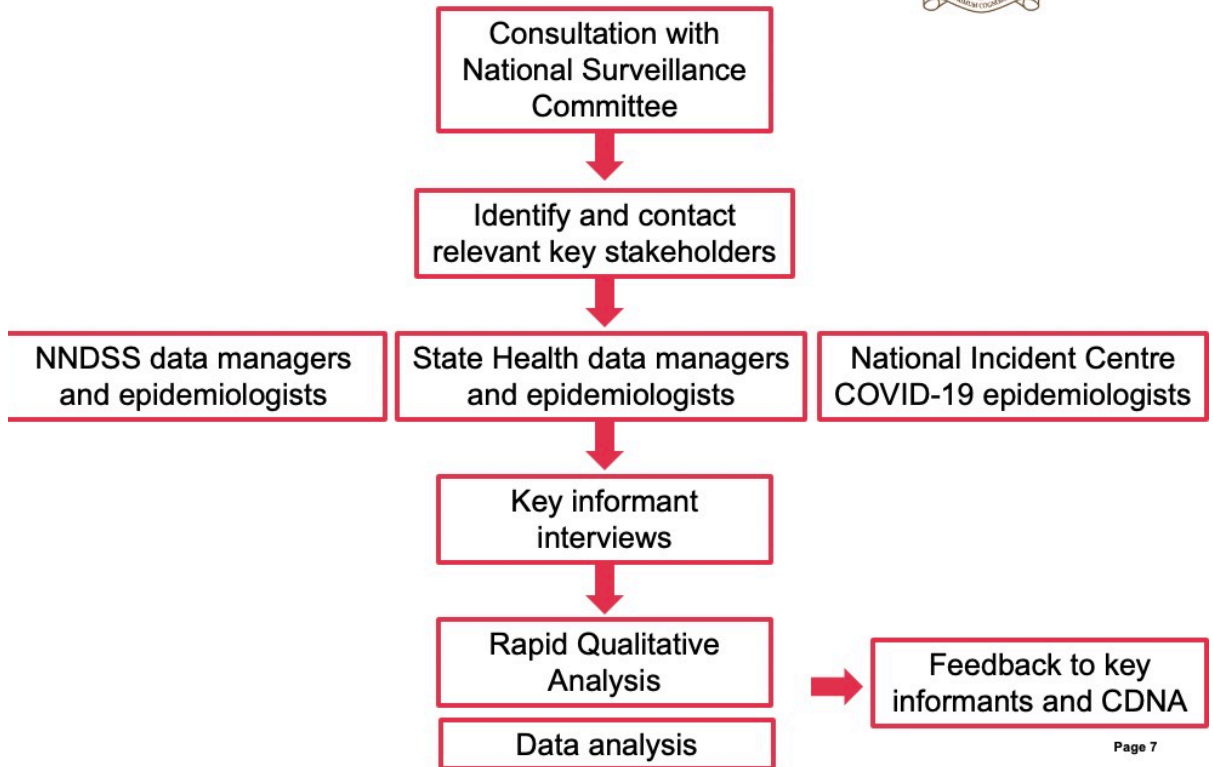
Background 2

Goal 9: To describe the clinical severity of COVID-19 cases to allow prediction of health resource use and to standardise models of care, as well as characterise risk factors for serious infection to allow for targeted public health strategies.

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Methods

Timeline
20 September to 09 November 2021



Evaluation Framework



**United States Centre for Disease Control and Prevention
Guidelines for Evaluating Public Health Surveillance Systems**

Simplicity

Flexibility

Data quality

Acceptability

Sensitivity

Predictive value positive

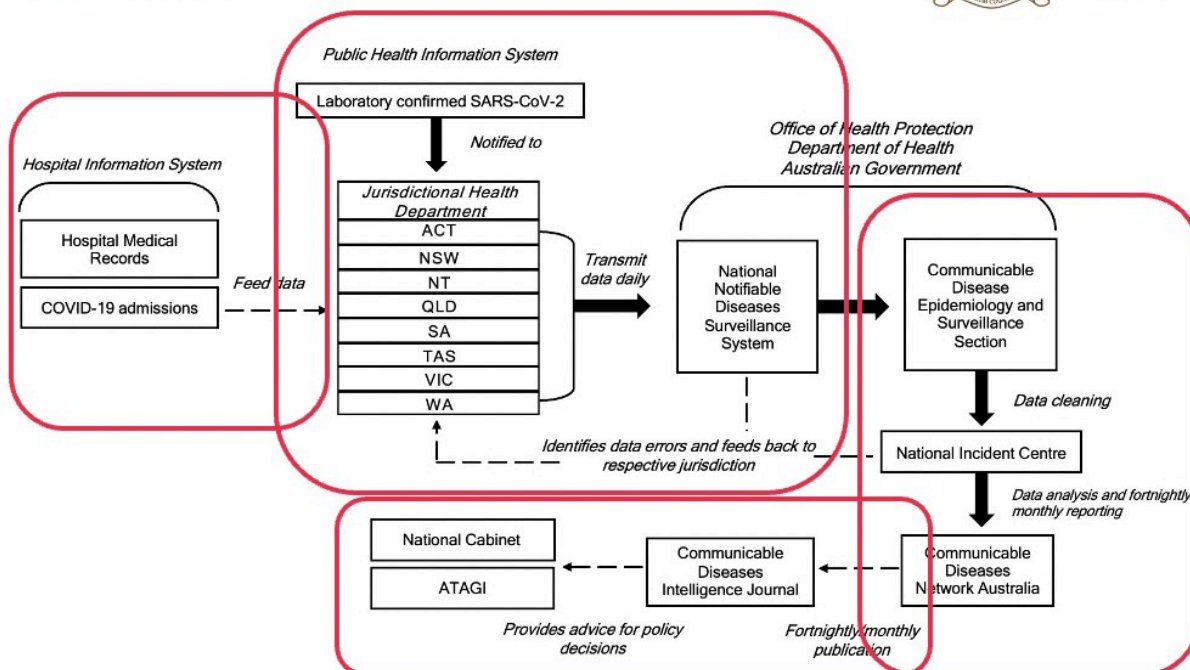
Representativeness

Timeliness

Stability

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Results



Abbreviations: ACT= Australian Capital Territory, NSW=New South Wales, NT=Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia, ATAGI= Australian Technical Advisory Group on Immunisation

Results



Simplicity

Both structure and ease of operation. Surveillance systems should be as simple as possible while meeting objectives

Common data fields all jurisdictions must report:

Sex
Age
Indigenous status
Postcode
Co-morbidities
Hospitalised
Ventilated
Death

No general linkage of hospitalisation data and public health information

"Traditionally there is a divide or siloing of public health information needs and clinical needs"

Results



Flexibility

Being able to adapt to changing information needs or operating conditions with little additional time, personnel, or allocated funds

First COVID-19 case
13 January 2020

First case definition
23 January 2020

Notifiable condition
06 February 2020

Hospitalised

- Hospital in the home
- Social admissions
- Overnight emergency room admissions
- Mandatory hospitalisation for all infected

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Results



Data Quality

Reflects the completeness and validity of the data recorded in the public health surveillance system

Pre-Delta
05/2021—06/2021

Peak of Delta
09/2021—10/2021

Overall **95%** **Indigenous status** **78%**

→

States with outbreak **85%** **Hospitalised** **40%**

75% **Co-morbidities** **30%**

→

> 50% reduction

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Recommendations



- Support jurisdictional health departments to link public health and hospital information systems
- Standardise definition of “hospitalised”
- Create an alternative surge capacity for emergency response

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Acknowledgements



- Co-authors: Noni Winkler, Alexis Pillsbury, Helen Quinn, Stephen Lambert, Aditi Dey, Frank Beard, Tambri Housen
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- NNDSS team
- National Incident Centre
- Queensland Health
- NSW Health
- SA Health
- ACT Health
- MAE colleagues

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Appendix B – Abstract submitted for the 11th TEPHINET Conference

Abstract

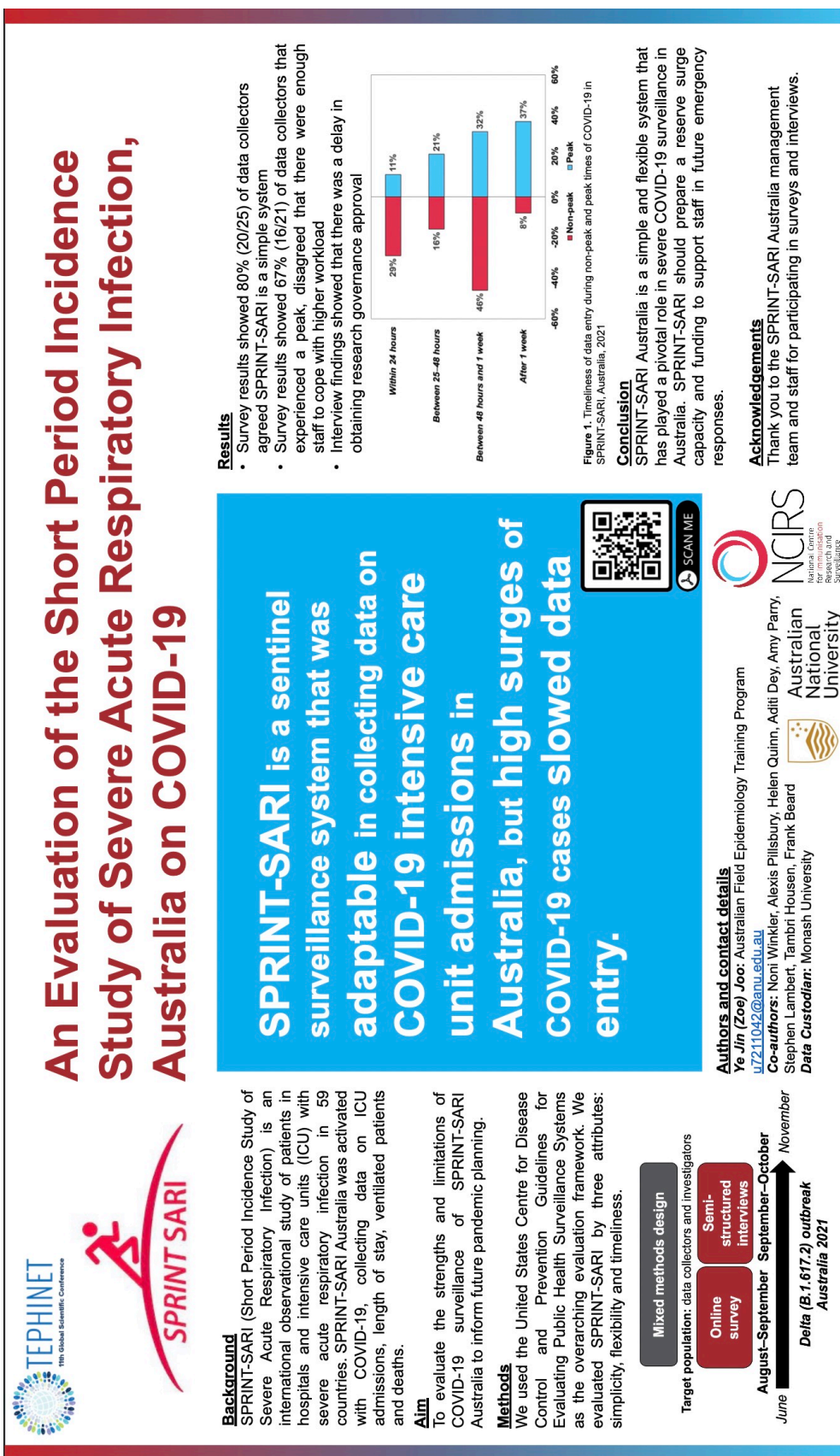
Title: An evaluation of the Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI) Australia on COVID-19

Background: Surveillance of severe COVID-19 is important to identify risk groups, predict health resource use and to target public health strategies. The Short Period Incidence Study of Severe Acute Respiratory Infection (SPRINT-SARI) Australia collects data on COVID-19 ICU admissions across 79 sites in all jurisdictions, comprising 96% of ICU beds in Australia. This is the first evaluation of the strengths and limitations of COVID-19 surveillance of SPRINT-SARI to inform future pandemic and COVID-19 endemic planning.

Methods: The ability of SPRINT-SARI to report data on ICU admissions, ventilated patients, and deaths was evaluated using guidelines from the United States Centers for Disease Control and Prevention, against three attributes: simplicity, flexibility, and timeliness. A mixed-methods design was implemented during the Delta (B.1.617.2) outbreak in Australia (June to November 2021), including surveys (September to October 2021) and semi-structured interviews of key stakeholders (August to October 2021).

Results: Survey results showed 80% (20/25) of data collectors strongly agreed or agreed that SPRINT-SARI is a simple system. SPRINT-SARI was flexible in incorporating COVID-19 surveillance and reducing the number of data fields captured during the peak of the Delta outbreak. However, challenges included delays in obtaining governance approval and reduced timeliness of data entry (n=24, 1 did not answer). In non-peak times of the pandemic, 29% (7/24) of data collectors entered patient data within 24 hours, compared to 11% (2/19, 5 did not experience peak) in peak times. Likewise, in non-peak times, 11% (2/19) entered data after one week of admission, compared to 37% (7/19) in peak times.

Conclusions: SPRINT-SARI is a simple, flexible system that has played a pivotal role in collecting and recording data on COVID-19 ICU admissions, length of stay, ventilated patients, and deaths in Australia. To address the challenges of timeliness, SPRINT-SARI should prepare a reserve surge capacity and funding to support and maintain efficiency for future emergency responses.



Chapter 3

Investigate an acute public health problem

An outbreak investigation of
gastroenteritis at a social event, Sydney
Olympic Park, New South Wales,
May 2022

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Preface

On the morning of Monday 02 May 2022, I received a phone call from the Western Sydney Public Health Unit (WSPHU) regarding a potential foodborne outbreak at an event at Sydney Olympic Park. At this point in time, I knew there were approximately 200 attendees at a social party and about 50 had reported illness. This was exciting as it was my first time being contacted for a potential foodborne outbreak since my MAE journey. I said “Yes!” without hesitation.

My role

Under the guidance of the infectious disease control team at the WSPHU, I assisted the lead epidemiologist to investigate a suspected gastroenteritis outbreak in Sydney Olympic Park. My role included:

- Ensuring relevant information was sourced from the venue
- Designing an online survey for all event attendees and staff
- Organising and distributing online surveys and sending reminders
- Cleaning, analysing, and interpreting data
- Following-up with attendees on clinical history, food items, and activities
- Writing up the final report for the Ministry of Health

Lessons learnt

This was the first time I was involved in an outbreak investigation (except for COVID-19) and it was a fantastic learning opportunity for me. I learnt first-hand the processes involved in an outbreak investigation. By the time I was contacted to begin this outbreak investigation, attendees at the event were already ill and the next step was to confirm diagnosis and collect data to find the cause of the gastrointestinal illness. I learnt the importance of specimen collection (particularly vomit and stool) for gastrointestinal illnesses to confirm diagnosis.

I also learnt that survey design must be done quickly to minimise recall bias and to test hypotheses. But I experienced the challenges of not being able to include all questions I wanted to due to time constraints and competing priorities. It was my first-time using Survey Monkey and it was difficult to create the ideal survey within a short amount of time and limited experience (although the survey

questions were well-designed and tested by several people). I learnt the importance of trialling surveys via desktop and phone, as user experience can be different. I found that it would have been best to use the survey platform that either my supervisor or I was confident in to minimise room for errors.

I had the opportunity to become familiar with the Centers for Disease Control and Prevention Guidelines for Confirming Cause of Foodborne Disease Outbreaks and learn about other pathogens that can cause gastroenteritis. I previously had limited knowledge about norovirus, learnt the different aspects of norovirus infection and illness, from the incubation period, symptoms, transmission, and duration.

Public health impact

One of the specific public health impacts of this investigation was creating an online survey for gastrointestinal outbreak surveys for the WSPHU. Although the Ozfoodnet Salmonella Hypothesis Generating Questionnaire is available, there was no previous online survey that could be used on the go nor a generic version that could be used at the WSPHU. The survey questions I designed will be helpful and used as a template for future gastrointestinal outbreak at the WSPHU.

This outbreak investigation has increased understanding of prevalent agents causing outbreaks in the Western Sydney catchment area. Furthermore, the investigation adds to the evidence of point source viral outbreaks with asymptomatic spread.

MAE competency addressed

- Investigate an acute public health problem or threat

Acknowledgements

A big thank you to all survey respondents of the social event and staff from the Sydney Olympic Park venue who co-operated with the investigative process. Thank you to laboratory staff at WiSE laboratory for fast turnaround of the specimen result.

At the WSPHU, I would like to thank Shopna Bag for always make me feel welcome at the WSPHU. Thank you, Sophie Norton, for contacting me to make this opportunity possible and guiding me through all the processes of the investigation. Thank you, Tracy Tsang, an MAE alumni and friend who answered all my silly questions and gave me advice on the outbreak and MAE journey. Thank you to Ben Silberberg and Stephen Crone for checking and providing feedback on the survey questions. Thank you, Conrad Moreira, for your conversations in the corridor and giving me ideas about further investigative possibilities.

Thank you to my field and academic supervisors for continuing their support even when I was at the WSPHU. Thank you, Amy, for your quick phone conversations and providing feedback on survey questions. Thank you, Tambri, for giving me guidance on the survey questions and encouraging me to go for an outbreak other than COVID-19. Thank you, Helen, for looking over the survey questions, helping me with the analysis of calculating relative risks and providing feedback on the write up. Thank you, Alexis, Tambri and Stephen for your comments on the final chapter.

Abstract

Background

On 1 May 2022, the Western Sydney Public Health Unit (WSPHU) became aware of a gastrointestinal outbreak occurring among attendees at a university social event in Sydney Olympic Park, Australia.

Methods

A retrospective cohort study was conducted to identify the cause of the gastrointestinal illness. Online surveys were sent to the attendees ($n=202$) and venue staff ($n=15$) to assess clinical history, food consumed, and pre- and post-event activities. We performed univariate analysis to identify the source of gastrointestinal illness. Data were analysed using Microsoft Excel and Stata/SE 14.0 (StataCorp, Texas, USA).

Results

The survey had a 75.7% (150/198) response rate for attendees, with 52 reporting gastrointestinal illness on the night of, or soon after the event. No staff reported illness either before or after the event. Symptoms reported by attendees included vomiting, diarrhoea, and abdominal cramps. The median duration of illness was 39.8 hours (range: 7.9–83.5 hours). Univariate analysis demonstrated a statistically significant association between illness and consumption of a cocktail drink [Relative Risk (RR) = 2.61, 95% Confidence Interval (CI): 1.64–4.15, $p=0.000$], however with a low attributable risk percent (34.2%). One stool sample collected tested positive for norovirus. There was also a statistically significant association between table seating and illness ($p=0.018$). No food samples were collected on premises.

Conclusions

The evidence gathered, the duration of illness, symptom profile, spread across table seating and laboratory specimen indicates that this is a point source outbreak of a viral source. We suspect that an attendee may have facilitated the spread of viral gastroenteritis at this event.

Introduction

Norovirus is highly infectious and the leading cause of gastrointestinal illness globally. (1-4) Approximately one in five cases of acute gastroenteritis (inflammation of the stomach or intestines) that leads to diarrhoea and vomiting is caused by norovirus. (5) In Australia, norovirus is not a notifiable condition but is the most common cause of gastroenteritis. (6, 7) In 2010, it was estimated that out of 4.1 million foodborne gastroenteritis cases in Australia, 276,000 cases were attributable to norovirus. (8)

Norovirus infection can occur in all ages. Symptoms typically begin after an incubation period of 12–48 hours, and include vomiting, diarrhoea, nausea, and abdominal cramps. (9) Fever and body aches may also be experienced. (9) Most symptoms will resolve without treatment after 1–3 days. (9) Approximately 10% of people with norovirus infection need to seek medical attention, which may include hospitalisation and treatment for dehydration. (10-12)

Outbreaks of norovirus are more common in institutional settings and close quarters, such as aged care facilities, hospitals, social events, schools, ships, and restaurants. (6) There are a variety of routes of transmission, but primarily norovirus is transmitted by person-to-person spread by the faecal-oral route, contact with contaminated surfaces and transmission via aerosolised vomit. (6, 9) Other forms of transmission of norovirus include foodborne and waterborne. (9)

The aim of this investigation was to determine the mode of transmission of the outbreak and recommend appropriate public health control measures.

Methods

On 1 May 2022, the Western Sydney Public Health Unit (WSPHU) was notified of a group of students experiencing gastrointestinal-like symptoms following a social event on 29 April in Sydney Olympic Park. We conducted a retrospective cohort study of attendees from 2 May to 11 May 2022 to investigate the potential cause of the outbreak.

Case definitions

A suspected case was defined as someone who had attended the venue on the night of 29 April and experienced symptoms associated with gastroenteritis (vomiting, diarrhoea, stomach cramps, blood in stool, nausea, fever, chills, muscle and body aches, fatigue, or rigor) within 72 hours of attending the event. Cases that reported onset of illness before the event were excluded. A broad suspected case definition was used to capture all potential cases.

A confirmed case was defined as someone meets the suspected case definition above and has a positive laboratory test from one of the following: 1) detection of human norovirus by antigen detection, 2) detection of human norovirus by Nucleic Acid Assays or 3) visualisation of norovirus by electron microscope. (6)

Epidemiological investigation

Gathering information

We contacted and gathered information from two sources: 1) the event organiser and 2) the venue manager. The event organiser provided general information about the event, the list of event attendees and their contacts details, and the seating arrangement at the venue. We also received information on how many people were ill and sought medical attention. From the venue manager, we retrieved the list of foods served on the night, the floor plan of the venue and a list of staff working at the venue, including in the kitchen. We found that the cosmopolitan cocktail drink was not provided by the venue but brought by the event organiser.

Survey development

With the information gathered we developed two surveys on Survey Monkey, one for event attendees (n=198) and the other for staff (n=15) working at the venue. We included questions on demographics, food items consumed, illness history, and pre- and post-event activities. The survey for event attendees was open from 2 May 12:00pm and closed at 11:59pm on 3 May 2022, with a reminder email sent on 3 May at 2:00pm. The survey for staff was sent on 3 May 12:00pm and closed at 11:59pm on 4 May 2022, with a reminder email sent on 04 May at 2:00pm.

Data cleaning

Data from Survey Monkey were merged onto Microsoft Excel. Preliminary data cleaning included: identifying and removing duplicates, renaming variables, recoding missing data, and generating a new variable to distinguish attendees who presented with gastroenteritis illness and attendees without symptoms.

Follow-up with survey respondents

Where data were missing or contradicting, I followed-up with survey respondents via a phone call to confirm information on demographics, food items consumed, illness history, and pre- and post-event activities. Data were then updated prior to statistical analysis.

Data and statistical analysis

The distribution of symptoms reported among survey respondents were summarised using frequencies, proportions, and an epidemic curve. I conducted chi-square tests comparing ill and not ill survey respondents by university year level and sex. I conducted a univariate analysis of food and drink items consumed (using Stata 14.0 [StataCorp, Texas, USA]), calculating attack rates, relative risk with 95% Confidence Intervals (Cis) and *p*-value between survey respondents that were exposed or not exposed to the food and drink item.

The population attributable risk (PAR) was calculated to see the difference between the risk of illness in the total population and in unexposed respondents. The attributable risk percentage (AR%) to find the proportion of ill respondents that are attributed to a certain food or drink item. The PAR and AR% were calculated using the following formulae using a 2 by 2 table:

		Exposure	
		<i>Exposed</i>	<i>Unexposed</i>
Outcome	Yes	a	b
	No	c	d

$$\text{Outcome rate exposed} = \frac{a}{(a + c)}$$

$$\text{Outcome rate not exposed} = \frac{b}{b + d}$$

$$\text{Relative risk} = \frac{\text{Outcome rate exposed}}{\text{Outcome rate not exposed}}$$

$$\text{Estimate of population exposure} = \frac{(a + c)}{(a + b + c + d)}$$

Population attributable risk

$$= 100 \times \frac{(\text{population exposure} \times (\text{relative risk} - 1))}{(1 + (\text{population exposure} \times (\text{relative risk} - 1)))}$$

Attributable risk percentage

$$= \text{Outcome rate exposed} - \text{outcome rate unexposed}$$

I also conducted a univariable analysis of survey respondent's table number and illness, calculating attack rate and *p*-value. A *p*-value of <0.05 was considered statistically significant. Data were analysed using Stata 14.0 (StataCorp, Texas, USA).

Laboratory investigation

With prior knowledge of which attendees sought medical attention and provided a stool sample, we contacted the laboratory for fast turnover of results. The sample was tested by either polymerase chain reaction (PCR) or by traditional culture. WiSE laboratory tested the sample for Salmonella, Shigella, Campylobacter, Rotavirus, Cryptosporidium and Norovirus.

Ethics approval

This study was conducted as part of a public health investigation under the powers of the Public Health Act 2010 (New South Wales). Ethics approval for this study falls under the "Request for waiver of consent for use of data in research

for an outbreak investigation for a Master of Philosophy in Applied Epidemiology, protocol: 2017/909”.

Results

Survey responses

The total guest list included 202 attendees but when the survey was sent out, two emails were not valid, and two attendees did not attend the event, bringing the total to 198. Out of the 198, there was a total of 164 attendee responses available on Survey Monkey, however 12 of these were duplicates, reducing the total to 152 attendee responses. Two responses indicated non-attendance at the event, making the total attendee responses to 150. Out of the full list of 202 attendees, two were non-attendees and two email addresses were not correct, therefore the overall survey response rate was 75.7% (150/198). The response rate for staff working at the event was 60% (9/15).

Demographics

Overall, there were 62 (46.6%) male and 71 female (53.3%) survey respondents, where a higher proportion of males (61.4%) reported illness, compared to 38.6% of females reporting illness. There was no statistically significant difference between females and males who reported illness or no illness. The overall median age of the survey respondents was 24 (range: 20–29). Attendance of the event was mostly represented by Year 1 (n=28), 2 (n=28) and 3 (n=26) students as well as guest attendees (n=36), with a further 17 attendees that did not complete the survey (total n=150). Only 15 Year 4 students attended the event. There was no statistically significant difference between year level and those who reported illness or no illness (Table 1).

Table 1. Demographic comparison of ill and not ill attendees following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=133)

a	<i>Ill</i>	<i>Not ill</i>	<i>Total</i>	<i>p-value</i>
	n (%)	n (%)	n (%)	
Sex				
Female	17 (38.6)	54 (60.7)	71 (53.3)	0.815
Male	27 (61.4)	35 (39.3)	62 (46.6)	
Total	44	89	133	
Median age	24 (21–32)	24 (20–39)	24 (20–29)	
Year level				
Year 1	10 (22.7)	18 (20.2)	28 (21.1)	0.417
Year 2	10 (22.7)	18 (20.2)	28 (21.1)	
Year 3	11 (25.0)	15 (19.9)	26 (19.5)	
Year 4	2 (4.5)	13 (14.6)	15 (11.3)	
Guest	11 (25.0)	25 (28.0)	36 (27.1)	
Total	44	89	133	

Symptoms and illness

Out of the 150 responses from attendees, 52 reported illness after the 29 April 2022 event (only 44 provided a valid onset date). Of these 44 attendees, all except four reported experiencing either vomiting or diarrhoea. Illness onset ranged from 11pm, 29 April to 9pm, 01 May 2022 (Figure 1). Four attendees reported having symptoms from 11–11:30pm on the night of event. Three out of these four attendees reported consuming alcohol, which may have contributed to vomiting. The median duration of illness was 39.8 hours, ranging from 7.9–83.5 hours.

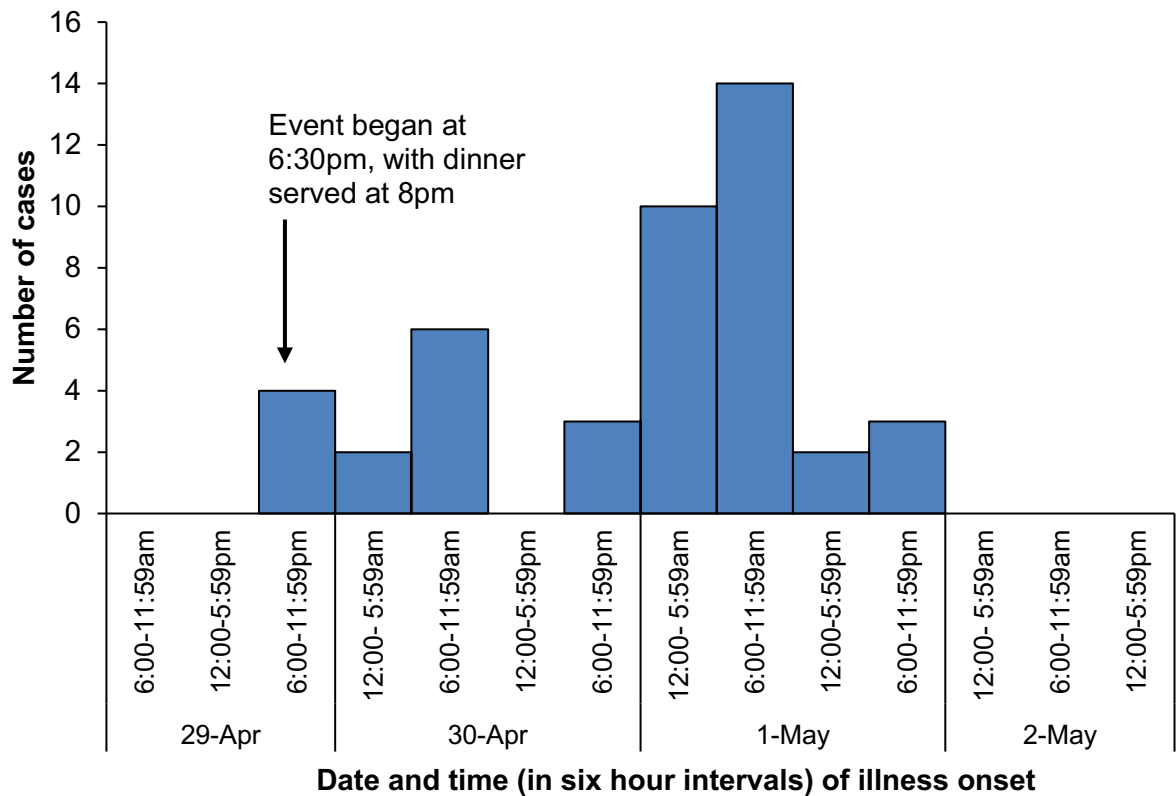


Figure 1. Epidemic curve of case onset date and time following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=44)

The most commonly reported symptoms were fatigue (86.4%), vomiting (84.1% and nausea (81.8%) (Table 2). Two cases reported blood in their stool but did not seek medical attention. Six attendees saw their general practitioner. Two attendees visited a hospital emergency department, where one had a blood sample collected and the other a stool sample. No one was admitted to hospital. Three attendees reported one member of their household to subsequently becoming unwell.

Table 2. Clinical symptoms of cases event attendees following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=44)

Symptom	n	%
Vomiting	37	84.1
Diarrhoea	30	68.2
Stomach cramps	33	75.0
Blood in stool	2	4.5
Nausea	36	81.8
Fever	22	50.0
Chills	27	61.4
Muscle and body aches	29	65.9
Fatigue	38	86.4
Rigors	5	11.4

Food and drink items

Univariate analysis identified no statistically significant association between illness and any food items served on the night of the event. We only included 107 responses that completed the food history section of the survey. Alternate meals (with a third vegan option) were served for dinner, including entrée, main and dessert. Attendees who consumed the Riverina beef main course dish were approximately two times more likely to experience illness than those who did not, but this difference was not statistically significant (Table 3). There was a statistically significant association between illness and one drink item. Attendees who consumed the cosmopolitan cocktail drink were 2.6 times more likely to experience illness than those who did not (Table 4). The attributable risk percentage was 43.5% and the population attributable risk was 21.1% for the cosmopolitan cocktail drink. The cosmopolitan cocktail drink (brought by the event organiser, not provided by the venue) was served as a welcome drink from 6:30pm.

Table 3. Univariate analysis of food items consumed by attendees following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=107)

Food item Exposure	Exposed			Not exposed			Relative Risk (95% CI)	p
	Total	Cases	Attack Rate %	Total	Cases	Attack Rate %		
Bread	61	19	31.1	44	16	36.4	0.86 (0.50–1.47)	0.574
<i>Entrée</i>								
Tiger prawns	59	20	33.9	48	16	33.3	1.02 (0.60–1.74)	0.951
Tuscan chicken	59	19	32.2	48	17	35.4	0.91 (0.53–1.55)	0.726
Hummus and ratatouille	8	3	37.5	99	33	33.3	1.13 (0.44–2.87)	0.805
<i>Main</i>								
Riverina beef	66	27	40.9	41	9	22.0	1.86 (0.98–3.56)	0.059
Honey mustard	57	17	29.8	50	19	38.0	0.78 (0.46–1.34)	0.373
Saffron and mushroom	8	3	37.5	99	33	33.3	1.13 (0.44–2.87)	0.805
Shared vegetables	36	11	30.6	68	24	35.3	0.87 (0.48–1.56)	0.631
<i>Dessert</i>								
Mojito slice	46	15	32.6	61	21	34.4	0.95 (0.55–1.63)	0.844
Chocolate cake	59	18	30.5	48	18	37.5	0.81 (0.48–1.38)	0.446
Vegan mousse	5	3	60	102	33	32.4	1.85 (0.86–4.00)	0.115

Table 4. Univariate analysis of drink items consumed by attendees following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=107)

Drink item	Exposed			Not exposed			Relative Risk (95% CI)	p
	Total	Cases	Attack Rate %	Total	Cases	Attack Rate %		
Drinks								
Sparkling wine	65	24	36.9	41	12	29.3	1.26 (0.71–2.24)	0.426
White wine	50	16	32.0	56	20	35.7	0.90 (0.52–1.53)	0.688
Red wine	25	7	28.0	81	29	35.8	0.78 (0.39–1.56)	0.487
Beer on tap	25	9	36.0	81	27	33.3	1.08 (0.59–1.98)	0.804
Bottled beer	-	-		106	35	33.0	-	-
Coke	12	3	25.0	94	33	35.1	0.71 (0.26–1.97)	
Lift	9	1	11.1	-	-	-	-	-
Ginger ale	29	9	31.0	77	27	35.1	0.89 (0.48–1.65)	0.700
Orange juice	6	2	33.3	100	34	34.0	0.98 (0.31–3.14)	0.973
Cointreau	34	13	38.2	72	23	31.9	1.20 (0.69–2.06)	0.517
Vodka	32	10	31.3	74	26	35.1	0.89 (0.49–1.62)	0.702
Cranberry juice	8	2	25.0	98	34	34.7	0.72 (0.21–2.47)	0.602
Lime juice	69	23	33.3	37	13	35.1	0.95 (0.55–1.65)	0.851
Water	21	12	57.1	-	-	-	-	-
Cosmo cocktail	17	12	70.6	85	23	27.1	2.61 (1.64–4.15)	0.000*

* Statistically significant ($p < 0.05$)

Spatial transmission

There were 20 tables at the venue with approximately 10 people seated on each table, according to the venue floor plan. However, we could not obtain data on who sat at which specific seat. Figure 2 depicts the number of people sitting around the table with the red dots indicating attendees who reported illness. Univariable analysis showed there was a statistically significant association ($p=0.018$) between table number and illness (Table 5). Table 10 (75%) and 15 (80%) had the highest attack rates.

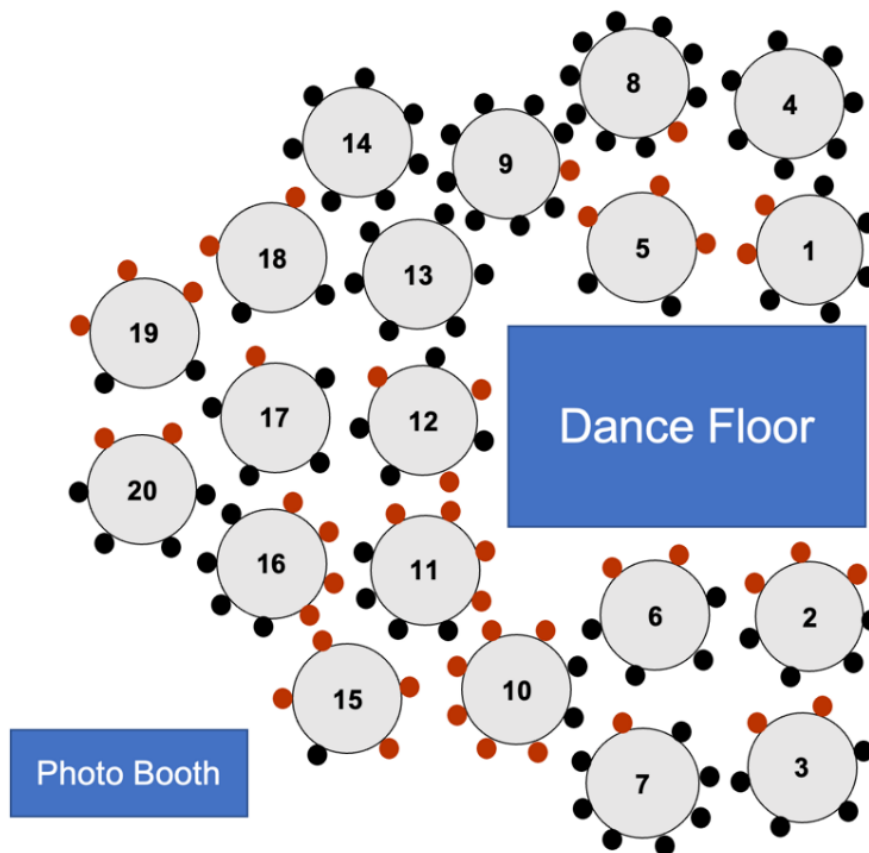


Figure 2. Approximate seating plan of attendees at a social event at Sydney Olympic Park on 29 April 2022, Australia (red dots are those with reported illness; black no illness) (N=133)

Table 5. Univariable analysis of attendees' table numbers and illness following a social event at Sydney Olympic Park on 29 April 2022, Australia (N=133)

Table number	Total	Cases	Attack Rate %	<i>p</i>
1	7	2	28.6	0.018
2	7	3	42.9	
3	5	2	40.0	
4	7	0	-	
5	5	3	60.0	
6	6	2	33.3	
7	8	1	12.5	
8	10	1	10.0	
9	9	1	11.1	
10	8	6	75.0	
11	8	4	50.0	
12	7	3	42.9	
13	6	0	-	
14	7	0	-	
15	5	4	80.0	
16	8	4	50.0	
17	5	1	20.0	
18	4	2	50.0	
19	5	3	60.0	
20	6	2	33.3	

Pre- and post-event activities

There were no organised pre-events on the night of the event. First year students had class together during the week and students in other years had been in hospital placement. None of the attendees reported coming into contact with anyone who was ill seven days prior to the event. During the event, the majority attended the dance floor (84%, 112/133) and photo booth (74%, 98/133). A minority (16.5%, 22/133) attended post-events, but no major post-event took place.

Venue staff

None of the staff were reported to have been ill before, during or after the event. Three out of nine (33.3%) who responded to the survey worked in the kitchen, two out of nine (22.2%) worked only in the function room, and four out of nine (44.4%) worked both in the kitchen and function room. All staff ate some food from the menu, varying from entrée only, to one main dish.

Laboratory investigations

Culture and PCR was completed on one stool specimen collected and tested. Culture was negative for Salmonella, Shigella, and Campylobacter. PCR was negative for Rotavirus and Cryptosporidium but positive for Norovirus-2.

Control measures

The New South Wales Food Authority was not involved in the investigation as evidence pointed to a viral outbreak, with the mode of transmission unlikely to be due to a food or a food handler.

Discussion

In this gastrointestinal investigation, we were able to gather information that pointed to a viral source of illness, potentially norovirus. This parallels to the fact that norovirus is the leading causes of acute gastroenteritis in Australia and worldwide. (6,7)

Descriptive and epidemiological evidence in our investigation is suggestive that the route of transmission is most likely person-to-person contact and not foodborne. The median incubation time was 39.8 hours, close to the 33-hour median incubation time of norovirus. (13) The single stool specimen provided by an ill attendee was positive for norovirus. In addition, the spatial pattern of spread observed in table arrangements, is indicative of person-to-person spread. There was no statistically significant difference between illness and alternate meals served on the night of the event. The symptoms reported by attendees followed the profile of norovirus. These all lead to the source of this outbreak being viral (most likely norovirus) and person-to-person contact.

Evidence for person-to-person transmission found in the investigation suggests that an attendee may have brought the virus to the event. However, all survey respondents reported experiencing no symptoms prior to the event and no contact with ill people seven days prior to the event, meaning we were unable to track the primary case. There is high potential that an event attendee could have been asymptomatic and started to spread the virus. Asymptomatic people can

shed norovirus and up to 30% of norovirus infections are asymptomatic. (9) In Australia,

Spatial analysis demonstrated that attendees reporting illness were found to be sitting together around table 10, 11 and 15. Table 10 and 15 had the highest attack rates, suggests how one attendee sitting at one of these tables could have spread the virus to others. Most respondents reported attending the dance floor and photobooth and this would explain how other tables far away from tables 10,11 and 15 reported attendees with illness.

The final evidence that pointed to norovirus being the causative agent was the PCR laboratory result. A single stool specimen from an ill attendee was collected and tested positive for norovirus. However, another positive specimen from an ill attendee would have provided stronger confirmation for norovirus as the causative agent. (13)

In the food and drink item analysis, there was a statistically significant association between the cosmopolitan cocktail drink served at the beginning of the night [$p=0.000$, $RR=2.61$ (95% CI: 1.64–4.15)]. The cosmopolitan cocktail drink was not brought by the event organiser. Attendees who had the cosmopolitan cocktail drink were 2.6 times more likely to become ill. However, the attributable risk percentage (43.5%) and population attributable risk percentage (21.1%) was low, therefore the likelihood of the cosmopolitan cocktail drink to drive viral spread is low.

Alternate meals were served on the night of the event, and there was no greater risk for illness for a certain meal over the other. Further to this, no staff reported illness. These suggest that the outbreak was not foodborne.

This investigation was limited by the lack of further investigative processes, and responses for follow-up. The WSPHU did not call for a food specimen and environmental investigation when the result of the single stool specimen results arrived. With a focus on minimising transmission of COVID-19, this outbreak was not a priority and public health action was not requested. Evidence from a food

and environment investigation would have strengthened the case for this outbreak not being foodborne. In our online survey, there was an issue with questions on symptoms becoming mandatory for respondents who did not report illness. Therefore, the results from the survey were difficult to interpret and had conflicting responses. Although time was spent to follow-up with respondents who provided incorrect information, not all could be reached, and this reduced the number of responses.

Another limitation of this investigation is that we did not collect data on the number of drinks consumed by the attendees. This eliminated the possibility of exploring of dose-response relationships that may have been present at this event.

If there was an opportunity for further investigation and implementation of public health measures of this likely person-to-person transmission of norovirus, the following would have been considered. An environmental investigation on site to sample for norovirus, to check for any record of staff absenteeism and a review of general hygiene and environmental cleaning precautions of the site would have been conducted. In addition to this, ongoing monitoring for new cases until there were no new cases (no new cases after 72 hours from the onset of symptoms of the last case) would have been appropriate. (6) Standard precautions on hand hygiene and cough etiquette, as well as how to clean up vomit, when to visit a doctor and isolation at home would have been explained to all attendees of the event.

Conclusion

Findings from this investigation support the outbreak of gastrointestinal illness at a social event in Sydney Olympic Park on 29 April 2022 was viral-mediated. The duration of illness, symptoms reported, no association with food or food handlers, person-to-person spread demonstrated through spatial analysis, and laboratory result point to norovirus being the causative agent. While the definitive source of the outbreak could not be confirmed, it is likely to be an attendee. The investigation highlights the importance of better understanding the role of asymptomatic infection in outbreaks. The need for multiple specimens to confirm laboratory diagnosis should be emphasised in gastrointestinal outbreaks.

References

1. Al-Thani A, Baris M, Al-Lawati N, Al-Dhahry S. Characterising the aetiology of severe acute gastroenteritis among patients visiting a hospital in Qatar using real-time polymerase chain reaction. *BMC Infect Dis.* 2013;13:329.
2. Lopman B, Zambon M, Brown DW. The evolution of norovirus, the "gastric flu". *PLoS Med.* 2008;5(2):e42.
3. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, et al. Foodborne illness acquired in the United States--major pathogens. *Emerg Infect Dis.* 2011;17(1):7-15.
4. Tam CC, Rodrigues LC, Viviani L, Dodds JP, Evans MR, Hunter PR, et al. Longitudinal study of infectious intestinal disease in the UK (IID2 study): incidence in the community and presenting to general practice. *Gut.* 2012;61(1):69-77.
5. Centres for Disease Control and Prevention. Norovirus Worldwide 2021 [Available from: <https://www.cdc.gov/norovirus/trends-outbreaks/worldwide.html>]
6. Commonwealth of Australia. Guidelines for the public health management of gastroenteritis outbreaks due to norovirus or suspected viral agents in Australia. 2010. [Available from: <https://www.health.gov.au/resources/publications/norovirus-and-suspected-viral-gastroenteritis-cdna-national-guidelines-for-public-health-units>]
7. Hall G, Kirk MD, Becker N, Gregory JE, Unicomb L, Millard G, et al. Estimating foodborne gastroenteritis, Australia. *Emerg Infect Dis.* 2005;11(8):1257-64.
8. Kirk M, Ford L, Glass K, Hall G. Foodborne Illness, Australia, Circa 2000 and Circa 2010. *Emerg Infect Dis.* 2014;20(11): 1857-1864
9. Centres for Disease Control and Prevention. Updated norovirus outbreak management and disease prevention guidelines. *MMWR Recomm Rep.* 2011;60:1-18.
10. de Wit MA, Koopmans MP, Kortbeek LM, Wannet WJ, Vinjé J, van Leusden F, et al. Sensor, a population-based cohort study on gastroenteritis in the Netherlands: incidence and etiology. *Am J Epidemiol.* 2001;154(7):666-74.
11. Phillips G, Tam CC, Conti S, Rodrigues LC, Brown D, Iturriza-Gomara M, et al. Community incidence of norovirus-associated infectious intestinal disease in England: improved estimates using viral load for norovirus diagnosis. *Am J Epidemiol.* 2010;171(9):1014-22.
12. Widdowson MA, Sulka A, Bulens SN, Beard RS, Chaves SS, Hammond R, et al. Norovirus and foodborne disease, United States, 1991-2000. *Emerg Infect Dis.* 2005;11(1):95-102.
13. Centres for Disease Control and Prevention. Guidelines for Confirming Cause of Foodborne Disease Outbreaks 2015 [Available from: https://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/confirming_diagnosis.html]

Chapter 4

Analysis of a Public Health Dataset

Analysis of COVID-19 notifications
reported to the National Notifiable
Diseases Surveillance System,
January 2020 to November 2021,
Australia

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Preface

Background

I still vividly remember my very first and last face to face Australian Technical Advisory Group on Immunisation (ATAGI) meeting. It was the 73rd meeting held on 20–21 February 2020 at the Hellenic Club of Canberra. It was only the beginning, and nobody exactly knew what coronavirus disease 2019 (COVID-19) would bring. I remember short discussions about COVID-19 amongst ATAGI members. One of the co-chairs was absent in a few sessions because of teleconferences with the National Cabinet on COVID-19.

But the majority of the 73rd meeting was run as usual, discussing strategic planning and ATAGI business. One of the discussions involved publishing a document that analysed a particular issue of vaccination coverage gap and needs with scientific evidence and epidemiological information, what was to become known as an ATAGI Targeted Review.

Fast-forward a year later, it is my first day of as a Master of Philosophy in Applied Epidemiology (MAE) scholar at the National Centre for Immunisation Research and Surveillance (NCIRS), 15 February 2021. I was informed that ATAGI was preparing a Targeted Review on COVID-19 vaccination. A short epidemiological review of COVID-19 in Australia was required. With my prior knowledge and experience with ATAGI as an NCIRS employee, it was a timely and fitting opportunity for me (now as an MAE scholar) to undertake this epidemiological analysis on COVID-19.

I felt very privileged to witness the beginnings of what this document would look like to be involved in this very first product as a field epidemiology trainee. The Targeted Review on COVID-19 vaccination was supposed to be publicly available in June 2021. However, due to other competing priorities on the ATAGI advice on COVID-19 vaccines, the publication of the Targeted Review was delayed and unpublished during my placement. I ended up pausing my work and another NCIRS employee worked on the Targeted Review. There were also delays with receiving data for my MAE (not for the ATAGI Targeted Review) and I ended up starting the analysis a year later in 2022.

My role

I was the primary investigator of the analysis of this dataset. I developed the study protocol, applied for ethics approval, applied for data request to the National Notifiable Diseases Surveillance System, undertook the analysis, and wrote the final chapter in this bound volume.

Lessons learnt

- This was the first project I started as a MAE scholar, and I learnt that writing up a solid data analysis plan is important as an epidemiologist. Going through this process helped me with my other projects.
- Through this project that data analysis plan is I learnt that is up to the epidemiologist's discretion to define the start and end of an outbreak. In this analysis, I selected ≥ 50 cases in one jurisdiction in a week to be the beginning of an outbreak and < 50 cases to be the end. This is how I defined the four time periods in this study.
- I learnt first-hand that being able to do descriptive epidemiology is a basic and essential skill for a MAE.
- I learnt to be much more confident in using Stata and manipulating data.
- I also learnt how to effectively present tables and figures for an audience, and this is time consuming. Many times, I had to recreate figures and tables so only essential information is presented.

Public health impact

This study has not yet been prepared as a manuscript but intends to be published in the near future. The findings of the analysis are unique in not only providing analysis on notifications, hospitalisations and deaths of COVID-19 but presenting information on public health and social measures implemented, vaccination coverage and emerging SARS-CoV-2 variants of concern accordingly allowed the story of the pandemic in Australia to be explained. The findings advocate for strengthening of surveillance and monitoring of data, more effective communication with the public to improve vaccination uptake in response to future pandemics.

MAE competences addressed

- Analyse a public health dataset

Acknowledgements

There is an old saying that it takes a whole community to raise a child. I felt like a child when I was undertaking this data analysis project. Although I started out confident to do the analysis for the Targeted Review, I shortly found that data analysis was not easy. I was then taken back by the long wait for data and interruptions to complete this chapter. In the long process of completing this chapter, several people helped me to bring it all together.

Thank you, Stephen who guided me, on my first take of data analysis and improve my way of presenting data. Thank you so much Helen for answering and responding to my unexpected and unending questions about analysis and code. Thank you to Meg Dalmau and Aidan Yuen my fellow MAE friends who provided moral support and technical assistance for this project when we were in Panama. Lastly, thank you Tambri for giving my ideas on how to present data and the importance of using meta-data.

Abstract

Background

The changing epidemiology of COVID-19 must be understood to identify and respond with effective public health intervention. The aim of this study was to explore the epidemiological characteristics of COVID-19 notification data in Australia from January 2020 to November 2021. There are four distinct periods, where the beginning of one period is defined as ≥ 50 cases per week from at least one jurisdiction and the end of a period as < 50 cases.

Methods

We conducted a retrospective descriptive secondary analysis of COVID-19 notifications, hospitalisations, and deaths reported to the National Notifiable Diseases Surveillance System (NNDSS) by all jurisdictions from 13 January 2020 to 30 November 2021. Data on public health measures and vaccination coverage was collated from various publicly available sources.

Results

The first and second period in the pandemic was successfully controlled by strict PHSM, such as lockdowns, contact tracing and isolation, and travel restrictions. The second period however impacted the elderly population, due to poor infection control in aged care facilities. The third period observed minimal transmission of virus with low COVID-19 vaccination coverage. The fourth period was characterised by the outbreak of Delta (B.1.617.2) variant, where the virulence of the virus surpassed the impact of PHSM.

Conclusions

Australia has been successful in 2020 to control transmission of SARS-CoV-2 using strict PHSM. In 2021, the high virulence of the Delta strain, the low uptake of COVID-19 vaccines and PHSM could not contain the virus. Continual surveillance and analysis of COVID-19 notification data and vaccination coverage will help respond to and prepare for future pandemics.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has transformed the lives of the global community. No continent has escaped the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case of COVID-19 in Australia was notified on 13 January 2020 and since then, SARS-CoV-2 continues to circulate and cause disease. (1)

In response to the COVID-19 pandemic, the Australian Government initially aimed to suppress SARS-CoV-2 circulation to minimise the number of COVID-19 cases and reduce severe outcomes. (2) Australia has achieved this primarily through public health and social measures (PHSM) such as closing of borders, contact tracing, isolation and high levels of testing. Australia strictly closed borders to all non-residents and non-Australian citizens and a travel ban was imposed on Australians travelling overseas on 20 February 2020. (3) A multitude of restrictions across Australia, including closure of interstate borders, restrictions on social gatherings, lockdowns, restrictions on access to hospitals and aged care were implemented throughout the pandemic.

Despite global efforts to curb the spread of SARS-CoV-2, there was a high urgency to develop a COVID-19 vaccine to protect populations that are at higher risk of severe disease. On 11 December 2020, the Pfizer-BioNTech COVID-19 vaccine was the world's first to receive regulatory approval from the United States, Food and Drug Administration for Emergency Use Authorisation. (4) In Australia, the Therapeutic Goods Administration provisionally approved the same COVID-19 vaccine for use in Australia on 25 January 2021. (5) Subsequently, the national COVID-19 vaccination program initially targeting priority groups commenced on 22 February 2021. (6) These groups included: people at risk due to occupational reasons (quarantine and border workers, frontline healthcare workers, aged care and disability staff), older adults, Aboriginal and Torres Strait Islander people and adults with underlying medical conditions. (6)

National COVID-19 epidemiology reports have been published in the Communicable Diseases Intelligence Journal on a regular basis (weekly or fortnightly) by the COVID-19 National Incident Room (NIR) since February 2020. (7) Reports generally include

broad descriptive analyses of the epidemiology of COVID-19 in Australia. Jurisdictional reports are also published, but these are focused on limited geographical settings and differ in the scope of reporting. (8-10) There is a need for in-depth analysis of COVID-19 by the different epidemiological periods observed in Australia in relation to PHSM and vaccination coverage. Therefore, the aim of this study is to define the epidemiological characteristics of COVID-19 notifications in Australia from January 2020 to November 2021.

Methods

Study type

A retrospective descriptive secondary analysis was conducted of COVID-19 notifications reported to the National Notifiable Diseases Surveillance System (NNDSS) dataset by all Australian jurisdictions between 13 January 2020 to 30 November 2021.

Case definitions

Confirmed case

There were many iterations of a case definition of COVID-19 throughout the pandemic since 2020. The Communicable Disease Network Australia (CDNA) first developed the initial case definition on 23 January 2020. (11) Based on the CDNA case definition (version 4.7) updated on 24 June 2021, a confirmed COVID-19 case has laboratory definitive evidence from either:

- detection of SARS-CoV-2 by nucleic acid test OR
- isolation of SARS-COV-2 in cell culture, with confirmation using a nucleic acid test OR
- SARS-CoV-2 IgG seroconversion or a four-fold or greater increase in SARS-CoV-2 antibodies of any immunoglobulin subclass including 'total' assays in acute and convalescent sera, in the absence of vaccination. (11)

COVID-19 hospitalisation

A COVID-19 hospitalisation on the NNDSS is a confirmed COVID-19 case with hospitalisation record at the time of their infection. In Queensland (QLD) and the

Northern Territory (NT), hospitalisation of most positive cases, regardless of clinical need, was undertaken to minimise risk of community spread, and this was more common in the first year of the outbreak.

COVID-19 death

A COVID-19 death is defined for “surveillance purposes as a death in a confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-10 (e.g. trauma). There should be no period of complete recovery from COVID-19 between illness and death. Where a Coroner’s report is available, these findings are to be observed.” “a death in a confirmed or probable COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19.” (11)

Data sources

The NNDSS collates data of de-identified information on nationally notifiable diseases across eight jurisdictions in Australia. COVID-19 is a nationally notifiable disease where there are core and enhanced data fields are being captured onto the NNDSS. The following data fields were provided by the NNDSS: diagnosis date (this a derived field and represents the onset date or when the date of onset is not known, the earliest of the specimen collection, the notification, or the notification received date), age at onset, source of infection, sex, state (this field represents the jurisdiction of residence of the notified case, where the case usually resides overseas, it’s the jurisdiction where the diagnosis took place), Indigenous status, postcode, hospitalised and died of condition.

Data analysis

Descriptive analysis

COVID-19 cases notified to the NNDSS from 13 January 2020 to 30 November 2021 were summarised by age-group, sex, jurisdiction, Indigenous status, remoteness area, hospitalised and died across four different epidemiological periods in Australia. The four time periods were defined according to the beginning and end of an outbreak. The beginning of an outbreak was defined as ≥ 50 cases per week from at least one jurisdiction. The end of an outbreak was defined as < 50 cases per week from at least one jurisdiction.

Hospitalised rate was calculated as the percentage of COVID-19 cases hospitalised in the specific time period. Case fatality ratio (CFR) was calculated by number of deaths divided by the number of COVID-19 cases multiplied by 100 (according to a defined time period).

Mid-year resident population estimates by jurisdiction and age-sex from the Australian Bureau of Statistics (ABS) were used to calculate notification rates per 100,000 population per year. (12) Mid-year resident population estimates for 2020 were used for the first and second period and estimates for 2021 were used for the third and fourth period.

Remoteness area is a geographical classification defined by the ABS which divides Australia into five categories of remoteness based on a measure of relative access to services. (13) The five categories are: major cities of Australia, inner regional Australia, outer regional Australia, remote Australia, and very remote Australia. There is a corresponding remoteness area for every postcode in Australia and this correspondence is available from the Australian Statistical Geography Standard. (14) The NNDSS data is used to classify the level of remoteness using postcode of residence. The reported postcode however may not necessarily represent the place where infection was acquired.

Data on national and jurisdictional border closures and vaccination coverage were gathered from publicly available information on the Australian Government webpage to provide detail to the epidemiological curve of COVID-19 notifications in Australia. Data were cleaned and analysed on Stata 14.2 (Stata Corp, Texas, USA). R software was used to merge remoteness categories and line listed data as well as reshaping and aggregating line listed data to count data. Microsoft Excel was used to create figures in this chapter.

Ethics approval

The study was approved by the Human Research Ethics Committee at the Australian National University (2021/221).

Results

Between 13 January 2020 and 30 November 2021 there were 211,937 notifications of COVID-19 reported to the NNDSS (Table 1). The median age of cases notified with COVID-19 was 30 years. There was a slightly higher proportion of males (50.9%, compared to 48.7% of females). Most of the notifications were in major cities (90.7%). Most COVID-19 notifications were from populations residing in Victoria (58.4%) and New South Wales (38.5%). Ninety percent of notifications were from people in major cities in Australia. Most COVID-19 notifications (71.5%) were from local transmission and only 3.8% were from overseas.

Table 1. Overall characteristics of COVID-19 notifications reported to the National Notifiable Diseases Surveillance System in Australia, 13 January 2020 to 30 November 2021

Characteristics	Number (%), Rate of notification per 100,000 population per year
Total cases	211,937 (100.0%)
Median age	30 years
Sex	
Male	107,957 (50.9%)
Female	103,293 (48.7%)
Unknown/Undetermined/Not available	687 (0.3%)
Indigenous status	
Indigenous	8,863 (4.2%)
Non-indigenous	161,947 (76.4%)
Unknown	41,127 (19.4%)
Jurisdiction	
Australian Capital Territory	2,142 (1.0%), 250.4
New South Wales	81,608 (38.5%), 534.5
Northern Territory	291 (0.1%), 61.9
Queensland	1,948 (0.9%), 19.8
South Australia	783 (0.4%), 23.0
Tasmania	237 (0.1%), 22.1
Victoria	123,804 (58.4%), 1002.3
Western Australia	1,124 (0.5%), 21.7
Remoteness	
Major cities	192,277 (90.7%)
Inner Regional	14,720 (6.9%)
Outer Regional	2,855 (1.3%)
Remote	341 (0.2%)
Very remote	215 (0.1%)
Not available	1,529 (0.7%)
Source of Infection	
Local	151,629 (71.5%)
Overseas	8,154 (3.8%)
Under investigation	52,145 (24.6%)
Not available	9 (0.0%)

Epidemiological curve of COVID-19 notifications

COVID-19 notifications first increased due to open Australian borders in the beginning of 2020 with the ancestral strain of SARS-CoV-2, Alpha (B.1.1.7) variant. Case numbers decreased with international and jurisdictional border closures by the end of May 2020. The first period begins from 8 January 2020, where the outbreak mostly affected NSW from the end of January and this period ends 3 June 2020 where the number of cases per week reduced to < 50. The second period starts from 10 June 2020, where the number of cases in Victoria increased to more than 50 cases per week and spread until numbers reduced (< 50 cases per week in Victoria), 7 October 2020. The third period is defined from 14 October 2020 to 9 June 2021 where there was very limited transmission of SARS-CoV-2 and national weekly case numbers were below 200. The final, fourth period begins from 16 June 2021, where a new variant of concern, Delta (B.1.617.2) replaces the previously predominating Beta (B.1.351) variant and increases spread. This period ends on 23 November 2021 because of the data that was available at the time of this evaluation. From 9 November 2021, a new variant of concern, Omicron (B.1.1.529) replaces Delta (B.1.617.2). A summary of the different time periods identified in this study is in Table 2 below.

Table 2. Four time periods identified in the COVID-19 pandemic in Australia, 8 January 2020 to 30 November 2021

Time period	Timeline (week beginning)
First	8 January 2020 to 3 June 2020
Second	10 June 2020 to 7 October 2020
Third	14 October 2020 to 9 June 2021
Fourth	16 June 2021 to 23 November 2021

From 8 January 2020 to 30 November 2021, overall, there were four different epidemiological waves, three different SARS-CoV-2 strains and multiple restrictions at national and jurisdiction level to minimise the spread of SARS-CoV-2 (Figure 1). During the first period, in the early stages of the pandemic, COVID-19 notifications were reported from every jurisdiction (Figure 2). The National Cabinet focused on closing international borders and limited social gathering with the increasing number of daily

cases (Figure 2). (3) Interstate borders were also closed to control the growing number of COVID-19 cases.

The second period was marked by the large Victorian outbreak with most cases coming from Victoria and some from New South Wales (Figure 2). During this time, the Victoria was under lockdown for at least 15 weeks. The third period had the smallest wave of COVID-19 where notifications were reported from several states (Figure 1). The spread was controlled by snap lockdowns in the local area where cases were reported (Figure 1). It's important to note that the first COVID-19 vaccine was administered during this period, on 21 February 2021 (Figure 1 and 3). The final, fourth period was the largest epidemic observed in Australia since the pandemic (Figure 1 and 3). With the new variant, Delta, spread was much faster. Most COVID-19 notifications were from New South Wales and Victoria (Figure 1 and 3). There were also notable outbreaks in South Australia and the Australian Capital Territory (Figure 3). There was a low uptake of COVID-19 vaccines since the vaccine roll out, taking more than 40 weeks for more than 90% of the population > 16 years of age to receive the first dose (Figure 3). By this time 24 November 2021, the number of new cases dropped by half since the peak on 3 October 2021 (Figure 3).

Throughout the pandemic in Australia, there were strict public health and social restrictions to minimise the spread of SARS-CoV-2. In addition to interstate border closures and lockdowns, there were but not limited to: (3)

- Restrictions in the number of people in social gatherings
- Restrictions on the number of visitors to a home
- Restrictions on the number of visitors to hospitals, aged-care facilities and other at-risk settings
- Ban of outdoor and indoor events
- Closure of schools and early childhood education centres
- Restaurants only allowing takeaway and/or home delivery
- Mask wearing

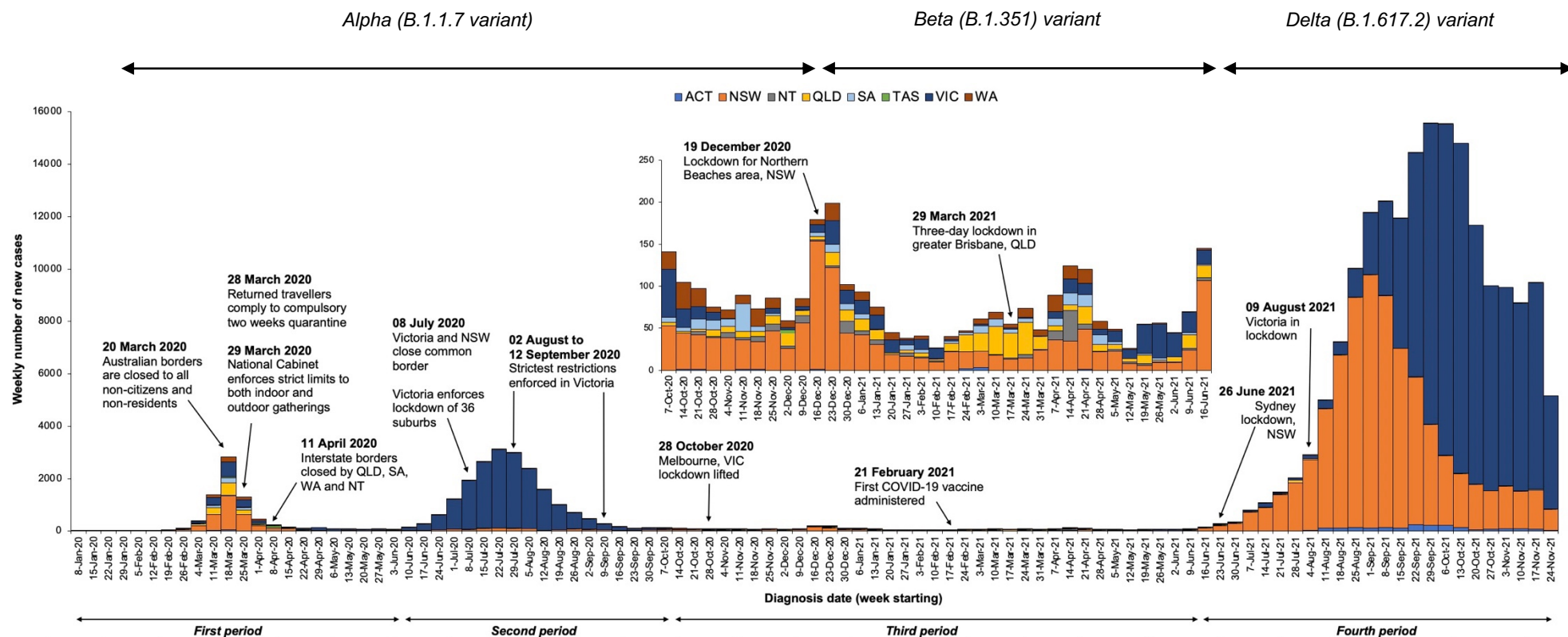


Figure 1. Epidemiological curve of weekly notifications of new COVID-19 cases by jurisdiction in Australia, with major national and jurisdictional restrictions, from 8 January 2020 to 30 November 2021

Abbreviations: ACT= Australian Capital Territory, NSW= New South Wales, NT= Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia

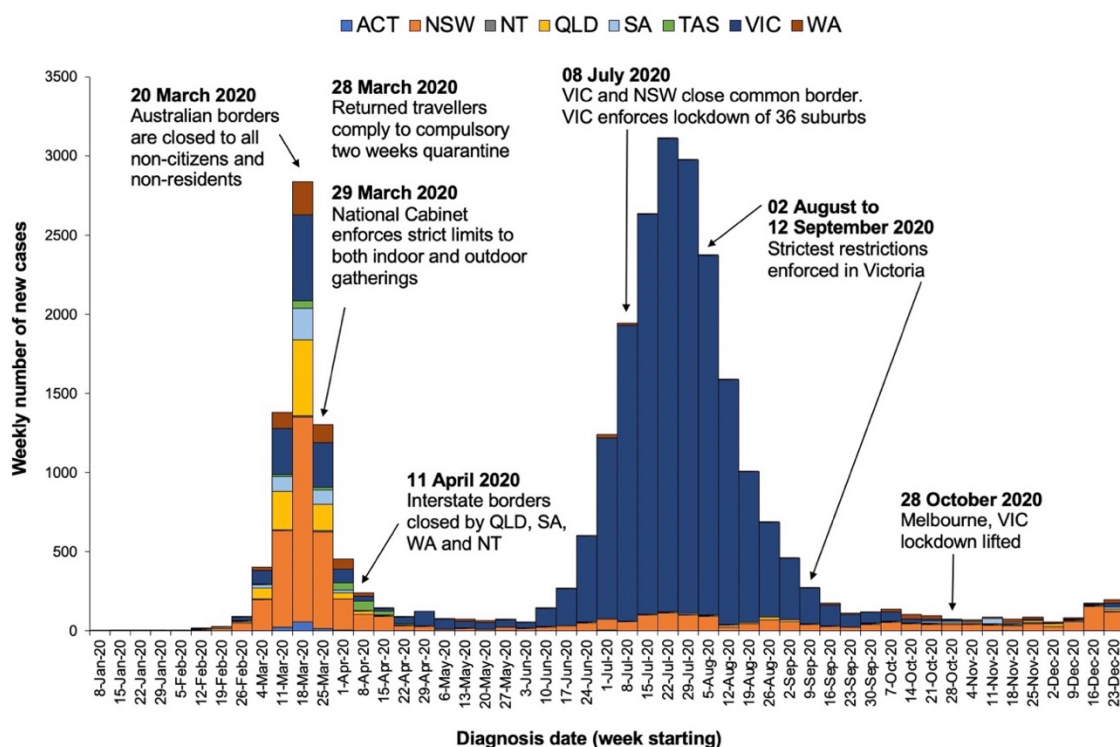


Figure 2. Epidemiological curve of weekly notifications of new COVID-19 cases by jurisdiction in Australia from 8 January 2020 to 29 December 2020 with national and interstate public health and social measures

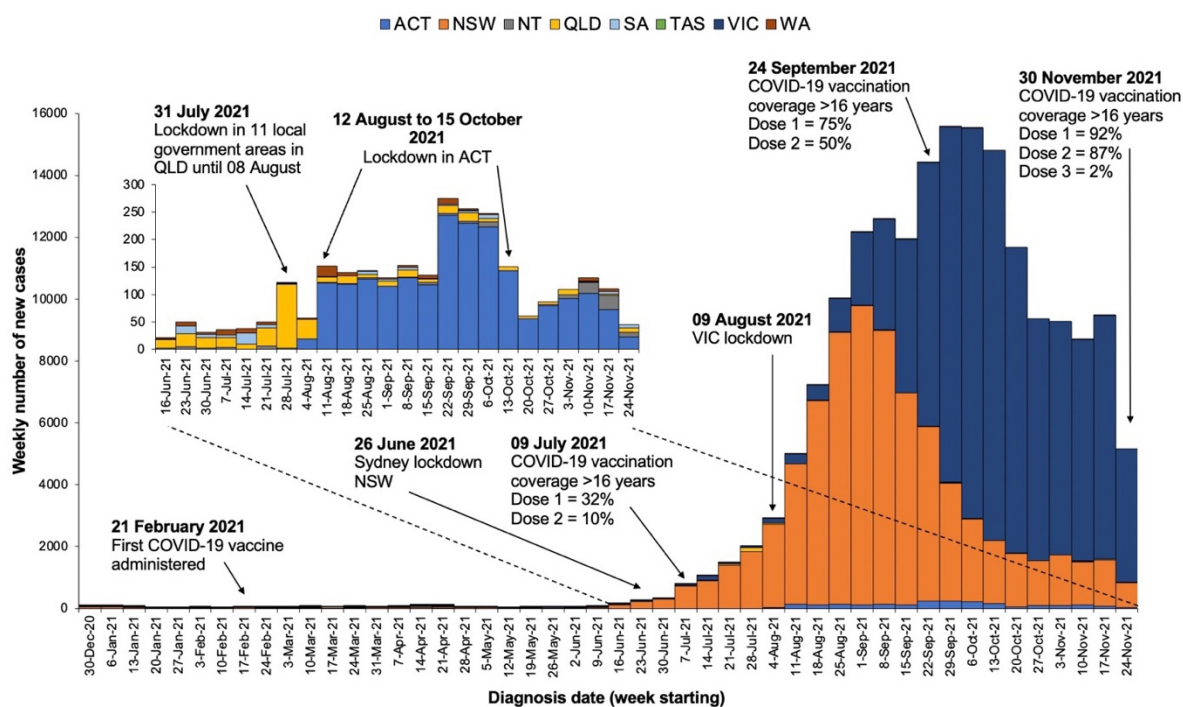


Figure 3. Epidemiological curve of weekly notifications of new COVID-19 cases by jurisdiction in Australia from 1 January 2021 to 30 November 2021 with public health and social measures, and COVID-19 vaccination national coverage of > 16 years

Abbreviations: ACT= Australian Capital Territory, NSW= New South Wales, NT= Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia

COVID-19 notifications by jurisdiction and time period

COVID-19 notification rates were distinct in each period and jurisdiction during the pandemic (Table 3). In the first period, all jurisdictions had a COVID-19 notification rate higher than 20 per 100,000 population per year. Tasmania (TAS) has the highest rate of 100.7 per 100,000 population per year and this is likely to be because of the localised outbreak of SARS-CoV-2 in the North-West Regional Hospital and comparatively smaller population of TAS. (15) NSW reported the second highest notification rate out of all the jurisdictions, 96.8 per 100,000 population per year, despite reporting the highest number of cases (n=3310) during this period. The embarkment of over 600 passengers with COVID-19 from the Ruby Princess Cruise ship in NSW on 8 March 2020 was one of the incidents increasing spread of SARS-CoV-2 in the jurisdiction and beyond. (16)

The second period was dominated by the large Victorian outbreak, where the notification rate was the highest out of all the jurisdictions, 811.7 per 100,000 population per year. This notification rate of VIC was 13 times higher than the rate in the first period. The Victorian outbreak attributed to 93.5% of national notifications. Local transmission through family gatherings and workers at an abattoir were thought to have initiated the widespread of SARS-CoV-2 in Victoria. (17) Virus transmission out of the hotel quarantine also may have contributed to the spread of SARS-CoV-2 in this time. (18) Other jurisdictions had minimal activity and low notification rates.

COVID-19 notifications rate was the lowest in the third period in all jurisdictions, except for Northern Territory (NT), where the rate was highest, 87.7 per 100,000 population per year. Although there was minimal community transmission in NT during this time, there were increasing repatriation flights into NT where passengers were found to be COVID-19 positive, contributing to a higher notification rate. (19)

The fourth period saw the highest rates of COVID-19 notifications, where the notification rate for VIC was 3443.3 per 100,000 population per year, 2506.6 per 100,000 population per year for NSW and notably 973.1 per 100,000 population per year for ACT (which is 16 times higher than the notification rate in the first

period).

Table 3. COVID-19 notification case counts and rate per 100,000 population *per year* by time period* and jurisdiction in Australia, 8 January 2020 to 30 November 2021

Jurisdiction	First period		Second period		Third period		Fourth period		Overall	
	Count	Rate	Count	Rate	Count	Rate	Count	Rate	Count	Rate
ACT	108	59.8	5	3.4	11	3.6	2018	973.1	2142	250.4
NSW	3310	96.8	1026	36.7	1164	21.5	76108	2056.6	81608	534.5
NT	29	28.1	2	2.4	146	87.7	114	100.1	291	61.9
QLD	1068	49.3	91	5.1	387	11.1	402	16.9	1948	19.8
SA	436	58.8	37	6.1	215	17.8	95	11.5	783	23.0
TAS	228	100.7	2	1.1	4	1.1	3	1.2	237	22.1
VIC	1724	61.5	18598	811.7	392	9.0	103090	3443.3	123804	1002.3
WA	592	53.1	125	13.7	307	16.7	100	8.0	1124	21.7
Total	7495	69.7	19886	226.3	2626	15.3	181930	1549.0	211937	437.4

* First period= 8 January to 9 June 2020, Second period = 10 June to 13 October 2020, Third period = 14 October 2020 to 15 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: ACT= Australian Capital Territory, NSW= New South Wales, NT= Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia

COVID-19 notifications by age-sex and time period

In the first period, the 20–29, 50–59, 60–69, and 70–79 years age groups had high rates of COVID-19 notifications, more than 80 per 100,000 population per year (Table 4). In the second period, the COVID-19 notification rate increased at least two-fold for all age groups except the 50–59, 60–69, 70–79 years age group. The notification rate in the 0–9 years age group was 12 times higher in the second period than the first period and 11 times higher for the 10–19 years age group.

The third period had the lowest rate, where all groups had a rate below 30 per 100,000 population per year. The ≥ 90 years age group had the lowest rate of 0 and 1.1 per 100,000 population per year for the male and female population respectively in the third period. The highest notification rate per 100,000 population per year was observed across all age groups in the fourth period. The age-groups with the highest notification rates were in the 0–9, 10–19 and 20–29 years, where the notification rate was over 2000 per 100,000 population per year for both the male and female population.

Table 4. COVID-19 notification rate per 100,000 population per year by age and time period* in Australia, 8 January 2020 to 30 November 2021

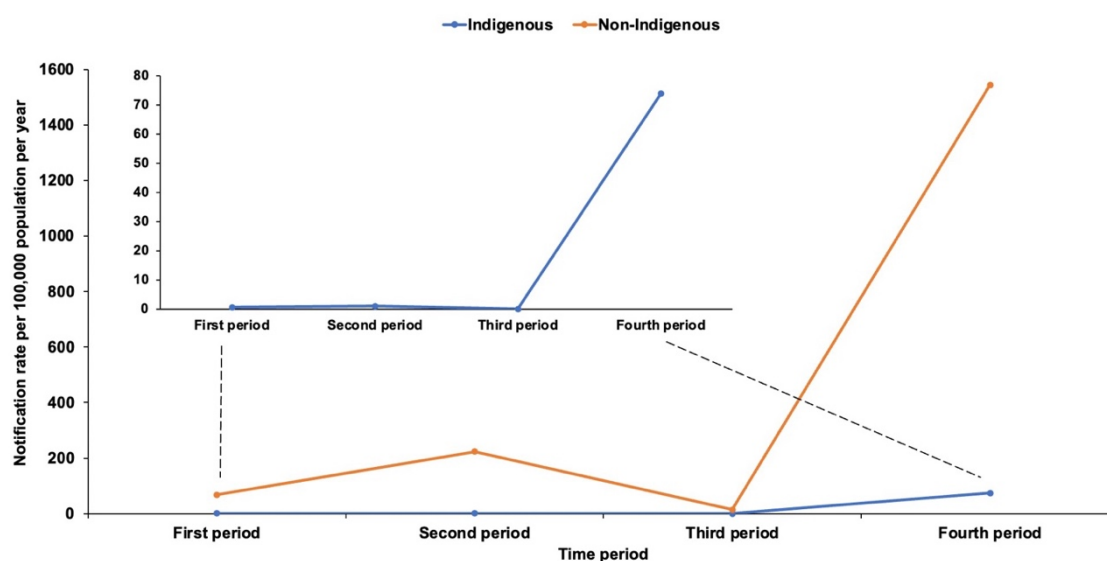
Age group (years)	Rate per 100,000 population per year				
	First period	Second period	Third period	Fourth period	Overall
0–9	9.0	116.5	12.8	2107.5	538.9
10–19	17.3	198.5	9.5	2079.5	547.2
20–29	101.9	376.8	20.3	2207.2	637.4
30–39	77.6	275.6	26.1	1791.5	510.8
40–49	69.9	221.1	18.2	1475.6	420.1
50–59	89.3	193.0	12.6	1116.1	329.6
60–69	103.2	124.8	8.8	757.0	231.6
70–79	98.3	127.6	4.7	548.2	177.9
80–89	39.8	256.3	2.4	634.7	232.0
≥ 90	60.1	1055.5	0.7	736.1	375.4
Total	68.2	223.1	14.6	1543.8	435.9

* First period= 8 January to 9 June 2020, Second period = 10 June to 13 October 2020, Third period = 14 October 2020 to 15 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: M= Male, F= Female

COVID-19 notifications in Indigenous population

The overall notification rate for the non-Indigenous population in the study period was 435.9 per 100,000 population per year. This is 18 times higher than the overall notification rate for the Indigenous population in the study period (18.2 per 100,000 population per year). The notification rate for both populations is highest in the fourth period and lowest in the third period (Figure 4). Among Indigenous people, in the fourth period, the notification rate was highest in the younger age group, 0–9 years age group (157.2 and 160.6 per 100,000 population per year in male and female populations respectively) and 10–19 years age group (143.2 and 140.3 per 100,000 population per year in male and female populations respectively) (Table 5).



* First period= 8 January to 9 June 2020, Second period = 10 June to 13 October 2020, Third period = 14 October 2020 to 15 June 2021, Fourth period = 16 June to 30 November 2021

Figure 4. COVID-19 notification rate per 100,000 population per year for Indigenous and non-Indigenous people by time period* in Australia, 8 January 2020 to 30 November 2021.

Table 5. COVID-19 notification rate per 100,000 population of Indigenous people by age-sex and time period* in Australia, 8 January 2020 to 30 November 2021.

Age group (years)	Rate per 100,000 population per year									
	First period		Second period		Third period		Fourth period		Overall	
	M	F	M	F	M	F	M	F	M	F
0–9	0.4	0.3	0.7	1.0	0.0	0.1	157.2	160.6	38.3	39.2
10–19	0.3	1.0	0.9	1.4	0.0	0.0	143.2	140.3	34.9	34.5
20–29	0.8	1.1	1.8	2.0	0.1	0.0	91.3	107.8	22.7	26.8
30–39	0.5	0.5	0.9	1.7	0.0	0.0	63.1	76.9	15.6	19.0
40–49	0.4	0.6	0.7	1.2	0.1	0.1	51.3	55.0	12.7	13.7
50–59	0.5	0.9	0.6	1.1	0.2	0.1	31.5	36.2	7.9	9.2
60–69	0.4	0.7	0.9	0.8	0.1	0.0	16.5	20.1	4.3	5.2
70–79	1.1	0.2	0.3	0.0	0.0	0.0	6.3	9.5	1.8	2.4
80–89	0.0	0.0	0.0	0.0	0.0	0.0	5.1	4.1	1.2	1.0
≥90	0.0	0.0	0.0	2.2	0.0	0.0	3.0	4.8	0.7	1.5
Total	0.5	0.6	0.9	1.2	0.1	0.0	72.4	75.3	17.8	18.6

* First period= 8 January to 3 June 2020, Second period = 10 June to 7 October 2020, Third period = 14 October 2020 to 09 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: M= Male, F= Female

Hospitalisation and case fatality ratio

COVID-19 hospitalisation rates (percentage of cases hospitalised) varied across the four different periods (Table 6). Although the rate of hospitalisation was highest in the third period (19.6%), this is because of higher proportion of hospitalisations in NT (100%) and QLD (79.8%) for infection control purposes (Table 6). In addition, in TAS, three out of four cases were hospitalised, bringing up the hospitalisation rate in the third period. When excluding hospitalisation data from NT and QLD the highest hospitalisation rate is observed in the first period (12.1%), followed closely by the second period (11.9%). Hospitalisation rate is lowest in the third period (2.8%) and then the fourth period (8.7%). The trends in hospitalisation rate in the different periods mostly reflect trends in case numbers. However, the hospitalisation rate in the fourth period was unexpectedly the lowest, considering that the risk of hospital admission with the Delta variant was twice the Alpha variant. (20) The NNDSS may have not picked up all COVID-19 hospitalisations during the fourth period because of high surges of hospitalisations and delays with data entry.

Hospitalisation rate was consistently highest in the ≥ 70 years population across all periods (Table 7). In the third period, hospitalisation rate was at least twice as higher in the 0–9, 10–19, 20–29, and 30–39 years age groups compared to the other periods. This could be because restrictions eased during this time and the younger population were more mobile. It is important to note that in the fourth period, the hospitalisation rate due in the ≥ 70 years population was lower than the other periods. Vaccination is likely to have had an impact in reducing hospitalisation in older age groups. (Note: In the third period, the 100% hospitalisation rate in the ≥ 90 years age group is from the one female case that was hospitalised. South Australia did not report any hospitalisations during this time.)

Table 6. COVID-19 hospitalisation counts and rate (percentage of cases hospitalised) by jurisdiction and time period* in Australia, 8 January 2020 to 30 November 2021

	COVID-19 hospitalisation counts and rate (%)							
	First period		Second period		Third period		Fourth period	
Jurisdiction	Count	Rate	Count	Rate	Count	Rate	Count	Rate
ACT	16	14.8	0	0.0	0	0.0	130	6.4
NSW	400	12.1	64	6.2	28	2.4	10222	13.4
NT	29	100	2	100	146	100	101	88.6
QLD	323	30.2	52	57.1	309	79.8	251	62.4
SA	-	-	-	-	-	-	-	-
TAS	42	18.4	2	100	3	75.0	0	0.0
VIC	199	11.5	2288	12.3	17	4.3	5494	5.3
WA	119	20.1	3	2.4	11	3.6	12	12.0
Total	1128	15.1	2411	12.1	514	19.6	16210	8.9

* First period= 8 January to 3 June 2020, Second period = 10 June to 7 October 2020, Third period = 14 October 2020 to 09 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: ACT= Australian Capital Territory, NSW= New South Wales, NT= Northern Territory, QLD= Queensland, SA= South Australia, TAS= Tasmania, VIC= Victoria, WA= Western Australia

Table 7. COVID-19 hospitalisation rate (percentage of cases hospitalised) by age-sex and time period* in Australia, 8 January 2020 to 30 November 2021

Age group (years)	First period		Second period		Third period		Fourth period		Overall	
	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)
0–9	9.7	7.0	3.3	2.7	21.6	17.2	2.5	2.2	2.7	2.3
10–19	7.0	5.5	0.9	1.5	16.8	5.6	2.4	3.2	2.4	3.2
20–29	5.0	6.3	2.6	3.8	21.4	13.7	5.0	7.5	4.9	7.1
30–39	9.8	11.9	4.0	5.2	20.3	22.7	7.7	9.3	7.7	9.2
40–49	12.6	12.1	9.3	7.0	25.0	12.7	11.4	10.8	11.5	10.4
50–59	16.2	15.2	15.5	10.0	22.6	28.2	15.1	14.4	15.3	14.1
60–69	20.5	19.8	28.5	21.0	26.7	19.7	22.5	20.5	22.9	20.5
70–79	31.7	25.6	48.0	45.4	34.3	30.8	32.9	30.9	34.6	32.2
80–89	52.3	46.2	59.1	51.0	57.1	57.1	49.5	41.1	51.8	44.5
≥ 90	52.4	36.7	54.3	42.1	0	100.0	51.2	37.9	52.6	40.1
Total	15.8	14.6	11.8	12.4	22.5	18.2	8.6	9.2	9.3	9.8

* First period= 8 January to 3 June 2020, Second period = 10 June to 7 October 2020, Third period = 14 October 2020 to 9 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: M= Male, F= Female

CFR was highest in the ≥ 90 years age, ranging from 17.2% to 51.0% across the four periods (Table 8). In the third period there was only one death reported in a male in the 80–89 years age group. Out of the four periods, CFR was highest in the second period. CFR was generally higher in males than females. The overall CFR throughout the four periods was 1.0% for males and 0.9% for females.

Table 8. Case fatality ratio (proportion of COVID-19 deaths out of cases) of COVID-19 by age-sex and time period* in Australia, 8 January 2020 to 30 November 2021

Age group (years)	First period		Second period		Third period		Fourth period		Overall	
	M	F	M	F	M	F	M	F	M	F
0–9	0	0	0	0	0	0	0	0	0	0
10–19	0	0	0	0	0	0	0	0	0	0
20–29	0	0	0	0	0	0	0	0	0	0
30–39	0	0	0.1	0	0	0	0.1	0	0.1	0
40–49	0	0	0.1	0	0	0	0.2	0.1	0.2	0.1
50–59	0	0	0.9	0.4	0	0	0.8	0.5	0.7	0.4
60–69	1.5	0.7	3.1	1.3	0	0	2.5	1.2	2.4	1.1
70–79	4.4	3.5	19.7	10.9	0	0	7.0	4.5	8.1	5.2
80–89	18.0	18.7	42.5	26.1	14.3	0	16.7	10.4	22.6	15.8
≥90	42.9	36.7	51.0	36.2	0	0	24.8	17.2	37.1	27.5
Total	1.5	1.2	4.0	4.1	0	0	0.7	0.5	1.0	0.9

* First period= 8 January to 3 June 2020, Second period = 10 June to 7 October 2020, Third period = 14 October 2020 to 9 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: M= Male, F= Female

Remoteness

For most of 2020 and 2021, there were extremely low rates of COVID-19 notifications in remote Australia. However, in the fourth period, the rate of COVID-19 notifications from very remote and remote areas increased by a factor of 200 from previous periods where rates were low as 0.02 notifications per 100,000 population per year (Table 9).

Table 9. COVID-19 notification rate per 100,000 population per year for populations living in remote and very remote areas by age-sex and time period* in Australia, 8 January 2020 to 30 November 2021.

Age group (years)	Rate per 100,000 population per year									
	First period		Second period		Third period		Fourth period		Overall	
	M	F	M	F	M	F	M	F	M	F
0–9	0.00	0.00	0.00	0.00	0.00	0.07	8.03	11.23	1.95	2.76
10–19	0.00	0.16	0.00	0.00	0.00	0.00	6.16	6.54	1.49	1.62
20–29	0.13	0.54	0.16	0.00	0.11	0.00	5.73	6.21	1.51	1.63
30–39	0.51	0.51	0.00	0.00	0.11	0.00	4.80	4.15	1.33	1.12
40–49	0.44	0.43	0.00	0.00	0.06	0.06	2.95	2.75	0.84	0.79
50–59	0.78	0.60	0.00	0.00	0.00	0.00	2.95	2.32	0.89	0.69
60–69	0.37	0.51	0.00	0.00	0.15	0.07	1.32	1.85	0.48	0.60
70–79	0.26	0.00	0.00	0.00	0.00	0.00	0.46	1.51	0.17	0.37
80–89	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.45	0.14	0.11
≥ 90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.30	0.34	0.00	0.00	0.05	0.02	4.20	4.48	1.12	1.18

* First period= 8 January to 3 June 2020, Second period = 10 June to 7 October 2020, Third period = 14 October 2020 to 9 June 2021, Fourth period = 16 June to 30 November 2021

Abbreviations: M= Male, F= Female

Discussion

First period

In the first period (13 January 2020 to 09 June 2020), initial international importation of SARS-CoV-2 introduced outbreaks across all jurisdictions in Australia. With rising case numbers, the Australian Government responded and developed a public health response. The major intervention implemented was closing of international borders to non-citizens and residents on 20 March 2020 and national level restrictions on gatherings of people on 29 March 2020. (3) This maximum suppression strategy, with other measures, such as contact tracing and isolation, testing and quarantine at borders, and travel restrictions allowed to curb transmission of SARS-CoV-2. (21, 22) Our analysis showed that in about one month after implementing restrictions, case numbers reduced. The early PHSM were effective in controlling virus, helping to buy time to strengthen health systems and for vaccine development. (22)

Second period

The large outbreak in Victoria, in the second period, from 10 June 2020 to 07 October 2020, attributed to 93.5% of national notifications. During the Victorian outbreak, VIC implemented one of the world's strictest lockdowns at that point in time, including restricting movement to within 5km, applying a curfew and mandatory mask wearing indoors. (23) The restrictions slowed down the spread of SARS-CoV-2 and ultimately curbed the Victorian outbreak. Hospitalisation rate and CFR was highest for the ≥ 70 years age group than any other period. This is because of the high transmission of SARS-CoV-2 in aged care facilities, where from January to October 2020 in VIC, there were 125 aged care facilities with SARS-CoV-2 transmission. (24) Poor infection control, lack of support and poor management of staff and residents in aged care facilities escalated the widespread of SARS-CoV-2 in elderly and across VIC. (17) Attention to funding, staff support, and increased supply of protective gear would have improved the situation in aged care residential settings.

Third period

There was limited transmission of SARS-CoV-2 across Australia in the third period (from 14 October 2020 to 9 June 2021). The national COVID-19 vaccine rollout began in the third period, from 21 February 2021. However, there was initially low vaccination coverage. This was because of the heavy reliance on the Oxford-AstraZeneca vaccine, as well as vaccine hesitancy related to thrombosis with thrombocytopenia. (25) With this rare side effect, the Australian Technical Advisory Group on Immunisation (ATAGI) recommended that the Pfizer-BioNTech vaccine was preferred over Oxford-AstraZeneca vaccine in adults under 50 years. (26) Only by 9 July 2021 (in the fourth period), vaccination for dose 1 reached over 30% for the > 16 years population in Australia. (27) However, not all recommended groups were vaccinated, and non-priority groups did not have access to COVID-19 vaccines. In the third period, COVID-19 vaccination had limited impact in reducing overall hospitalisation. But CFR was lowest in this period, indicating that vaccination may have been successful in protecting older age group as well as better control of outbreaks in aged care settings.

Fourth period

The fourth period, from 16 June 2021 to 30 November 2021 was when the new, more infectious, and virulent Delta (B.1.617.2) variant dominated Australia. With limited lockdown measures in Sydney, NSW, a small outbreak of the Delta variant in mid-June, caused the virus to spread across Australia and New Zealand. (25) Strict public health control measures, including lockdowns could not contain the virus. Therefore, rather than suppressing the virus through public health and social measures (including contact tracing, lock downs timely PCR testing), the strategy shifted to vaccination. (25) The younger age groups 0–9, 10–19 and 20–29 years had highest notification rates (over 2000 per 100,000 population per year). This is because the Delta variant affected younger populations which previous variants had not. Younger populations with medical conditions and many children were hospitalised due to social reasons during this time. (28) The younger population were also prioritised much later in the national vaccine rollout. Also, the Pfizer vaccine was approved by the Therapeutic Goods Administration

on 27 August 2021 for use in adolescents 12–15 years of age, delaying protection in the younger population. (29)

However, populations ≥ 70 years had the lowest notification rate, hospitalisation, and CFR than the first and second period. By this time, this age-group was achieving high vaccination coverage. By the end of August 2021 (halfway through the fourth period), 58.7% and 35.0% of people > 16 years had received dose 1 and 2 of COVID-19 vaccines, respectively. (27) Whereas 87.4% and 62.9% of adults ≥ 70 years had received dose 1 and dose 2, respectively. (30) Although the Delta variant was found to cause more severe outcomes, including increased risk for hospitalisation and death than previous strains vaccination did protect older adults in this period. (31-33)

Indigenous people and people living in remote areas were only affected by COVID-19 in the fourth period. This is likely due to a combination of less effective PHSM, the high transmissibility of Delta and moderate vaccination coverage in remote communities.

Limitations

There are several limitations to this study regarding data. The NNDSS is a national dataset that collects data from jurisdictions, meaning the data completeness and quality is dependent on the jurisdiction. However, variables such as postcode, source of infection, and Indigenous status was not well completed and missing. There were many unknown data points for hospitalised and died variables too. Study results therefore should be interpreted carefully.

Two jurisdictions, QLD and NT used hospitalisation for infection control purposes. Therefore, hospitalisation rates in these jurisdictions in the overall figures could be an over-estimate (see Table 6). There is variability in how the severity data could be interpreted. This study did not use other data sources to compare COVID-19 hospitalisations and deaths.

Another limitation is with detecting the true number of COVID-19 cases. Throughout the pandemic, only COVID-19 cases with a laboratory diagnosis

were reported to the NNDSS. Any cases that were not tested would not be counted in our study. From 1 November 2021, rapid antigen-tests (RATs) became approved in Australia. (34) However, any self-reported COVID-19 cases using rapid antigen-tests were not reported to the NNDSS for our study period and we may have missed RAT-diagnosed COVID-19 cases in the month of November 2021.

Conclusion

Australia effectively used PHSM in 2020 to control the transmission of SARS-CoV-2 in 2020. The older population was most affected during the VIC outbreak. The low COVID-19 vaccination coverage impacted the younger population during the second half of 2021. But vaccination in older populations helped to lower hospitalisation rates during the Delta (B.1.617.2) outbreak.

The COVID-19 pandemic continues in Australia, and national notification rates have increased even more rapidly with the more infectious Omicron (B.1.1.529) variant since mid-November 2021. Australia is now living with minimal PHSM, and the focus is on minimising severity of disease. Continual analysis of notification data, surveillance of COVID-19 hospitalisations, monitoring vaccination coverage, and use of other data sources would help to better interpret COVID-19 notification trends in Australia.

References

1. Australian Government. Department of Health. 2019-nCoV acute respiratory disease, Australia Epidemiology Report: Reporting week 26 January – 1 February 2020. Commun Dis Intell, 2020; 44. [Available from: [https://www1.health.gov.au/internet/main/publishing.nsf/Content/C50CAE02452A48A7CA2587320081F7BF/\\$File/2019_ncov_acute_respiratory_disease_epidemiology_report_1_reporting_week_26_january_2020.pdf](https://www1.health.gov.au/internet/main/publishing.nsf/Content/C50CAE02452A48A7CA2587320081F7BF/$File/2019_ncov_acute_respiratory_disease_epidemiology_report_1_reporting_week_26_january_2020.pdf)]
2. Commonwealth Government: Department of Health. Government response to the COVID-19 outbreak 2021. 2021.
3. Campbell K, & Vines, E,. COVID-19: a chronology of Australian Government announcements (up until 30 June 2020) 2021 [Available from: https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp2021/Chronologies/COVID-19AustralianGovernmentAnnouncements]
4. Food and Drug Administration. FDA Takes Key Action in Fight Against COVID-19 By Issuing Emergency Use Authorization for First COVID-19 Vaccine. [Available from: <https://www.fda.gov/news-events/press-announcements/fda-takes-key-action-fight-against-covid-19-issuing-emergency-use-authorization-first-covid-19>]
5. Commonwealth of Australia. Department of Health and Aged Care. Australia's vaccine agreements. [Available from: [https://www.health.gov.au/our-work/covid-19-vaccines/about-rollout/vaccine-agreements#:~:text=Comirnaty%20\(Pfizer\),-As%20part%20of&text=The%20TGA%20provisionally%20approved%20the,product%20on%2013%20July%202023.](https://www.health.gov.au/our-work/covid-19-vaccines/about-rollout/vaccine-agreements#:~:text=Comirnaty%20(Pfizer),-As%20part%20of&text=The%20TGA%20provisionally%20approved%20the,product%20on%2013%20July%202023.)]
6. Australian Government. Priority groups for COVID-19 Vaccination Program: Phase 1B. [Available from: https://www.health.gov.au/sites/default/files/documents/2021/03/priority-groups-for-covid-19-vaccination-program-phase-1b_1.pdf]
7. Commonwealth of Australia. Coronavirus disease 2019 (COVID-19) epidemiology reports, Australia, 2020–2022. [Available from: https://www1.health.gov.au/internet/main/publishing.nsf/Content/novel_coronavirus_2019_ncov_weekly_epidemiology_reports_australia_2020.htm]
8. NSW Government. COVID-19 weekly surveillance reports. 2021 [Available from: <https://www.health.nsw.gov.au/Infectious/covid-19/Pages/weekly-reports.aspx>]
9. Queensland Government. Queensland COVID-19 statistics. 2021 [Available from: <https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics>]

10. State Government of Victoria. Victorian coronavirus (COVID-19) data 2021 [Available from: <https://www.dhhs.vic.gov.au/victorian-coronavirus-covid-19-data>]
11. Australian Government. Coronavirus Disease 2019 (COVID-19) CDNA National Guidelines for Public Health Units (version 4.7). In: Department of Health. 24 June 2021. [Available from: <https://www.health.gov.au/resources/publications/coronavirus-covid-19-cdna-national-guidelines-for-public-health-units>]
12. Australian Bureau of Statistics. National, state and territory population tables, March 2022 [Available from: <https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release#data-downloads-data-cubes>]
13. Australian Bureau of Statistics. Remoteness Structure 2016 [Available from: <https://www.abs.gov.au/statistics/statistical-geography/remoteness-structure>]
14. Australian Bureau of Statistics. Australian Statistical Geography Standard: Correspondence, 2017 Postcode to 2016 Remoteness Area 2018 [Available from: <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.005July%202016?OpenDocument>]
15. Government of Tasmania. COVID-19 North West Regional Hospital Outbreak - Interim Report. Department of Health; 29 April 2020. [Available from: https://doh.health.tas.gov.au/_data/assets/pdf_file/0006/401010/North-West-Regional-Hospital-Outbreak-Interim-Report.pdf]
16. New South Wales Government. Special Commission of the Inquiry into the Ruby Princess. 2020 14 August 2020. [Available from: <https://apo.org.au/node/307566>]
17. BBC News. Coronavirus: Why has Melbourne's outbreak worsened? 2020 [Available from: <https://www.bbc.com/news/world-australia-53259356>]
18. Davey DA, G., . A foreseeable catastrophe: how Covid-19 swept through Victoria's nursing homes. The Guardian. 2020. [Available from: <https://www.theguardian.com/australia-news/2020/jul/29/a-foreseeable-catastrophe-how-covid-19-swept-through-victorias-nursing-homes>]
19. Doyle M. COVID: NT records six new coronavirus cases from Indian repatriation flight – as it happened. ABD News. 2021. [Available from: <https://www.abc.net.au/news/2021-04-17/coronavirus-blog-india-flight-six-new-cases-nt/100075822>]
20. Abu-Raddad LJ, Chemaitelly H, Butt AA, National Study Group for C-V. Effectiveness of the BNT162b2 Covid-19 Vaccine against the B.1.1.7 and B.1.351 Variants. N Engl J Med. 2021;385(2):187-9.
21. Basseal JM, Bennett CM, Collignon P, Currie BJ, Durrheim DN, Leask J, et al. Key lessons from the COVID-19 public health response in Australia. Lancet Reg Health West Pac. 2022:100616.

22. De Foo C, Grepin KA, Cook AR, Hsu LY, Bartos M, Singh S, et al. Navigating from SARS-CoV-2 elimination to endemicity in Australia, Hong Kong, New Zealand, and Singapore. *Lancet*. 2021;398(10311):1547-51.
23. McCosker L. Reflections on one of the world's harshest COVID-19 lockdowns, and on the possibility of eliminating COVID-19 in Australia. *HPHR*. 2021;29.
24. Australian Government. COVID-19 outbreaks in Australian residential aged care facilities. Department of Health; 2020. [Available from: https://www.health.gov.au/sites/default/files/documents/2020/10/covid-19-outbreaks-in-australian-residential-aged-care-facilities-23-october-2020_0.pdf]
25. Kenyon G. Australia's struggle with the delta variant. *Lancet Infect Dis*. 2021;21(10):1358.
26. Australian Government: Department of Health and Aged Care. ATAGI statement on AstraZeneca vaccine in response to new vaccine safety concerns 2021 [Available from: <https://www.health.gov.au/news/atagi-statement-on-astrazeneca-vaccine-in-response-to-new-vaccine-safety-concerns>]
27. Ting I, Shatoba, K. & Palmer, A. Charting Australia's COVID vaccine rollout 2022 [Available from: <https://www.abc.net.au/news/2021-03-02/charting-australias-covid-vaccine-rollout/13197518>]
28. Williams P, Koirala A, Saravanos GL, Lopez LK, Glover C, Sharma K, et al. COVID-19 in New South Wales children during 2021: severity and clinical spectrum. *Med J Aust*. 2022;217(6):303-10.
29. Australian Government. ATAGI statement on the use of COVID-19 vaccines in all young adolescents in Australia. 2021 [Available from: <https://www.health.gov.au/news/atagi-statement-on-the-use-of-covid-19-vaccines-in-all-young-adolescents-in-australia>]
30. Australian Government: Operation COVID Shield. COVID-19 Vaccine Roll-out 2021 [Available from: <https://www.health.gov.au/sites/default/files/documents/2021/08/covid-19-vaccine-rollout-update-31-august-2021.pdf>]
31. Bager P, Wohlfahrt J, Rasmussen M, Albertsen M, Krause TG. Hospitalisation associated with SARS-CoV-2 delta variant in Denmark. *Lancet Infect Dis*. 2021;21(10):1351.
32. Fisman DN, Tuite AR. Evaluation of the relative virulence of novel SARS-CoV-2 variants: a retrospective cohort study in Ontario, Canada. *CMAJ*. 2021;193(42):E1619-E25.
33. Twohig KA, Nyberg T, Zaidi A, Thelwall S, Sinnathamby MA, Aliabadi S, et al. Hospital admission and emergency care attendance risk for SARS-CoV-2 delta (B.1.617.2) compared with alpha (B.1.1.7) variants of concern: a cohort study. *Lancet Infect Dis*. 2022;22(1):35-42.
34. Commonwealth of Australia. COVID-19 rapid antigen self-tests that are approved in Australia 2022 [Available from:

<https://www.tga.gov.au/products/covid-19/covid-19-tests/covid-19-rapid-antigen-self-tests-home-use/covid-19-rapid-antigen-self-tests-are-approved-australia>]

Chapter 5

Design and conduct an epidemiological study

Assessing the association between socio-economic status and invasive meningococcal disease in Australia, 2010–2020

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Preface

Background

In late 2021, I was informed about an interesting project on investigating the association between invasive meningococcal disease (IMD) and socio-economic status (SES). The former Director of the National Centre for Immunisation Research and Surveillance (NCIRS) was aware that New Zealand (NZ) was conducting a similar study (unpublished) and suggested an investigation in the context of Australia. I have always been keen on understanding and researching the social determinants of health to improve population health. I thought this project would be a great opportunity to develop knowledge of Australia's measure of SES and understand IMD. Prior to this project, I had minimal understanding of IMD and only had knowledge about the recent policy changes for meningococcal B vaccination on National Immunisation Program (NIP). Therefore, I chose to conduct a literature review on prior studies that investigated the association between SES and IMD.

My role

My role in this project included drafting a concept note, completing the Australian National University (ANU) Human Research Ethics Committee (HREC) ethics submission, submitting data request to the National Notifiable Diseases Surveillance System (NNDSS). I was then responsible for undertaking a literature review, cleaning, and analysing data and the write up of this chapter.

Lessons learnt

In a short time, I learnt about the epidemiology of IMD globally and in Australia. I came to understand what age-groups and what serogroups were prevalent in Australia. I learnt the various risk factors for IMD through the literature review. I also learnt about the NIP in terms of IMD vaccination.

My major learning was in SES. Growing up in NZ, I knew of the NZ Deprivation Index to measure SES. With the literature review, I also discovered and learnt about the SES measure in the United Kingdom (UK) and found there was no universal way of capturing SES – although similar factors are included in these indexes. I developed an

understanding of the Australian Socio-Economic Indexes for Areas (SEIFA) and became familiar with the Index of Relative Socio-economic Disadvantage (IRSD) to measure the level of disadvantage.

Public health impact

I investigated and developed the use of SEIFA and the IRSD to assess SES relating to notifiable vaccine preventable diseases in Australia and produced the first analysis method for IMD. The methods I used can be broadly used for other vaccine preventable diseases in Australia and help better understand the epidemiology, allowing for identification of risk groups, and potentially recommendations which can be used to advocate for funding for vaccination.

The study findings also highlight the importance of targeting age-groups for serogroup B specific IMD. The analysis provides evidence that specific age groups, such as the 2–4 years group should be prioritised for funding for NIP IMD vaccination.

MAE competencies addressed

- Plan and conduct an epidemiological study
- Analysis of a public health dataset
- Conduct a targeted literature review

Acknowledgements

My sincere thanks go to Frank Beard and Stephen Lambert for their sharp eye for detail when I developed the concept note. Thank you to Tambri Housen, Helen Quinn and Alexis Pillsbury for your comments also. All your feedback and comments helped me to shape a clear and detailed concept note that later made it easier for me to conduct my project. Thank you to Alice Richardson for checking my analysis strategy and helping me understand multivariable statistical analysis. Special thanks to Stephen for his commitment to provide timely comments for this chapter and being available for me. Thank you, Frank and Peter who helped me to make the finishing touches for this chapter.

Abstract

Background

Invasive meningococcal disease (IMD) is a rare but serious condition caused by *Neisseria meningitidis*. A range of risk factors, primarily age and pre-existing medical conditions, are known to be associated with IMD, but the association between residence in areas of low socio-economic status (SES) as a proxy for individual risk has been less studied. This study aimed to examine the strength of association between residence in low SES areas and IMD in Australia, 2010–2020. Serogroup B was closely studied as meningococcal B vaccine is a non-funded vaccine for populations living in low SES areas and this study has potential for policy considerations.

Methods

A retrospective descriptive secondary analysis of IMD notification data (2010–2020) from the National Notifiable Diseases Surveillance System (NNDSS) was conducted. Using the postcode of residence recorded in NNDSS, the associated socio-economic indexes for area (SEIFA) of the index of relative socio-economic disadvantage (IRSD) decile were matched to each case. We used Pearson's chi-square test to determine the statistical significance between serogroup and SES index and logistic regression to model if serogroup B notifications are more likely to arise from areas with lower SES.

Results

A higher proportion of cases in the youngest decade (0–9 years) were living in the lowest SES quintile, and among those < 5 years, there was a significant relationship gradient for serogroup B notifications by socio-economic index decile. Across all age groups, there was no significant association between serogroup B IMD and SES but in a logistic regression analysis, age, Aboriginal and/or Torres Strait Islander status and jurisdiction were important predictors for a higher serogroup B IMD incidence. The odds of IMD notification being serogroup B in the 2–4-year age group were five-fold higher than other serogroups.

Conclusions

Although there was no direct association between serogroup B IMD notification and SES, we found that the 2–4-year age group was an important predictor for serogroup B notification. National vaccination strategies and policies should target this age group to reduce meningococcal B disease in Australia.

Introduction

Invasive meningococcal disease

Invasive meningococcal disease (IMD) is a rare but serious condition. Meningococcal bacteria, *Neisseria meningitidis* invade the body from the throat or nose resulting in a range of clinical syndromes, most commonly meningitis and septicaemia. (1, 2) About one in ten people are “carriers” of this bacteria in their throat or nose but do not become ill. (2) Transmission of meningococcal bacteria follows prolonged close contact with a carrier. Types of contact can include living in the same household, living in close quarters and intimate contact. Smokers have increased carriage rates, which may increase transmission. (3) In about 5–10% of IMD patients die within 48 hours even after receiving treatment. (4) Long-term sequelae have been reported in 10–20% of survivors (4). Sequelae (physical, neurologic and psychological) include amputations, skin scars, hearing loss, anxiety, learning difficulties, emotional and behavioural difficulties. (4)

There are 12 serogroups of meningococcal bacteria, but the most infections are caused by A, B, C, X, Y or W serogroups. (5) In Australia, the IMD notification rate was 0.3 cases per 100,000 population per year in 2021. (6) In the United States (US), a higher incidence rate of 0.11 per 100,000 population per year in 2019 was reported. A much higher rate was reported in the United Kingdom (UK), reporting 1 per 100,000 population per year in the period 2019–2020. (8) New Zealand reported the highest notification rate of 2.3 per 100,000 population per year between the 1 January and 30 September 2019. (9)

Overall, global incidence of IMD has reduced due to vaccination but more recent reductions are likely to be because of public health measures implemented during the COVID-19 pandemic. (6, 8, 11) In the US, the rate of meningococcal disease has reduced from 0.12 per 100,000 population per year in 2015 to 0.06 per 100,000 population per year in 2021 (10). The UK has also reported a lower incidence over the years from 1.61 per 100,000 population per year in 2010 to 1.17 per 100,000 per year in 2018 (11). Australia has experienced a decline from 3.5 per 100,000 population per year in 2002 to 0.3 cases per 100,000 population per year in 2021. (6)

In Australia, there is a bimodal age distribution for IMD. Infection is most commonly observed in children <2 years old and in adolescents 15–19 years old. (12) In the US, the highest incidence rates of IMD were in the 0–4 years, young adults 15–19 years, 20–24 years and adults >80 years in the past decade. (7) Similarly to the US and Australia, IMD was observed in the younger age groups and adolescents in the UK. (8) In NZ, the highest number of cases were reported in the <1 year and 1–4 year age groups in 2019. (9)

In Australia, UK and NZ, serogroup B was the major cause of IMD in children, adolescents, and young adults, (8-9,12) whereas in the US in 2019, serogroup C accounted for almost as many cases (22.7% vs 26.4%). (13)

Invasive meningococcal disease and vaccination in Australia

Before the introduction of meningococcal C vaccine in 2003, IMD notifications in Australia were predominantly serogroup B and serogroup C. (14) From the 1990s, IMD notifications steadily increased and peaked in 2002 with 3.5 cases per 100,000 population per year (14), where most disease was caused by serogroup B (63%) or serogroup C (41%). (15). When meningococcal C vaccine was introduced onto the NIP in 2003, resulting in a decline in the number of IMD notifications. (1) There was a substantial reduction in IMD caused by serogroups B and C between 2003 and 2013. From 2013, there has been an increase in meningococcal serogroup W and Y. (16) From 2017, Australian jurisdictions implemented a Meningococcal ACWY (Men ACWY) vaccination program for adolescents to manage increasing cases. In 2018, Men ACWY vaccine was introduced to the NIP for toddlers aged 12 months. (17)

The multicomponent recombinant meningococcal B (MenB) vaccine has been available through private prescription since 2014. The vaccine is recommended for various at-risk groups. (18) In 2018, the NIP recommended the MenB vaccine NIP for Aboriginal and Torres Strait Islander people aged 2 months to 19 years, adolescents and young adults aged 20–24 years who live in close quarters, and adolescents and young adults aged 20–24 years who are current smokers. (18) However, the vaccine is not funded for these groups.

The MenB vaccine is a relatively expensive vaccine and not easily accessible. After evidence that Aboriginal and Torres Strait Islander children under 2 years of age are 4 times more at risk of getting MenB than non-Indigenous children, in 2020, the MenB vaccine became NIP funded for this group and other high-risk groups on the NIP. (20) The high-risk groups include all people with asplenia, hyposplenia, complement deficiency and those undergoing treatment with eculizumab. (19)

In 2020, there were 90 notifications of IMD reported to the NNDSS in Australia. (6) This is the lowest number documented since the inception of NNDSS in 1991. Of these 90 notifications, serogroup B accounted for 64% of infections. (6). Targeting risk groups that are more likely to acquire IMD, particularly serogroup B is necessary to reduce notifications and help improve recommendations on the NIP.

There are many risk factors associated with IMD in the global literature, including: younger age, smoking, living in close quarters, being of indigenous origin, medical risk factors, and low SES. (21-28) A recent paper on meningococcal vaccination coverage in Australia included socio-economic measures such as the socioeconomic indexes for area (SEIFA) of the index of relative socioeconomic advantage and disadvantage (IRSAD) quintile as financial barriers are preventing people from being vaccinated. (29) Another study in Australia reported how people most at risk from meningococcal B disease, including Aboriginal children and children from crowded households are often associated with lower SES but less likely to have access to vaccination. (30)

The Australian NIP doesn't recommend the MenB vaccine for people with low SES. Prior studies in the UK have found living in areas of low SES increased the risk by up to 2.6 times for IMD. (23, 26, 28, 31, 32) Details of these studies are in the results section of this chapter. No epidemiological studies on SES and IMD have been conducted in Australia. It is important to understand if low SES is a risk factor for IMD in Australia to include new risk groups to the NIP meningococcal vaccine recommendation and potentially NIP funded.

Methods

This epidemiological study included a literature review and an analysis of IMD notification data from the NNDSS by SES. The aim of this work was to investigate if there was an association between IMD and SES in Australia from 2010 to 2020.

Literature review

I undertook a literature review to identify previous studies on exploring an association with IMD and SES. A focussed review of the published literature was conducted using the MEDLINE search database. The research question for the literature review was “What is the association between meningococcal disease and socio-economic factors?”

A combination of Medical Subject Heading (MeSH) terms and corresponding text words were used to answer the research question and ensure all possibilities around socio-economic factors was captured. MESH terms used included: '*Neisseria meningitidis*', 'Meningococcal Infections', 'Socioeconomic Factors', 'Geography, Medical', 'Rural Population', 'Indigenous Peoples', 'Oceanic Ancestry Group', 'Indians, North American' and 'Inuits'. Text word terms used included: 'meningococc\$', 'socioeconomic\$', 'geograph\$', 'remote\$', 'rural\$', 'aborigin\$', 'torres strait', 'indigenous', 'koori', 'maori\$', 'eskimo\$', 'inuit\$', 'aleut\$', 'american indian\$', 'native american\$', 'first nation' and 'first nations'. The truncation symbol '\$' was used to include variant textword endings and adjacency operators were used where required. No language or date limits were applied.

Inclusion criteria:

- All publication years after 1980 and article types, AND
- Where the Title, Abstract or full text describes meningococcal disease and socio-economic factors (both components)

Exclusion criteria:

- Articles not published in the English language
- Insufficient information to determine whether the article meets the inclusion criteria

Study type

A retrospective descriptive secondary analysis of IMD notifications reported to the NNDSS dataset by all Australian jurisdictions, 2010–2020 was conducted. We undertook a time-series analysis using notification data and conducted an ecological study comparing IMD notifications and SES, specifically serogroup B notifications then overall IMD notifications.

Case definitions

Invasive meningococcal disease notifications

According to the Communicable Diseases Network Australia (CDNA), a confirmed case of IMD requires either: 1) laboratory definitive evidence or 2) laboratory suggestive evidence and clinical evidence. (33) A probable case of IMD requires clinical evidence only. (33) See Figure 1 for more detailed definitions.

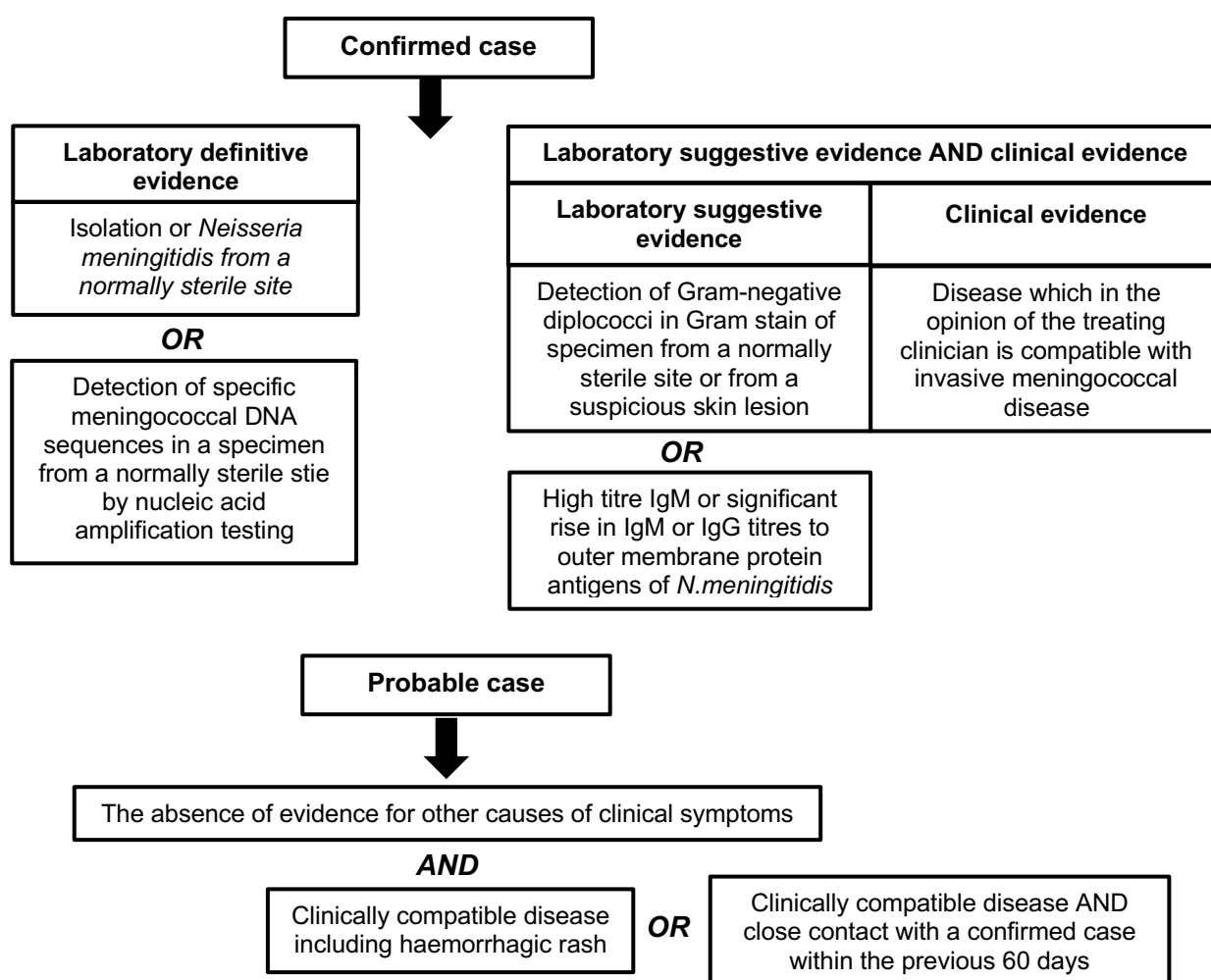


Figure 1. Confirmed and probable case definitions of invasive meningococcal disease in Australia according to the Communicable Diseases Network Australia, updated 1 July 2010.

Invasive meningococcal disease deaths

IMD deaths are defined as either died because of IMD or IMD was a contributing factor for death (according to the NNDSS data caveats).

Data sources

Notification data

The NNDSS collates de-identified data on nationally notifiable diseases across the eight jurisdictions in Australia. Both confirmed and probable IMD cases are notifiable in all jurisdictions. (33) The following data fields for IMD notifications from 2010–2020 were provided from the NNDSS: diagnosis date, age at onset, sex, serogroup, organism, Indigenous status, postcode and died of disease.

Socio-economic Index

In 2006, the Australian Bureau of Statistics (ABS) developed the Socio-Economic Indexes for Areas (SEIFA), ranking areas in Australia to relative socio-economic advantage and disadvantage. (34) SEIFA is based on data from the Australian Census, collected every five years, and ranks are based on geographic areas: Statistical Area Level 1, Statistical Area Level 2, Local Government Area, State Suburb and Postal Area. (34)

There are four SEIFA indexes and for this study I used the Index of Relative Socio-economic Disadvantage (IRSD). (35) The IRSD summarises the various economic and social conditions of people and households within an area. (35) Variables included in the IRSD are low income, jobless parents, no internet connection, highest level of education, unemployment, rent, disability, car ownership, and overcrowding (see Appendix A for full explanation of IRSD variables). (35) A high score on the IRSD indicates lack of disadvantage, whereas a low score indicates relatively greater disadvantage. (35) Every postcode in Australia has an associated IRSD score and decile (a number from 1–10). We matched postcode of residence from our IMD line-listed NNDSS data to the IRSD associated IRSD score and decile.

Population data

Mid-year resident population data estimates from the ABS by state from 2010–2020 were used to calculate notification rates per 100,000 population per year. (36) Population estimates by age and sex from the ABS were used to calculate notification rates per 100,000 population by age group from 2010 to 2020. (36–41) Population estimates and projects of the Aboriginal and Torres Strait Islander population for 2006 to 2021 from the ABS was used to calculate notification rates per 100,000 population by age group from 2010 to 2020. (42)

Data analysis

Descriptive analysis

IMD notifications from 2010 to 2020 were first summarised by year, month, sex, age group, jurisdiction, Indigenous status, serogroup, died of disease, and IRSD decile. We analysed IMD serogroup with the following variables, age-group, sex, jurisdiction, month, Indigenous status, IRSD quintile (grouped two deciles) and died of disease. We analysed IRSD decile with the following variables, age-group and case fatality ratio (CFR). CFR was calculated by number of deaths divided by the number of IMD cases multiplied by 100 (according to a defined time period). Data completeness for data fields (serogroup and postcode) was assessed.

Univariate analysis

We used Pearson's chi-square to test for statistical significance between serogroup B and other serogroups in relation to SES using the IRSD decile.

Regression analysis

We used a logistic regression model to predict if meningococcal B notifications are more likely to arise from areas with a lower socio-economic index (IRSD decile) than other serogroup IMD notifications. We included the following predictors: month of notification, age, sex, Aboriginal and/or Torres Strait Islander status, and jurisdiction to calculate odds ratio with 95% confidence intervals (CIs).

Data were cleaned and analysed on Stata 14.2 (Stata Corp, Texas, USA). Microsoft Excel was used to create figures in this chapter.

Ethics approval

The study was approved by the Human Research Ethics Committee at the Australian National University (2022/200).

Results

Synthesis of findings from literature review

The literature search found 689 relevant articles but only five were eligible for inclusion in the literature review, (Figure 2) based on investigating the association between living in high deprivation areas and risk of meningococcal disease – all were conducted in the UK during the 1990s and early 2000s (Table 1). The studies calculated relative risk or risk ratio for meningococcal disease in the most deprived group.

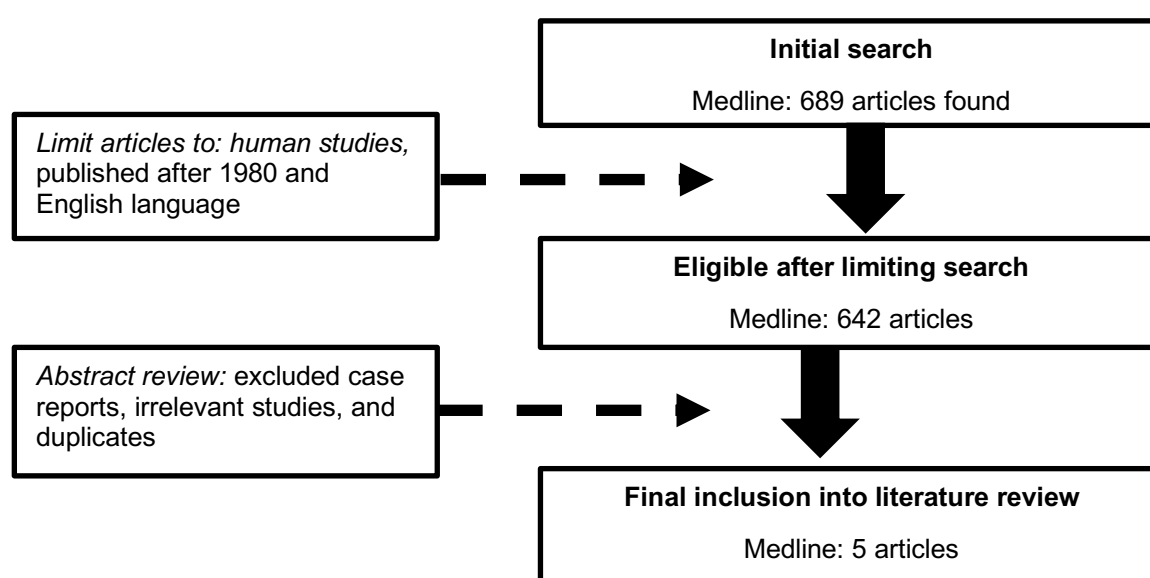


Figure 2. Flow chart of database search, articles included and excluded, and final articles for literature review on meningococcal disease and socio-economic factors

All studies except one used the 1991 Townsend Index as the measure of SES. The Townsend Index is calculated from census data at the district (about 450 people in 200 households) or ward (about 5500 people in 2400 households) level, and it combines local measures of unemployment, car ownership, overcrowding and housing tenure. (23, 28, 43) A higher Townsend score indicates a more deprived area. Scores are usually split into five equally sized groups (quintiles) and the highest quintile represents the lowest 20% deprivation. (18) In Olowokoure et al., 2006, the Townsend score was

split into quartiles and in Williams et al., 2003 the score was split into three groups. (28, 44)

The Index of Multiple Deprivation (2010) is a measure of seven indices relating to income deprivation, employment deprivation, health deprivation and disability, education skills and training deprivation, barriers to housing and services, living environment deprivation, and crime, reflecting the broad range of deprivation that people can experience. (45) This index is split into deciles, but often grouped into quintiles, as in Hughes and Gorton, 2015. (46) Updated versions of the Townsend Index and the Index of Multiple Deprivation is used today in the UK for health, economic and community research.

In all studies except one, the national or regional notification system or surveillance system was used to extract information on meningococcal cases of all ages. (28, 31, 44, 46) Only Heyderman et al., 2004 used national hospital episode statistics as the study population was for children aged less than 5 years. (23) Data on notification date, age and postcode were the most often used fields for analysis. In all studies, except Williams et al., 2003 postcode data were linked to district of residence (which will correlate to a Townsend score or Index of Multiple Deprivation). (23, 31, 44, 46) Standard population estimates from census data were used to calculate incidence rates. In William et al., 2003, the postcode georeference (using the National Health System postcode database) was used to map cases and then used to assign deprivation scores. (28)

In terms of statistical analysis, all papers except Olowokure et al., 2006 quantified association between meningococcal cases and SES (using the Townsend Index or Index of Multiple Deprivation) using count regression, mostly Poisson model. (23, 28, 31, 46) Incidence rates of meningococcal disease were calculated then used to associate with SES. In Olowokure et al., 2006, the relative risk was calculated by comparing the different groups of deprivation quartile by incidence rates per 100,000 population in urban and rural settings by chi-square tests. (44)

All five papers reported increasing incidence rates of meningococcal disease with increasing levels of social deprivation (Table 1). (23, 28, 31, 44, 46) Hence, a higher

relative risk for meningococcal disease in the highest deprivation level. Hughes and Gorton, 2015 reported the highest RR of meningococcal disease in the most deprived level, RR=2.46 (95% CI: 1.44–4.17) a similar estimate to Fone et al., 2003, RR=2.4 (95% CI: 1.7–3.6). (31, 44) In 1991–1994, Heyderman et al., 2004 reported the lowest elevation of risk ratio in the most deprived quintile, for boys (1.50, 95% CI: 1.31–1.72) and girls (1.70, 95% CI: 1.45–1.99) and in 1995–1999 for boys (1.54, 95% CI: 1.39–1.69) and girls (1.41, 95% CI: 1.27–1.57). (23) Notably, Heyderman et al., 2004, had the largest number of cases (n=10,524) over the longest time period (1991–1999) compared to the other studies. (23) The lower risk ratio could be due to the fact this study was limited to children under five, excluding adolescents who are also at higher risk of meningococcal infection.

Only Fone et al., 2003 compared the incidence of meningococcal disease between the different serogroups of meningococcal disease. (31) Serogroup B was the most prevalent serogroup for meningococcal disease in Gwent, Southeast Wales, 1996–1999. Serogroup B more strongly associated with the Townsend score than Serogroup C (magnitude of effect: 5.2%, 95% CI, -2.6–12.9). (31)

Overall, the studies in this literature review support an association between meningococcal disease and SES. Postcode was used as a proxy of SES. All five papers indicated that there is an increased risk of meningococcal disease with increasing deprivation of socio-economic index. However, all these studies were conducted in the UK, with no studies identified through this search of the published literature in any other country. In addition, all used the Townsend index or Index of Multiple Deprivation to measure SES. We cannot use these two indexes to generalise for other countries and further investigation on appropriate markers of SES is required. More studies on finding the association between meningococcal disease and SES at national levels and comparisons between different serogroups would be of benefit.

Table 1. Five articles published on the association between meningococcal disease and socio-economic status worldwide, 1980–2022

	Disease	Setting and population	Study design	Measure of socio-economic status	Analysis	Magnitude of difference
Fone et al 2003 (31)	Meningococcal disease (B vs C)	Gwent, Southeast Wales, 1996–1999 All ages Cases=295	Ecological study	Townsend score (area) Five quintile groups Score based on unemployment, car ownership, and housing tenure	Quantified association between all cases and Townsend score using Poisson regression Analysis for: Confirmed and unconfirmed cases, serogroups B and C, and <5 and ≥5 years	Incidence relative risk in the most deprived area: 2.4 (1.7–3.6) Serogroup B (13.7%, 95% CI: 7.9–19.4) was more strongly associated with Townsend score than serogroup C (5.2%, 95% CI: -2.6–12.9)
Heyderman et al 2004 (23)	Meningococcal disease	England (national hospital episode statistics database), 1991–1999 Under 5 years Cases=10,524	Ecological study	Townsend score (area) Five quintile groups Score based on unemployment, car ownership, and housing tenure	Standardised rates Association between incidence, mortality, and area deprivation quintiles calculated using Poisson regression.	Risk ratio for most deprived quintile and incidence for meningococcal disease 1991–1994 Boys: 1.50 (1.31–1.72) Girls: 1.70 (1.45–1.99) 1995–1999 Boys: 1.54 (1.39–1.69) Girls: 1.41 (1.27–1.57)
Williams et al 2004 (28)	Meningococcal disease	Eastern region, UK, 1999–2000 All ages Cases=451	Ecological study	Townsend score (area) Divided into three wards Score based on unemployment, car ownership, and housing tenure	Poisson confidence intervals for wards and deprivation group incidence rates were calculated.	Incidence relative risk compared to least deprived wards Most deprived wards: 1.97 (1.55–2.51)

	Disease	Setting and population	Study design	Measure of socio-economic status	Analysis	Magnitude of difference
Olowokure et al 2006 (43)	Meningococcal disease	Shropshire County (rural), Telford and Wrekin (urban), England, 1996–2001 All ages Cases=183	Ecological study	Townsend material deprivation score (five quintiles)	Standardised rates Differences between groups were assessed using chi-square tests and relative risk	Risk of meningococcal disease in the most deprived quartile in urban areas was twice the risk in rural areas, RR=2.02 (95% CI: 1.27–2.22) The risk of disease in the most deprived quartile in urban areas was three times greater than the least deprived quartile (3.33, 95 CI: 1.68–6.60).
Hughes and Gorton 2015 (45)	Invasive meningococcal infection + 20 infectious diseases	Northeast of England, 2007–2011 All ages Cases=364	Ecological study	Index of Multiple Deprivation (five quintiles)	Count regression modelling with hierarchical approach using Index of Multiple Deprivation. Poisson modelling used for invasive meningococcal infection	Association between deprivation and the incidence of infectious diseases calculated by using Incidence rate ratio (IRR) IRR in the most deprived quintile was 2.46 (95% CI: 1.44–4.17)

Data analysis

From 2010 to 2020, there were 2,394 IMD notifications reported to the NNDSS (Table 2). The median age of cases notified with IMD was 20 years. A similar proportion of males (51.1%) and females (48.8%) reported IMD. There was high representation of Aboriginal and/or Torres Strait Islander people (13%) reporting IMD. The highest proportion of notifications came from New South Wales (NSW) (27.2%), followed by Queensland (QLD) (21.9%) and then Victoria (VIC) (21.7%). The most prevalent serogroup notified was serogroup B (57.4%). The distribution of SES was not skewed as about 10% of IMD notifications was associated with each IRSD decile.

Table 2. Overall characteristics of invasive meningococcal disease reported to the National Notifiable Diseases Surveillance System in Australia, 2010–2020.

Characteristics	Number (Proportion), rate per 100,000 population per year
Total cases	2,394 (100%)
Median age	20 years, (0–101 years)
Sex	
Male	1,223 (51.1%)
Female	1,168 (48.8%)
Undetermined	3 (0.1%)
Aboriginal and/or Torres Strait Islander status	
Aboriginal and Torres Strait Islander	6 (0.25%)
Aboriginal only	293 (12.2%)
Torres Strait Islander	11 (0.5%)
Not Aboriginal or Torres Strait Islander	2,028 (84.7%)
Not stated	56 (2.3%)
Jurisdiction	
Australian Capital Territory	19 (0.8%), 0.04
New South Wales	651 (27.2%), 0.07
Northern Territory	70 (2.9%), 0.24
Queensland	525 (21.9%), 0.09
South Australia	286 (12.0%), 1.39
Tasmania	71 (3.0%), 0.11
Victoria	519 (21.7%), 0.07
Western Australia	253 (10.6%), 0.08
Serogroup	
B	1,375 (57.4%)
C	75 (3.1%)
E	2 (0.1%)
W	507 (21.2%)
Y	299 (12.5%)
Unknown/ungrouped	136 (5.7%)
Index of Relative Socio-economic Disadvantage (IRSD)	
Decile 1 (lowest socio-economic group)	290 (12.1%)
Decile 2	244 (10.2%)
Decile 3	189 (7.9%)
Decile 4	229 (9.6%)
Decile 5	248 (10.4%)
Decile 6	277 (11.6%)
Decile 7	213 (8.9%)
Decile 8	219 (9.2%)
Decile 9	239 (10.0%)
Decile 10 (highest socio-economic group)	211 (8.8%)
Unknown	355 (1.46%)

Secular trends

Over the study period, the highest notification rate per 100,000 population per year for IMD was observed in 2017 (Figure 3). The most prevalent serogroup across the 11 years was serogroup B. Since the inception of the NNDSS in 1991, IMD notification rate had been on the rise, reaching the peak in 2001 (3.5 per 100,000 population per year) when serogroup C was prominent and declining since, except in 2015–2017 in association with a rise in serogroup W and serogroup Y IMD notification rates. (45) In 2020, the overall IMD notification rate was lowest, at 0.35 per 100,000 population per year, 4.4 times lower than in 2017 (1.54 per 100,000 population per year), coinciding with the implementation of Australia's strict public health measures (such as closing of international and interstate borders, restrictions on social gatherings, and lockdowns) to control the COVID-19 pandemic.

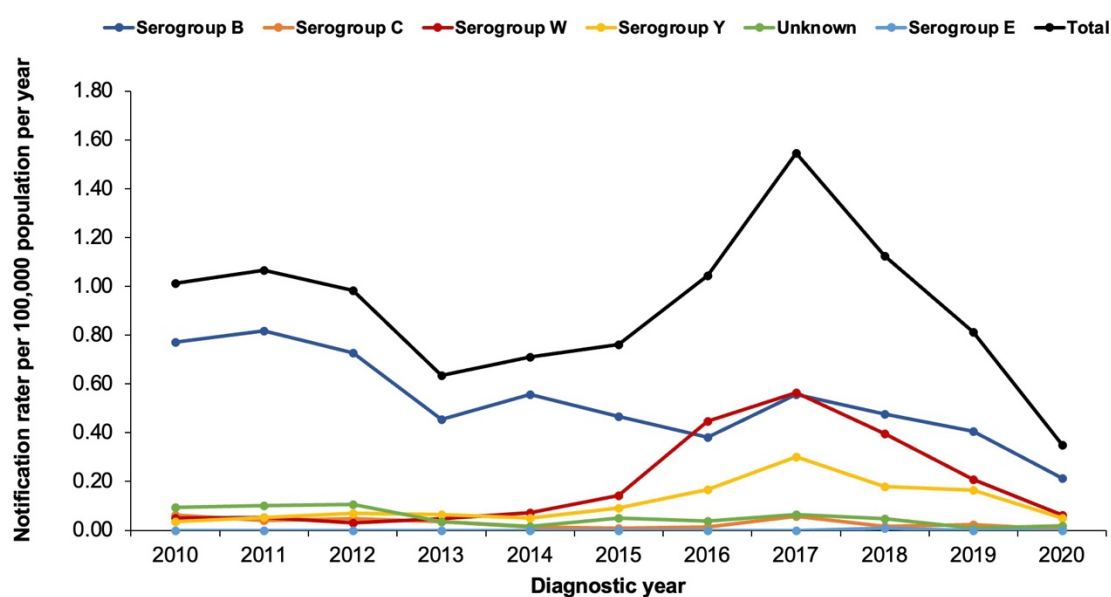


Figure 3. Trends in invasive meningococcal disease notification rate per 100,000 population per year by serogroup and diagnostic year, Australia, 2010–2020

From 2010–2020, IMD notifications followed a seasonal pattern, peaking during winter and spring months from July to October, with the lowest number of notifications in the summer month of February (Figure 4). The number of notifications in July (n=239), August (n=286), September (n=284) and October (n=251) in the 11 years was more than twice the number in February (n=115). Serogroup B was the most prevalent serogroup, followed by serogroup W then serogroup Y.

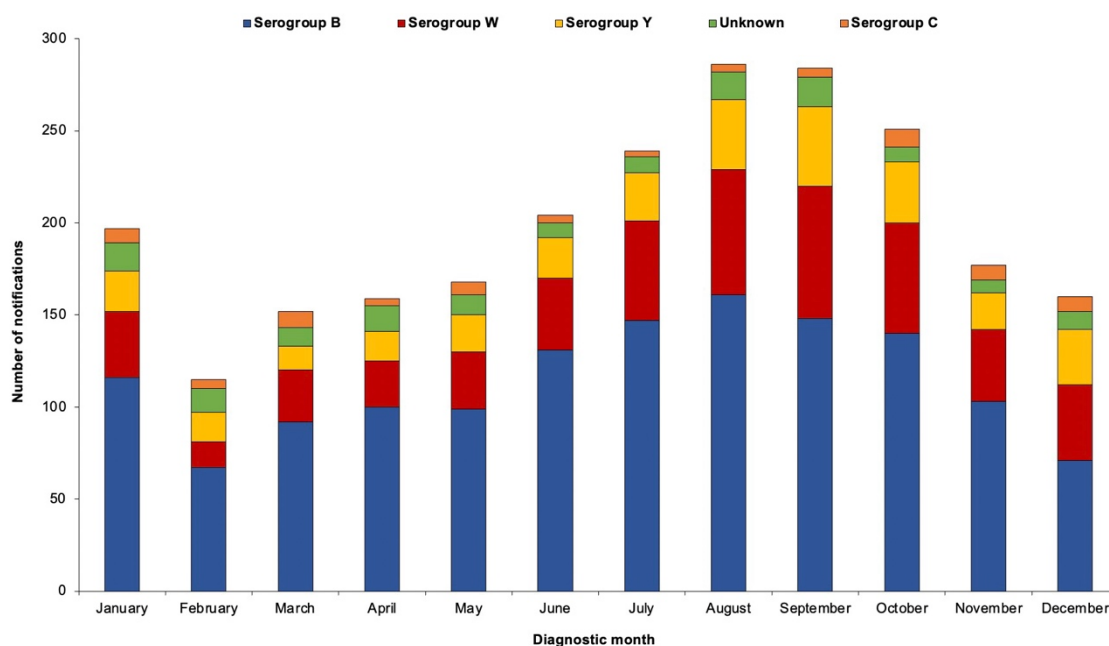
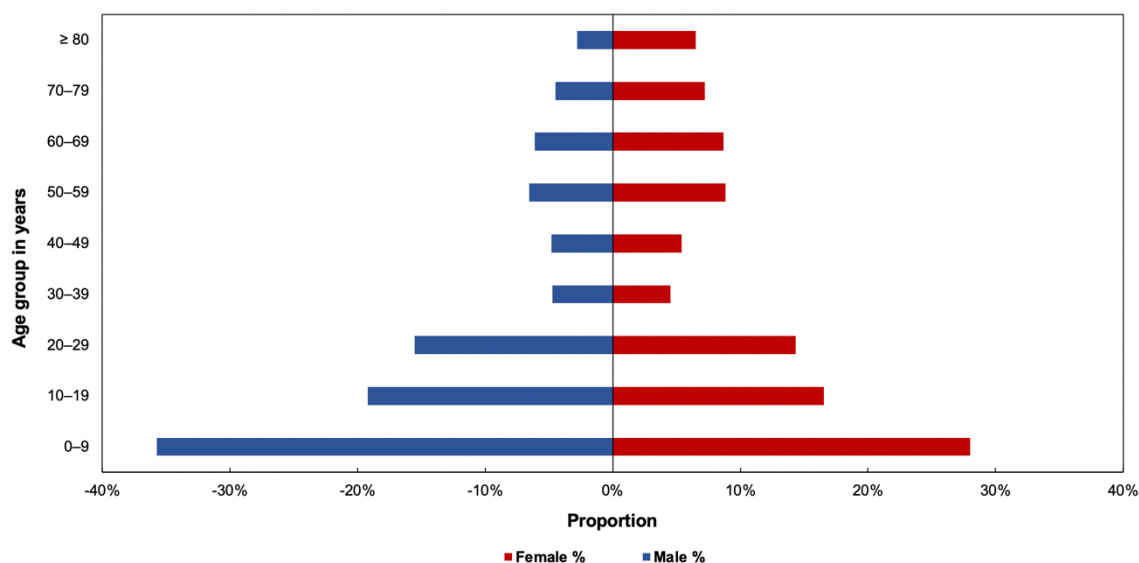


Figure 4. Number of invasive meningococcal notifications by serogroup and month, Australia, 2010–2020.

Trends in age group

Overall, in 2010–2020, a higher proportion of males reported IMD notifications than females (Figure 5). The highest proportion of notifications were in the 0–9 years age group, followed by the 10–19 years then 20–29 years age group. There was not a remarkable difference between males and females.



Note: Excluded undetermined sex

Figure 5. Proportion of invasive meningococcal disease notifications by age group, sex, Australia, 2010–2020

Over the 11 years, in the younger age groups (0–1 year, 2–4 years, 5–9 years, 10–19 years), serogroup B accounted for the highest IMD notification rates per 100,000 population per year compared to other serogroups (Figure 6). In infants 0–1 year age group, the serogroup B notification rate reached 5.1 per 100,000 population per year. In the ≥ 65 year age group, IMD notification rate per 100,000 population per year of serogroup W and serogroup Y were higher than serogroup B.

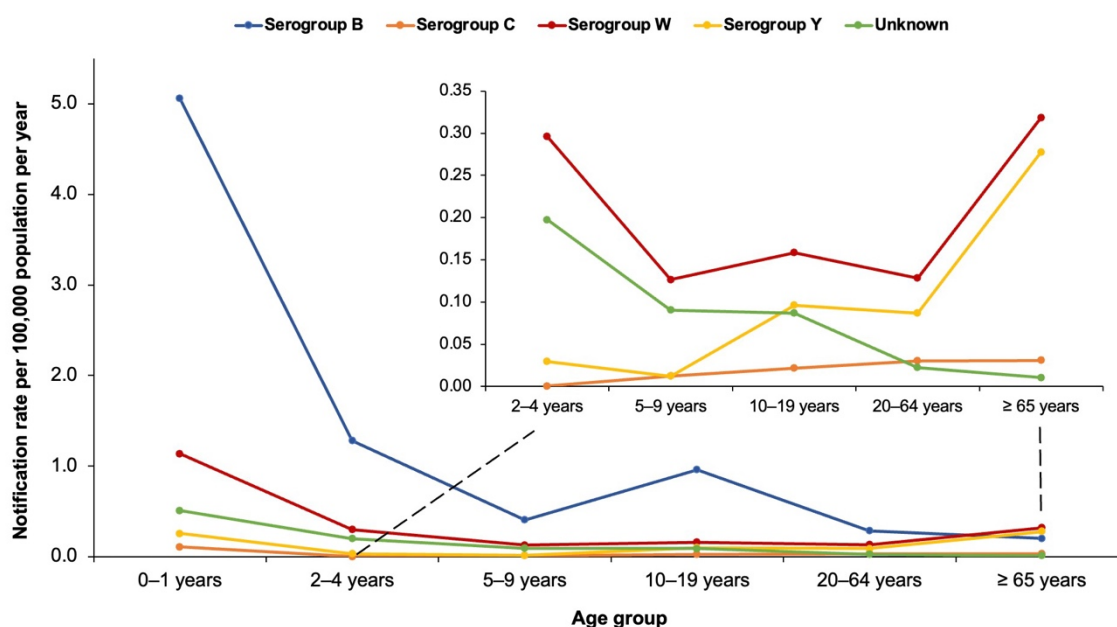


Figure 6. Age-specific invasive meningococcal disease notification rate per 100,000 population per year by serogroup, Australia, 2010–2020

Trends in Aboriginal and/or Torres Strait Islander people

Overall, there is a declining trend of notification rate of IMD and Aboriginal and/or Torres Strait Islander status with increasing age (Table 3 and Figure 7). The highest notification rate of serogroup IMD was in the 0–1 year age group. Most notably, the notification rate of Aboriginal and/or Torres Strait Islander people aged 0–1 year for serogroup B IMD was seven times higher than non-Indigenous people (2.5 per 100,000 population per year). Among Aboriginal and/or Torres Strait Islander people 0–1 years, the notification rate of serogroup B IMD was two times higher than other serogroups (18.4 vs 9.1 per 100,000 population per year). In non-Indigenous people, the serogroup B IMD notification rate compared to the other serogroup IMD notification rate was 4 times higher in the 0–1 years and 10–19 years group, and 6 times higher in the 2–4 years group.

Table 3. Notification rate per 100,000 per year of serogroup B and other serogroup invasive meningococcal disease by age group and Aboriginal and/or Torres Strait Islander status, Australia, 2010–2020.

	Notification rate per 100,000 population per year			
	Non-Indigenous		Aboriginal and/or Torres Strait Islander	
Age group	Serogroup B	Other serogroups	Serogroup B	Other serogroups
0–1 years	2.5	0.6	18.4	9.1
2–4 years	0.6	0.1	5.0	4.2
5–9 years	0.3	0.0	1.9	1.9
10–19 years	0.8	0.2	1.4	0.5
20–64 years	0.2	0.2	0.3	0.7
≥ 65 years	0.2	0.6	0.8	0.6
Total	0.4	0.3	2.0	1.5

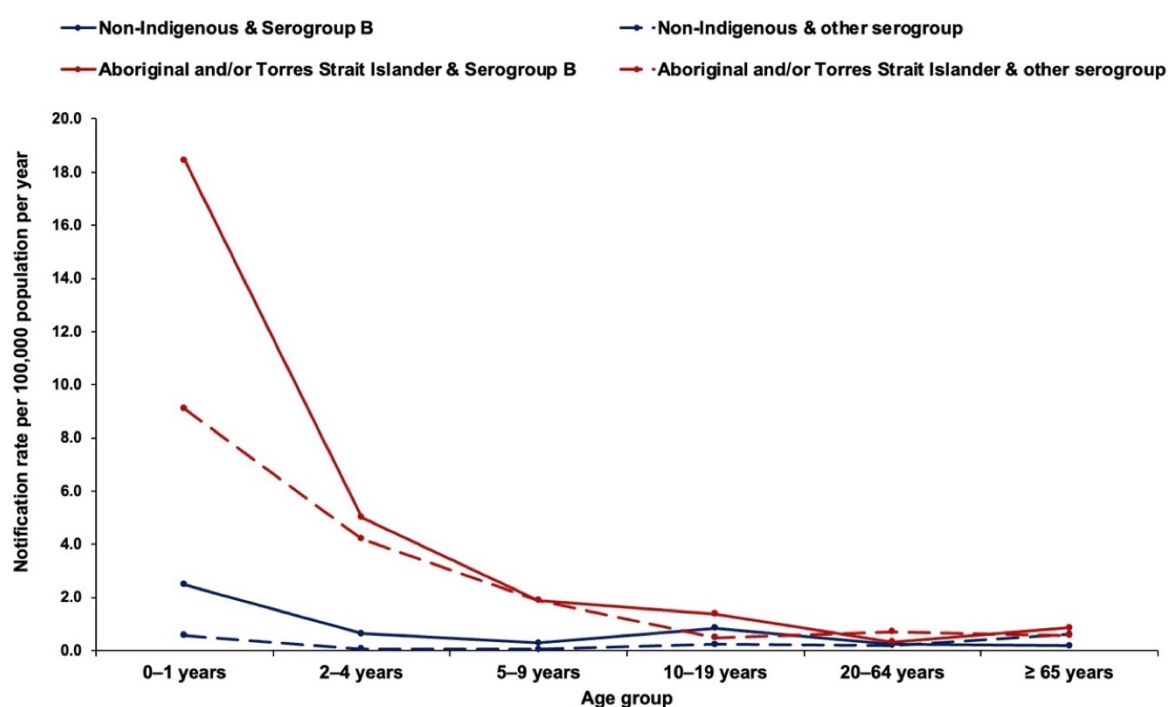


Figure 7. Age-specific invasive meningococcal disease notification rate per 100,000 population per year by serogroup and Aboriginal and/or Torres Strait Islander status, Australia, 2010–2020

Mortality in invasive meningococcal disease notifications

In most years, IMD deaths occurred in cases of serogroup B except in 2015–2017, where most deaths arose from serogroup W notifications. (Figure 8). There was a steady decline in the CFR from 2010–2013, then an increase between 2014–2015. The highest number of deaths (n=31) as well as the highest CFR (8.2%) was observed in 2017, driven by mortality for serogroup W. Despite the

decreasing number of deaths since 2017, the CFR among a low total number of cases in 2020 (6.7%) was higher than earlier years, between 2010 and 2012.

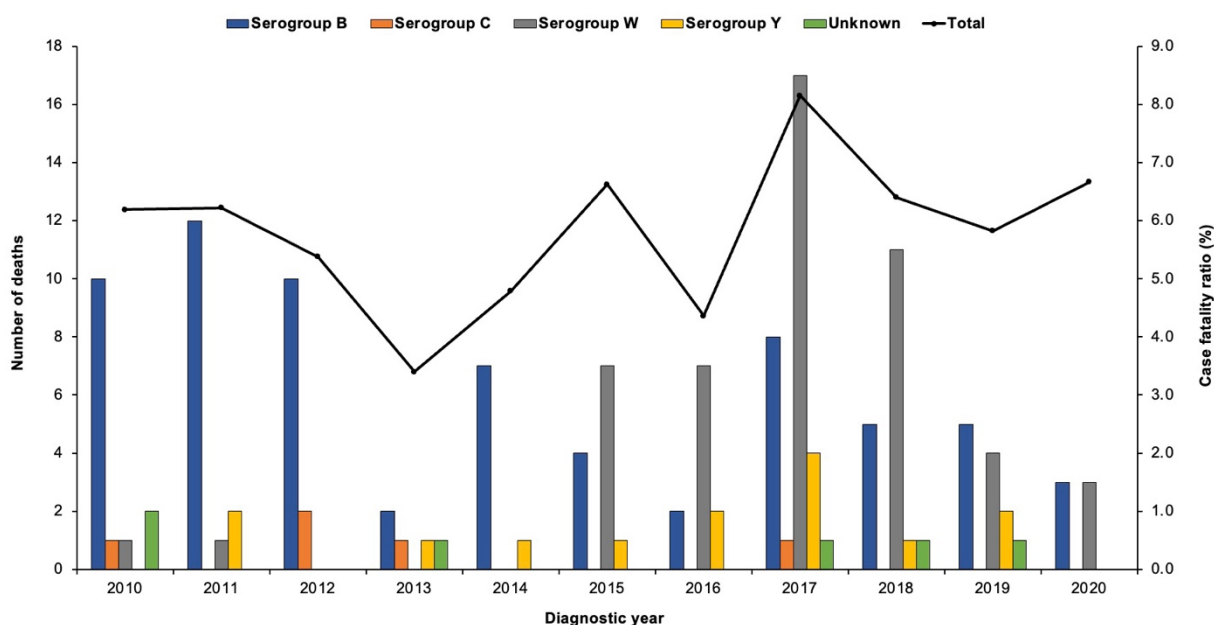


Figure 8. Number of deaths (died of invasive meningococcal disease [IMD] or IMD was a contributing factor) and case fatality ratio (proportion of deaths out of IMD cases) by year and serogroup, Australia, 2010–2020.

From 2010 to 2020, the number of deaths ($n=32$) was highest in the 0–9 years age group for serogroup B IMD notifications (Figure 9). There were more deaths from other serogroups (not serogroup B) in all age groups, except the 0–9 years and 50–59 years age group. Number of deaths did not correlate with CFR. CFR was highest (23.5%) in the ≥ 80 years age group (this is because of the low number of cases over deaths 4/17). In comparison, for other serogroups, the CFR was highest in the 30–39 years age group (13.8%).

Analysis of the number of deaths by diagnostic year (Figure 10) showed that from 2010–2014, there were more deaths from serogroup B than other serogroups. However, from 2015, there more deaths from other serogroups than serogroup B. There have been fluctuations in the CFF over the past 11 years. The highest CFR was observed in 2015 from other serogroups.

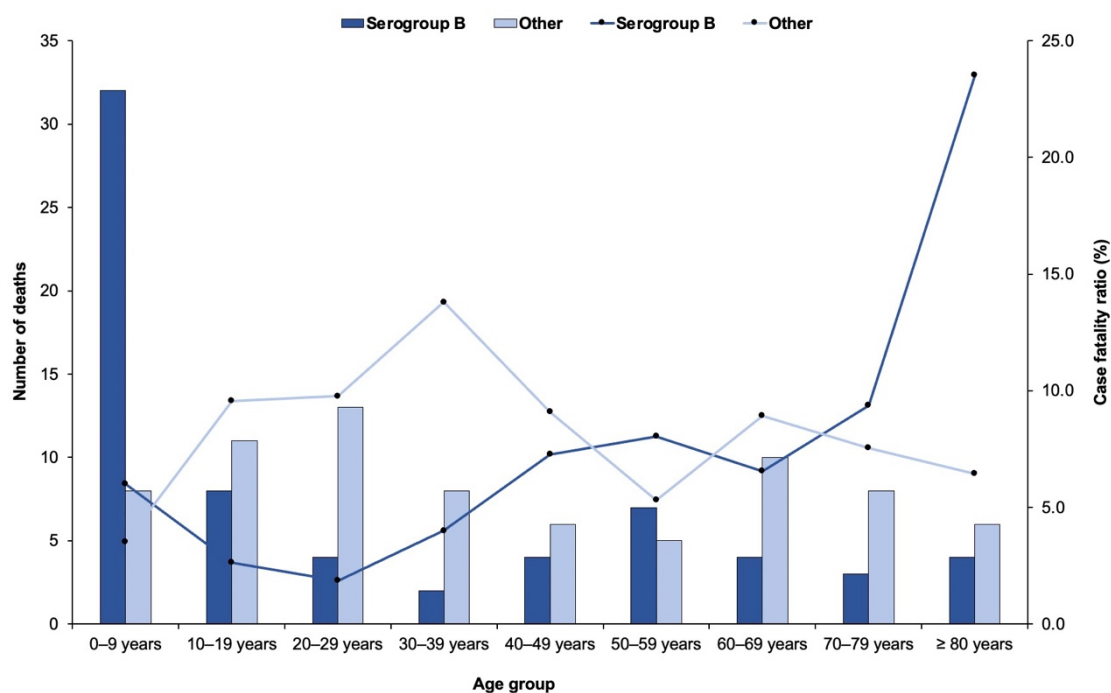


Figure 9. Number of deaths (died of invasive meningococcal disease [IMD] or IMD was a contributing factor) and case fatality ratio (proportion of deaths out of IMD cases) of IMD in serogroup B and other serogroups by age group, Australia, 2010–2020.

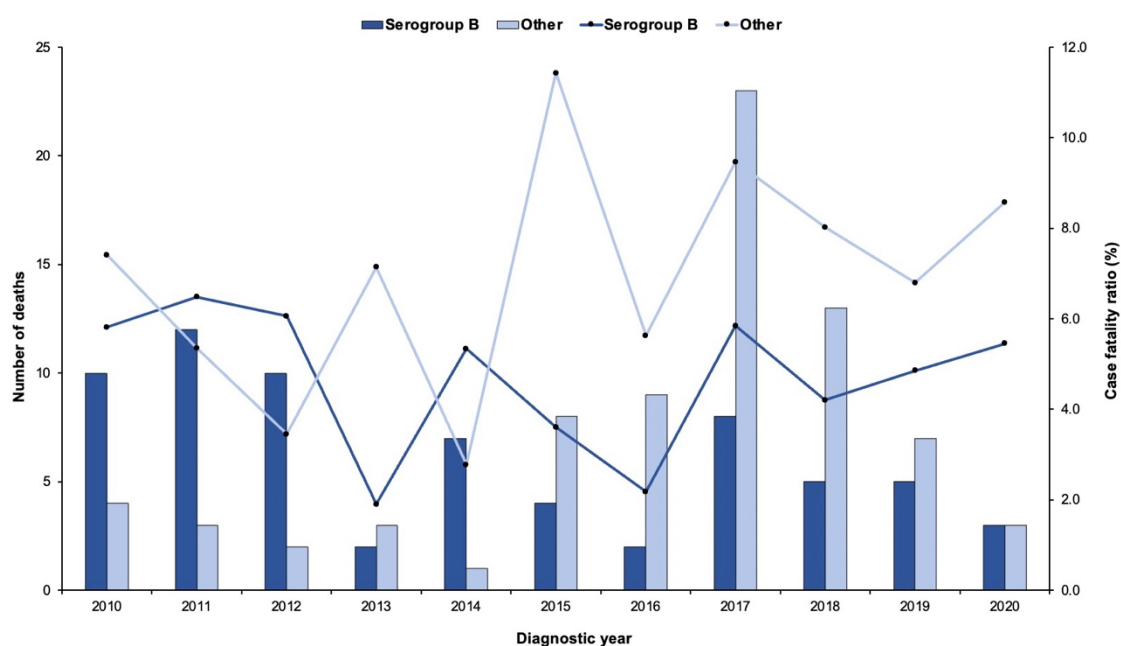


Figure 10. Number of deaths (died of invasive meningococcal disease [IMD] or IMD was a contributing factor) and case fatality ratio (proportion of deaths out of IMD cases) of IMD in serogroup B and other serogroups by diagnostic year, Australia, 2010–2020.

Analysis on socio-economic status

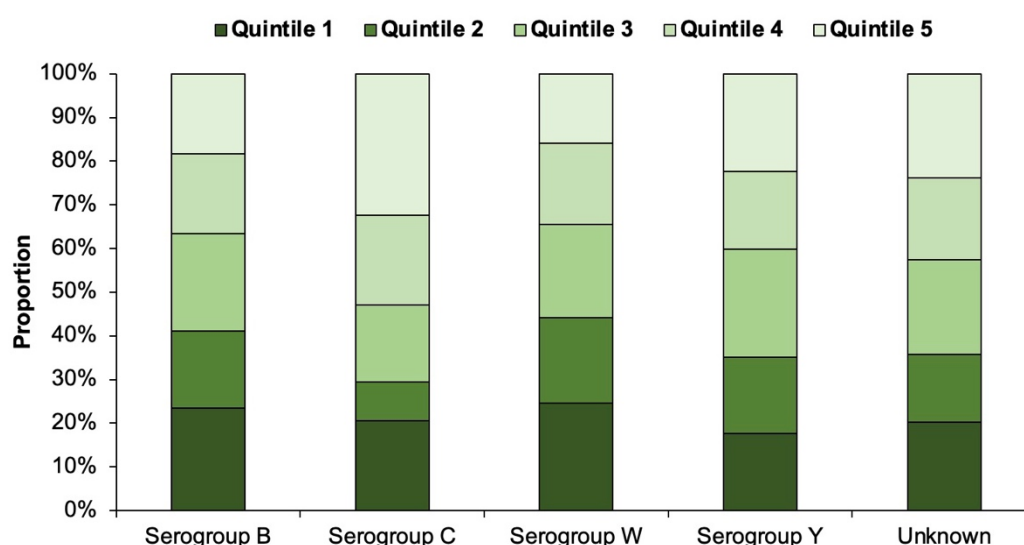
Overall, there was a higher proportion of Aboriginal and/or Torres Strait Islander people living in areas of the lowest socio-economic index in Australia from 2010–2020 (Table 4). Across the board, 44.2% of IMD notifications of Aboriginal and/or Torres Strait Islander people came from individuals living in areas of the lowest quintile, this is more than twice the proportion of non-Indigenous people (19.3%). Only 2.6% of Aboriginal and/or Torres Strait Islander people with IMD notifications were living in areas with the highest socio-economic quintiles. In contrast, non-Indigenous people had an even spread of SES.

Table 4. Number and proportion of invasive meningococcal disease notifications by age-group and socio-economic index quintiles, Australia, 2010–2020.

	Number of notifications (proportion)		
	All people n (%)	Aboriginal and/or Torres Strait Islander N (%)	Non-Indigenous n (%)
Quintile 1 (lowest index)	522 (22.6)	136 (44.2)	386 (19.3)
Quintile 2	404 (17.5)	70 (22.7)	334 (16.7)
Quintile 3	514 (22.3)	45 (14.6)	469 (23.5)
Quintile 4	422 (18.3)	49 (15.9)	373 (18.7)
Quintile 5 (highest index)	442 (19.2)	8 (2.6)	434 (21.7)
Total	2304 (100%)	308 (100%)	1996 (100%)

Excluded unknown socio-economic index and unknown Aboriginal and/or Torres Strait Islander status data points

Overall, there was no particular trend observed in SES and the different IMD serogroups in Australia from 2010–2020 (Figure 11). Notifications of IMD occurred in populations living in areas of low to high SES. One observation is that there was a higher proportion of Serogroup C notifications in Quintile 5 compared to other serogroups (Figure 10).



Note: Two serogroup E notifications were excluded

Figure 11. Proportion of invasive meningococcal disease notifications by socio-economic index quintile and serogroup, Australia, 2010–2020.

There was a higher proportion of notifications among younger age groups living in areas of lower SES (Table 5). In the 0–9 year age group, 34.5% (262/759) of IMD cases were living in the lowest SES quintile, compared to 9.7% (74/759) living in the highest quintile. A higher proportion of < 5 years were living in areas with lower SES (quintile 1 and 2) (Table 6). The ratio of < 5 years living in areas of quintile 1 and 2 compared to quintile 4 and 5 for non-Indigenous people (43.6/32.6) was 1.34 for serogroup B notifications. A higher ratio of 2.0 was observed for Aboriginal and/or Torres Strait Islander people, (51.8/25.9).

Table 5. Number and proportion of invasive meningococcal notifications by socio-economic index quintile and age group, Australia, 2010–2020.

		Number of notifications by socio-economic index quintile (%)					
		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Total
Age group in years	0–9	262 (49.3)	154 (37.4)	174 (33.4)	95 (21.9)	74 (16.6)	759 (32.4)
	10–19	70 (13.2)	61 (14.8)	98 (18.8)	85 (19.6)	105 (23.5)	419 (17.9)
	20–29	51 (9.6)	40 (9.7)	88 (16.9)	84 (19.4)	83 (18.6)	346 (14.8)
	30–39	24 (4.5)	15 (3.6)	19 (3.6)	25 (5.8)	25 (5.6)	108 (4.6)
	40–49	25 (4.7)	16 (3.9)	23 (4.4)	27 (6.2)	19 (4.3)	110 (4.7)
	50–59	29 (5.5)	29 (7.0)	33 (6.3)	40 (9.2)	50 (11.2)	181 (7.7)
	60–69	33 (6.2)	42 (10.2)	32 (6.1)	32 (7.4)	34 (7.6)	173 (7.4)
	70–79	24 (4.5)	28 (6.8)	30 (5.8)	25 (5.8)	30 (6.7)	137 (5.8)
	≥ 80	13 (2.5)	27 (6.6)	24 (4.6)	20 (4.6)	26 (5.8)	110 (4.7)
Total		531 (100)	412 (100)	521 (100)	433 (100)	446 (100)	2343

Note: Excluded unknown quintiles

Table 6. Invasive meningococcal disease notifications and proportion in under 5 years by serogroup, Aboriginal and/or Torres Strait Islander status and socio-economic index quintile, Australia, 2010–2020.

Quintile	Non-Indigenous n (%)		Aboriginal and/or Torres Strait Islander n (%)	
	Serogroup B	Other serogroup	Serogroup B	Other serogroup
Quintile 1	69 (19.8)	15 (22.4)	28 (25.9)	22 (34.4)
Quintile 2	83 (23.8)	18 (26.9)	28 (25.9)	15 (23.4)
Quintile 3	83 (23.8)	13 (19.4)	24 (22.2)	14 (21.9)
Quintile 4	65 (18.6)	15 (22.4)	24 (22.2)	13 (20.3)
Quintile 5	49 (14.0)	6 (9.0)	4 (3.7)	0
Total	349	67	108	64

Note: Excluded unknown quintiles, unknown serogroups and unknown Aboriginal and/or Torres Strait Islander status

Overall, IMD deaths were not dominated by a certain socio-economic index group (Figure 12). Deaths occurred in all quintiles throughout the 11 years. In 2016 and 2020 there were no deaths from the lowest socio-economic quintile. In 2011, 2012, 2014, 2018 and 2019, more than half the deaths were from cases from the two lowest socio-economic quintiles.

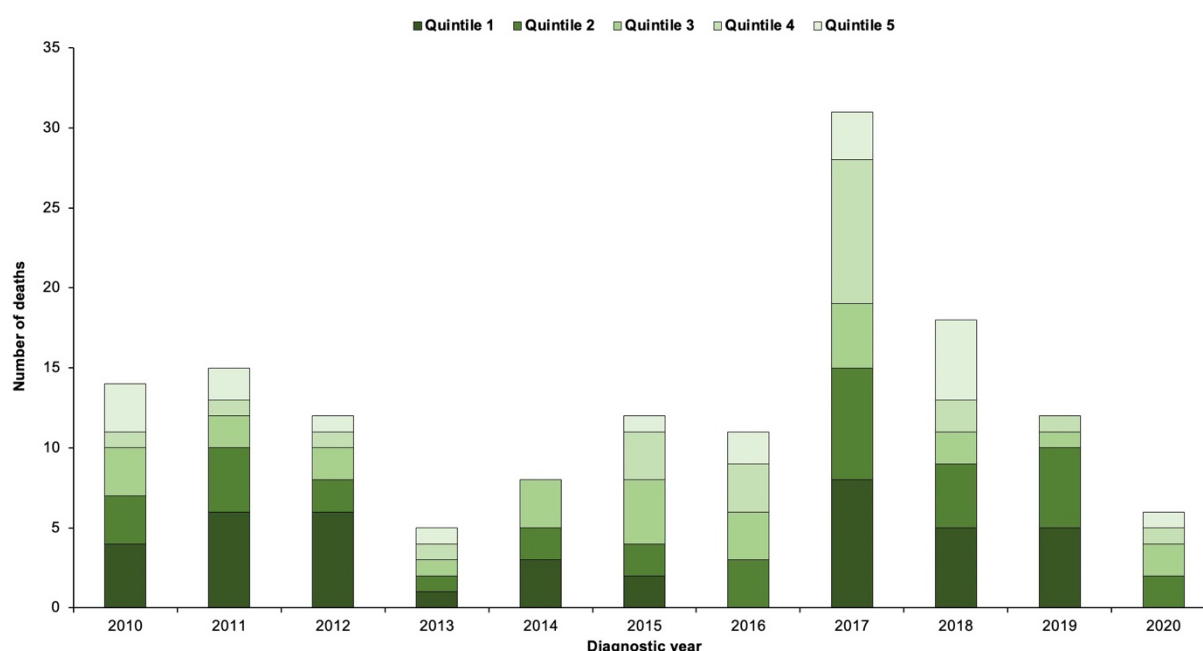


Figure 12. Number of invasive meningococcal disease deaths by year and socio-economic index quintile, Australia, 2010–2020.

Univariate analysis

After grouping serogroup B notifications and other serogroups, we conducted a Pearson's chi-square test between serogroup and socio-economic index deciles. We excluded unknown values in the serogroup variable removing 134 data points and unknown decile groups, removing 35 data points. There was no statistically significant difference by serogroup (B vs other) and socio-economic index deciles (1–10) nor quintiles (1–5) across all age groups.

When investigating different age groups, and there was a significant relationship between all serogroups and socio-economic index deciles in < 5 years, X^2 (9, $N=688$), $p=0.003$. In the < 5 years age group, there was also a significant relationship between serogroup B and socio-economic index deciles, X^2 (9, $N=688$), $p=0.020$. However, in the age group < 2 years, the significant relationship between serogroup B and socio-economic index decile did not reach statistical significance, X^2 (9, $N=426$), $p=0.305$.

Regression analysis

Logistic regression was used to analyse the relationship between SES (using decile) and serogroup B. When looking at the relationship between decile and serogroup B only, the odds point estimate of a notification being serogroup B (over other serogroups) in the lowest socio-economic group was 1.23 times higher (95% CI: 0.84–1.81, $p=0.290$) than in the highest socio-economic group, however this was not a statistically significant difference. This model was however not statistically significant (probability > $\chi^2=0.9721$) and similar odds were observed in all other deciles, with point estimates ranging from 0.98–1.23.

I then used logistic regression to analyse the relationship between SES (using decile), month, jurisdiction, age group and Aboriginal and/or Torres Strait Islander status to predict if the odds of an IMD notification is more likely to be serogroup B over other serogroups. In this model, decile did not have any effect on predicting whether an IMD notification will be serogroup B. Age group, month and jurisdiction were important predictors (Table 7). The model with all the predictors was statistically significant (probability > $\chi^2=0.000$).

The model predicted that the odds of a IMD notification being serogroup B (over other serogroups) was 5.1 times higher in the 2–4 years age group than the 20–65 years age group. The odds were at least four times higher in other age groups, 0–1 year and 5–9 years. Aboriginal and/or Torres Strait Islander status was a statistically significant predictor of an IMD notification, however with a low odds ratio of 0.48. All months, except September predicted that the odds of a IMD notification being serogroup B was at least 1.7 times higher than in December. The odds of an IMD notification being serogroup B was higher in South Australia than all other jurisdictions, and four times higher than Victoria (used as the comparator jurisdiction).

Table 7. Associations between age group, Aboriginal and/or Torres Strait Islander status, month and jurisdiction and notification of serogroup B, Australia, 2010–2020.

	Category	Odds Ratio	95% Confidence Interval		p-value
Outcome: Serogroup B vs other serogroups					
Predictors					
Age group	0–1 years	4.23	3.14	5.71	0.000
	2–4 years	5.12	3.24	8.08	0.000
	5–9 years	4.35	2.54	7.45	0.000
	10–19 years	3.09	2.31	4.14	0.000
	≥ 65 years	0.25	0.19	0.34	0.000
Age group base: 20–65 years					
Aboriginal and/or Torres Strait Islander	Aboriginal and/or Torres Strait Islander	0.48	0.34	0.67	0.000
Indigenous base: non-Indigenous					
Month	January	2.20	1.32	3.66	0.002
	February	2.13	1.17	3.88	0.013
	March	2.15	1.25	3.72	0.006
	April	2.77	1.60	4.80	0.000
	May	2.23	1.31	3.79	0.003
	June	2.80	1.70	4.62	0.000
	July	2.31	1.43	3.74	0.001
	August	1.76	1.10	2.81	0.018
	September	1.43	0.90	2.90	0.130
	October	1.92	1.20	3.10	0.007
	November	1.80	1.08	3.00	0.025
Month base: December					
Jurisdiction	ACT	0.85	0.28	2.56	0.771
	NSW	1.54	1.16	2.05	0.003
	NT	0.46	0.24	0.86	0.015
	QLD	1.66	1.23	2.23	0.001
	SA	4.90	3.29	7.31	0.000
	TAS	1.18	0.65	2.16	0.587
	WA	0.83	0.58	1.19	0.313
Jurisdiction base: VIC					
Constant		0.46	0.27	0.77	0.004

Abbreviations: ACT=Australian Capital Territory, NSW=New South Wales, NT=Northern Territory, QLD=Queensland, SA= South Australia, TAS=Tasmania, WA=Western Australia and VIC= Victoria

Discussion

Over the past 11 years, 2010–2020, serogroup B was the dominating strain among IMD notifications in Australia (except 2016–2017). In every month, and every age group (except ≥ 65 years), the number of serogroup B IMD cases and

notification rate per 100,000 population per year was the highest. We observed higher notification rates of serogroup B IMD among Aboriginal and/or Torres Strait Islander people and in the younger population < 5 years. A higher proportion of the younger population (0–9 years) were found to be living in the lowest SES (quintile) compared to other age groups. We found there was a significant relationship (using Pearson's chi-square test) between serogroup B notifications and socio-economic index decile in < 5 years. However, we could not find any association between serogroup B and socio-economic index using logistic regression. The odds of a IMD notification being serogroup B over another serogroup was 1.23 times higher in the lowest socio-economic decile than the highest decile. However, this value was not statistically significant, and the odds were similar for other deciles, low, mid and high.

This finding is not consistent with previous studies where an association between IMD incidence and lower SES was established. (21, 26, 29, 41, 43) Studies from the UK (conducted around the same time, 1990s and early 2000s and mostly in regional areas) reported that living in socio-economically deprived areas increased the risk of meningococcal disease by at least 1.41 times, and as high as 3.33 times. (21, 41) These studies however did not analyse serogroup specific IMD and all studies except one were for all ages. In this study we did not have access to population estimates by socio-economic index decile and could not calculate incidence of serogroup B IMD notification by decile and could not conduct Poisson analysis similar to previous studies.

There is limited representation of similar studies of association between meningococcal disease and SES across the world. There could be potential confounders that may have led to finding a positive association between meningococcal disease and low SES in the UK during this time.

All of the UK studies, except for Heyderman et al., 2004 had a small sample size of less than 500 and this could potentially lead to associations between low SES and IMD incidence by chance. (21, 26, 29, 41, 43) In this study from 2010–2020, the study population was 2,394. For future analyses, earlier IMD data from the late 1990s could be retrieved to increase statistical power. Further to this, this

study had no controls (similar to the five UK studies), limiting the analysis and comparisons that can be made with socio-economic index.

In this study, the younger population < 10 years age group reported the highest notification rate of serogroup B IMD (compared to other serogroups) and a high proportion were living in areas of low socio-economic index. However, in our logistic regression analysis for all cases and other covariates, age-group, Aboriginal and/or Torres Strait Islander status, month and jurisdiction, there was no independent association between serogroup B and socio-economic index. Age was found to be an important predictor of serogroup B IMD notifications in the regression analysis. Further investigation in comparing age groups by serogroup and socio-economic index decile could present associations.

Children and adolescents are well known to be at-risk populations for meningococcal disease around the world. In the UK, US and NZ, serogroup B was the dominating serogroup B among the younger age group (< 10 years). (10, 11, 13) This is consistent with our findings in Australia from 2010 to 2020 and suggestive that national policy for meningococcal B vaccination should focus on vaccinating the younger population of Australia.

In South Australia, a state-wide MenB immunisation program for children aged 6 weeks to 12 months commenced in October 2018, including a catch-up program for those 12 months to less than 4 years of age (17) The program expanded to include grade 10 students with a catch-up program for grade 11 students and those aged 17 to < 21 years. (17) The state-wide MenB immunisation program was initiated to account for the high notification rate of meningococcal B notifications. (28) In early 2020, the catch-up program ceased but the program continues in other age groups, ages 6 weeks to 12 months and grade 10 students. (17) A nation-wide program will also benefit to lower rates of meningococcal B among younger populations in Australia.

There are some limitations of the study which should be considered when interpreting the findings. One limitation is the ecological nature of the study. Area-based indices have lower discriminatory power than individual score as there are

disadvantaged people living in advantaged areas. This could lead to bias, and we could not account for this in our analysis. Furthermore, the small number of notifications may have likely to have reduced power for analysis, increasing the analysis time period may have provided more accurate findings regarding an association between low SES and serogroup B notifications in Australia.

Conclusion

Serogroup B was the most dominant serogroup among IMD notifications in Australia from 2010 to 2020. There was a higher proportion of the younger population living in areas with low SES and a significant relationship between serogroup B and socio-economic index decile in < 5 years. However, there was no direct association between serogroup B IMD notifications and SES. The 2–4 years age group was the most important predictor of whether an IMD notification would be serogroup B over another serogroup. Vaccination strategies and policies should target and fund younger populations to reduce notifications of meningococcal B disease in Australia.

References

1. Australian Government Department of Health. Invasive meningococcal disease 2020 [Available from: <https://www1.health.gov.au/internet/main/publishing.nsf/Content/ohp-meningococcal-W.htm>]
2. National Centre for Immunisation and Respiratory Diseases. Meningococcal Disease: Causes and How It Spreads. 2022. [Available from: <https://www.cdc.gov/meningococcal/about/causes-transmission.html>]
3. Stuart JM, Cartwright KA, Robinson PM, Noah ND. Effect of smoking on meningococcal carriage. *Lancet*. 1989;2(8665):723-5.
4. Olbrich, KJ, Muller D, Schumacher S, Beck, E. Systematic Review of Invasive Meningococcal Disease: Sequelae and Quality of Life Impact on Patients and Their Caregivers. *Infect Dis Ther*. 2018; 7:421–438.
5. Jafri RZ, Ali A, Messonnier NE, Tevi-Benissan C, Durrheim D, Eskola J, et al. Global epidemiology of invasive meningococcal disease. *Popul Health Metr*. 2013;11(1):17.
6. Lahra MM, George CRR, Shoushtari M, Hogan TR. Australian Meningococcal Surveillance Programme Annual Report, 2020. *Commun Dis Intell* (2018). 2021;45.
7. Centres for Disease Control and Prevention. Meningococcal Disease: Surveillance 2022 [Available from: <https://www.cdc.gov/meningococcal/surveillance/index.html>]
8. Public Health England. Invasive meningococcal disease in England: annual laboratory confirmed reports for epidemiological year 2019 to 2020. 2021.[Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/951142/hpr0121_imd-ann.pdf]
9. Institute of Environmental Science and Research. Invasive Meningococcal Disease Quarterly Report. 2019.[Available from: https://surv.esr.cri.nz/PDF_surveillance/MeningococcalDisease/2019/MeningococcalDisease_Q3_2019.pdf]
10. Centres for Disease Control and Prevention. Meningococcal Disease Surveillance. 2021. [Available from: <https://www.cdc.gov/meningococcal/surveillance/index.html>]
11. de Santayana CP, Htar MTT, Findlow J, Balmer P. Epidemiology of invasive meningococcal disease worldwide from 2010–2019: a literature review. *Epidemiology and Infection*. 2023;151,e57:1–9.
12. National Centre for Immunisation Research and Surveillance. Meningococcal vaccines for Australians: Factsheet 2020 [Available from: https://ncirs.org.au/sites/default/files/2020-06/Meningococcal%20vaccines%20for%20Australians%20fact%20sheet_1%20July%202020_Final_0.pdf]
13. Centres for Disease Control and Prevention. Enhanced Meningococcal Disease Surveillance Report, 2019. In: National Centre for Immunisation and Respiratory Diseases. [Available from: <https://www.cdc.gov/meningococcal/downloads/NCIRD-EMS-Report-2019.pdf>]

14. Lahra MM, Hogan TR. Australian Meningococcal Surveillance Programme annual report, 2019. Communicable Diseases Intelligence. 2020;44. [Available from: [https://www1.health.gov.au/internet/main/publishing.nsf/Content/AD2DF748753AFDE1CA2584E2008009BA/\\$File/australian_meningococcal_surveillance_programme_annual_report_2019.pdf](https://www1.health.gov.au/internet/main/publishing.nsf/Content/AD2DF748753AFDE1CA2584E2008009BA/$File/australian_meningococcal_surveillance_programme_annual_report_2019.pdf)]
15. Tapsall J. Annual report of the Australian Meningococcal Surveillance Programme. The Australian Meningococcal Surveillance Programme. 2003; 27(2). [Available from: [https://www1.health.gov.au/internet/main/publishing.nsf/Content/cda-2003-cdi2702-pdf-cnt.htm/\\$FILE/cdi2702f.pdf](https://www1.health.gov.au/internet/main/publishing.nsf/Content/cda-2003-cdi2702-pdf-cnt.htm/$FILE/cdi2702f.pdf)]
16. Veitch MG, Owen RL. Rise in invasive serogroup W meningococcal disease in Australia 2013-2015. Commun Dis Intell Q Rep. 2016;40(4):E451-E3.
17. National Centre for Immunisation Research and Surveillance. Significant events in meningococcal vaccination practice in Australia 2020 [Available from: <https://www.ncirs.org.au/sites/default/files/2021-02/Meningococcal-history-Feb%202021.pdf>]
18. Archer BN, Chiu CK, Jayasinghe SH, Richmond PC, McVernon J, Lahra MM, et al. Epidemiology of invasive meningococcal B disease in Australia, 1999-2015: priority populations for vaccination. Med J Aust. 2017;207(9):382-7.
19. National Centre for Immunisation Research and Surveillance. Significant events in meningococcal vaccination practice in Australia 2020 [Available from: <https://ncirs.org.au/sites/default/files/2020-07/Meningococcal-history-July%202020.pdf>]
20. National Centre for Immunisation Research and Surveillance. Meningococcal B vaccination - a guide for healthcare providers. 2021. [Available from: <https://www.ncirs.org.au/meningococcal-b-vaccination-a-guide-for-healthcare-providers>]
21. Baker M, McNicholas A, Garrett N, Jones N, Stewart J, Koberstein V, et al. Household crowding a major risk factor for epidemic meningococcal disease in Auckland children. Pediatr Infect Dis J. 2000;19(10):983-90.
22. Burgess S. Social and environmental influences affecting the risk of development of meningococcal disease: considerations for prehospital care. Australasian Journal of Paramedicine. 2015;4(1).
23. Heyderman RS, Ben-Shlomo Y, Brennan CA, Somerset M. The incidence and mortality for meningococcal disease associated with area deprivation: an ecological study of hospital episode statistics. Arch Dis Child. 2004;89(11):1064-8.
24. Lundbo LF, Benfield T. Risk factors for community-acquired bacterial meningitis. Infect Dis (Lond). 2017;49(6):433-44.
25. Massey P, Durrheim D. Aboriginal and Torres Strait Islander peoples at higher risk of invasive meningococcal disease in NSW. N S W Public Health Bull. 2008;19(5-6):100-3.
26. Stuart JM, Middleton N, Gunnell DJ. Socioeconomic inequality and meningococcal disease. Commun Dis Public Health. 2002;5(4):327-8.
27. Taha MK, Weil-Olivier C, Bouee S, Emery C, Nachbaur G, Pribil C, et al. Risk factors for invasive meningococcal disease: a retrospective analysis of the French national public health insurance database. Hum Vaccin Immunother. 2021;17(6):1858-66.

28. Williams CJ, Willocks LJ, Lake IR, Hunter PR. Geographic correlation between deprivation and risk of meningococcal disease: an ecological study. *BMC Public Health*. 2004;4:30.
29. de Oliveira Costa J, Gianacas C, Beard F, Gonzalez-Chica D, Chidwick K, Osman R, et al. Cumulative annual coverage of meningococcal B vaccination in Australian general practice for three at-risk groups, 2014 to 2019. *Hum Vaccin Immunother*. 2021;17(10):3692-701.
30. Marshall HS, Lally N, Flood L, Phillips P. First statewide meningococcal B vaccine program in infants, children and adolescents: evidence for implementation in South Australia. *Med J Aust*. 2020;212(2):89-93.
31. Fone DL, Harries JM, Lester N, Nehaul L. Meningococcal disease and social deprivation: a small area geographical study in Gwent, UK. *Epidemiol Infect*. 2003;130(1):53-8.
32. Kriz P, Bobak M, Kriz B. Parental smoking, socioeconomic factors, and risk of invasive meningococcal disease in children: a population based case-control study. *Arch Dis Child*. 2000;83(2):117-21.
33. Communicable Diseases Network Australia. Invasive meningococcal disease - Surveillance case definition. 2022. [Available from: <https://www.health.gov.au/diseases/meningococcal-disease>]
34. Australian Bureau of Statistics. Socio-Economic Indexes for Areas 2022 [updated 06 May 2022. Available from: <https://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa>]
35. Australian Bureau of Statistics. Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016 2018 [Available from: <https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2033.0.55.001~2016~Main%20Features~IRSD~19>]
36. Australian Bureau of Statistics. National, state and territory population, Jun 2020 [Available from: <https://www.abs.gov.au/how-cite-abs-sources>]
37. Australian Bureau of Statistics. Population estimates by age and sex, by LGA, 2020 [Available from: <https://www.abs.gov.au/statistics/people/population/regional-population-age-and-sex/2020#data-download>]
38. Australian Bureau of Statistics. Population estimates by age and sex, by LGA, 2019 2019 [Available from: <https://www.abs.gov.au/statistics/people/population/regional-population-age-and-sex/2019#data-download>]
39. Australian Bureau of Statistics. Population estimates by age and sex, Local Government Areas (ASGS 2018), 2018 2018 [Available from: <https://www.abs.gov.au/statistics/people/population/regional-population-age-and-sex/2018#data-download>]
40. Australian Bureau of Statistics. TABLE 59. Estimated Resident Population By Single Year Of Age, Australia 2019 [Available from: <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Jun%202019>]
41. Australian Bureau of Statistics. Population by age and sex - national 2021 [Available from: <https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release#data-downloads-data-cubes>]
42. Australian Bureau of Statistics. Table 5: Estimated resident and projected population, Aboriginal and Torres Strait Islander Australians, series B,

single year of age, Australia, states and territories – 2006 to 2031. [Available from: <https://www.abs.gov.au/statistics/people/aboriginal-and-torres-strait-islander-peoples/estimates-and-projections-aboriginal-and-torres-strait-islander-australians/2006-2031>]

43. Adams J, Ryan V, White M. How accurate are Townsend Deprivation Scores as predictors of self-reported health? A comparison with individual level data. *J Public Health*. 2004;27(1):101-6.
44. Olowokure B, Onions H, Patel D, Hooson J, O'Neill P. Geographic and socioeconomic variation in meningococcal disease: a rural/urban comparison. *J Infect*. 2006;52(1):61-6.
45. McLennan D, Barnes, H., Noble, M., Davies, J., Garratt, E., and Dibben, C. The English Indices of Deprivation 2010. In: Department for Communities and Local Government, editor.: *Communities and Local Government*,; 2011.
46. Hughes GJ and Gorton R. Inequalities in the incidence of infectious disease in the North East of England: a population-based study. *Epidemiol Infect*. 2015;143(1):189-201.
47. Maguire JE. *Infectious Disease Epidemiology in the Asia-Pacific Region*: Australian National University; 2019. [Available from: <https://openresearch-repository.anu.edu.au/handle/1885/164111>]

Chapter 6

New South Wales and the War of Delta

The public health response to
SARS-CoV-2 transmission in New South
Wales

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Preface

This chapter details my two major experiences during the New South Wales Delta outbreak from June to December 2021. My first experience was working at the Western Sydney Public Health Unit to assist with contact tracing. The second experience was working on the New South Wales schools SARS-CoV-2 transmission project.

MAE competencies addressed

- Investigate an acute public health problem or threat
- Analyse a public health dataset
- Communicate to a lay audience

Public Health Response at the Western Sydney Public Health Unit

Background

From 16 June 2021, New South Wales (NSW) experienced its biggest outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to date and its first of the Delta (B.1.617.2) strain. The months following June involved a combination of pressure on contact tracers, laboratory testing, hospitals, and the health care workforce. This resulted in economic disruption, stress upon individuals and the entire community. In the early days of the Delta outbreak, my fellow MAE scholar, Zoe Croker and I got in contact with the Western Sydney Public Health Unit (WSPHU) to assist in contact tracing. This section includes reflections and learnings as a first time contact tracer.

My role

From 13–31 July 2021, my role at the WSPHU as a contact tracer involved contacting and following-up with COVID-19 cases and close contacts. This included conducting case interviews, recording information on the Notifiable Conditions Information Management System (NCIMS), disseminating information on isolation and quarantine requirements, communicating with the COVID-19 response team, including the Medical Advisor and the Team Leader, finding epidemiological links, and submitting relevant referrals, such as Special Health Accommodation (SHA), Integrated Chronic Care Program (ICCP), COVID-19 Outpatient Response Team (CORT), and disaster relief.

Lessons learnt

My short stay at the WSPHU taught me lessons for my career life. Contact tracing is not just collecting facts, but an art of reading the case's situation. Contact tracing is also extremely time consuming with many different processes required to assess each case. I learned that the difficulty of the COVID-19 outbreak in NSW was not necessarily because of the shortage of staff nor the inability to isolate people in a timely manner. I became aware that the challenges associated with controlling and responding to the outbreak in NSW was influenced by a multitude of social and economic factors in vulnerable groups. Finally, I enjoyed

learning the clinical and epidemiological component of contact tracing, such as observing the rapid increase of viral load in close contacts through PCR test results and the effects of vaccination.

Acknowledgements

I would like to first thank the WSPHU staff, especially Dr. Shopna Bag for welcoming me and Zoe Croker to the contact tracing team during one of the most stressful times of the pandemic in 2021. Thank you to all staff who guided and trained me, particularly Alison, Kate and Silvia. Thanks to Ling, Conrad, Penny, Jenny, Stephen and Tracy for answering all my questions. With the increasing number of new daily cases in local government areas in Western Sydney, the team never failed to be composed, and so hardworking even into the late hours of the night. The team was always prepared for every challenge, with a surplus supply of snacks.

Reflection

After each shift, I made a short diary entry, noting what happened, what I learnt and what I wish could have been done better. Below is a summary of my entries.

Shift 1 (Morning)

On my first day, there was a team meeting at 9am, where I was introduced to the team, there was a debrief of what had happened the night before and roles were allocated. The team consisted of the public health unit controller, medical advisor, the Operations Team Leader, contact tracers and risk assessment team members. I shadowed a contact tracer and learnt two things:

- 1) The contact tracer can provide disaster relief packages to cases who do not have access to groceries,
- 2) If a case does not answer their phone multiple times, the PHU can request for the Police Operations Centre Liaison Officer (POCLO) and the Police will intervene by a home visit.

Shift 2 (Morning)

In the morning, I was taught how to navigate and record information on NCIMS. After lunch, I had the opportunity to sit through a full COVID-19 case interview. Interesting points about this case:

- 1) initial negative PCR result but returned a positive result after nine hours
- 2) case was asymptomatic at time of interview.

There was a debrief with the Medical Advisors and Team Leads after the interview, where the contact tracer explained the situation, and everyone discussed on next steps. An executive decision on isolation requirements was made and communicated to the case's household. Before my shift ended, I sent emails, updated notes on NCIMS and on the team board. A way of visualising transmission between cases on NCIMS would have enhanced the investigation. It would also be good to have one system that can hold and utilise information, rather than recording same information across different interfaces (Microsoft Teams Excel, NCIMS, hard drive, whiteboards).

Shift 3 (Morning)

Today was a lesson on the benefit of the doubt. Family members who lived in separate dwellings (after checking on Google maps) insisted they had no contact with each other but were found to be PCR positive. Identifying and communicating with other household members to request PCR testing was essential. In the afternoon, I had the opportunity to conduct my first case interview with supervision. I was a little nervous but excited that I could do finally do a case interview! I already knew about the case's household situation, so it was not a difficult interview. Afterwards, there was a quick debrief with the Medical Advisors, and we confirmed because all household members are now positive, there was no need to request for Special Health Accommodation. Special Health Accommodation is provided by NSW Health for people who cannot isolate at home.

Shift 4 (Morning)

Saturday morning was quiet, and I made attempts to call private laboratory clinics to confirm PCR results of close contacts. In the early afternoon, a laboratory

notification came through. It was my first time doing a case interview without any support. The interview was very long (over an hour) because the case was a logistics truck driver and had travelled to several locations across NSW. I created handover notes for the afternoon shift. An in-depth risk assessment was made for this case due to the many high-risk places they visited during their infectious period. I also tracked the housemate of the case, and they had become a positive case; a single Pfizer dose had not protected them against infection (as they only had received the dose six days prior).

Shift 5 (Morning)

In the morning, I was asked to chase up PCR test results from close contacts involved in a high-risk venue (a medical centre). This involved calling close contacts, checking PCR results, updating the line list, and sending it through to a senior staff member. Afterwards, I assisted a social worker with a case interview. We didn't know at that point in time, but we started an investigation of the largest super-spreading event I knew at the WSPHU (with more than 100 people ended up testing positive). The primary household involved had many family members with a complex household situation. Only one of the children could speak English well and the parents required translation services. The social worker used Translating and Interpreting Services (TIS) and I had the opportunity to observe. The contact tracer aimed to understand the family situation and obtain information on who was living in the household.

Shift 6 (Night)

My first night shift was unexpectedly busy with long phone calls, but the PHU was quiet, making it easier to focus. The case I was working on contracted the virus at a high-risk venue but didn't comply with isolation requirements and was found to be positive at their exit swab on day 13. Initially, I thought the case was asymptomatic. The case reported diarrhoea on day 5 which they thought was from 'off-food'. The case also reported having a runny nose on day 7, which they thought was from being in the cold. After debriefing with the Team Lead and Medical Advisor, we found that the symptoms were likely COVID-19 related, low viral load was deemed the possible reason for a negative PCR test on day 7. The case was not fluent in English, and I used TIS. The landlord living with the case

was furious and anxious about what had happened, it took a long time to comfort and help the landlord to relax using TIS. On this shift I spent more than four hours using TIS services. It was a challenging night where I listened to a foreign language and sent emails in a foreign language. A big thank you to the interpreters who helped me on that night.

Shift 7 (Morning)

Today I had an interesting shift because it was my first-time interviewing hotel quarantine cases. A family of five arrived in Sydney and tested negative before their flight. But after 12 days in Sydney, one of the children became positive. The family was then moved to the Special Health Accommodation and family members were split up. The mother (who was with the COVID-19 positive child) tested positive three days later, and another sibling (in a different room) became positive four days later. After a debrief with the Team Lead, we thought that the primary case likely acquired the infection in hotel quarantine, rather than on the flight because of the long incubation period.

Shift 8 (Night)

On this shift, I worked on two cases. By this time (end of July), the source of infection for many cases were unknown (usually before the case interview we were able to make connections and identify who and where the case may have contract the virus). This meant interviews took longer to obtain the all the necessary information. PHUs were seeking assistance from other PHUs and interstate health departments were helping with contact tracing. The first case I interviewed was thought to have acquired the virus from their household. This household member was later found to have acquired COVID-19 from a childcare centre they worked in. The second case contracted the virus from tenants who lived downstairs in the same dwelling. The tenants had been sent off to the SHA. To end the shift, I sent through Integrated Chronic Care Program (ICCP) referrals, which allows clinicians follow-up on the progress of cases who are at home. None of the cases were vaccinated.

Final thoughts

My time at the WSPHU was an eye opening and a fast-paced learning experience of COVID-19 contact tracing. Being exposed to many acronyms, processes and steps was challenging and I had to quickly adapt to the expectations and environment of the WSPHU. It was a serious time where NSW was under strict lockdowns. Even during contact tracing, we were wearing masks and following social distancing measures. As someone who jumped into the middle of the outbreak, it would have been effective to have a flow chart of processes and a list of important phone numbers for contact tracers in each room.

One of the frustrations I had in my time at the WSPHU was the sociocultural barriers between us as public health practitioners and the public. Western Sydney is one of the most culturally diverse areas in NSW, however I felt I was not aware of the support that local communities could receive. The language barrier, poor health literacy, and lack of information available in other languages slowed down the process of contact tracing. If we could refer these vulnerable groups to a community that could communicate and provide information (just like the PHU but in a socially and culturally appropriate way), we may have had much better outcomes.

Another big issue was on data management and visualisation. There was a need to have built in data visualisation tools to understand chains of transmission quickly - rather than using a whiteboard! A single health information system to keep all information would also be of benefit, rather than duplicating efforts.

Below is a summary of my understanding at the time of the steps and processes undertaken in contact tracing at the WSPHU (Figure 1).

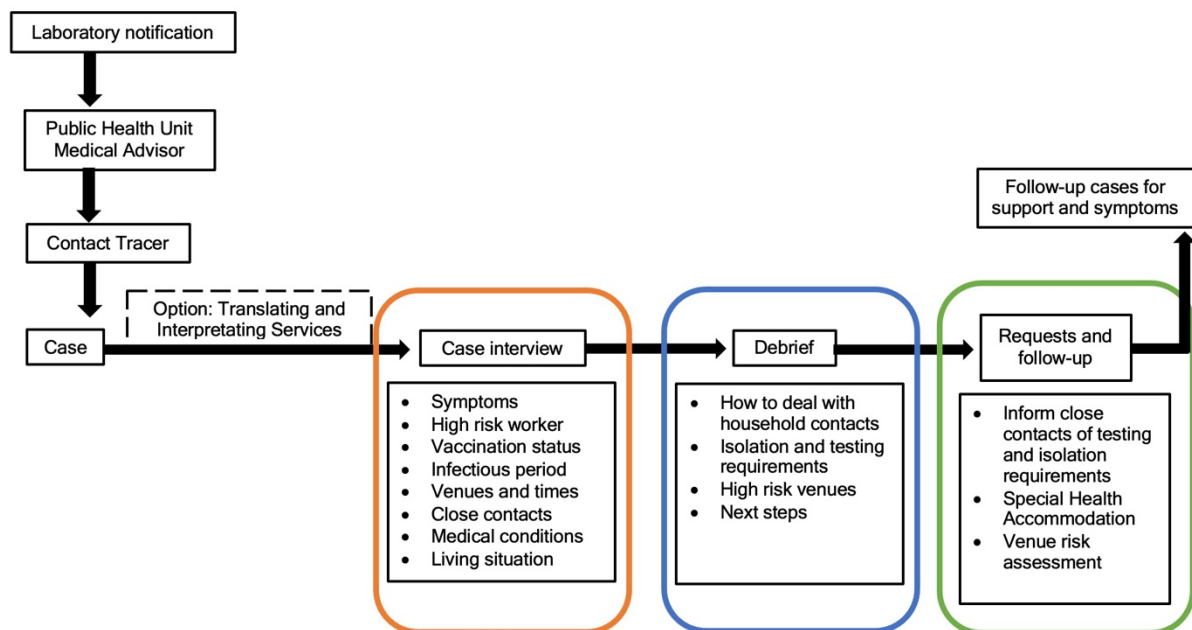


Figure 1. Steps and processes undertaken for COVID-19 contact tracing in the Western Sydney Public Health Unit, Australia, July 2021

Transmission of SARS-CoV-2 in educational settings in New South Wales

Background

During the Delta outbreak in NSW from June to December 2021, there was a rapid increase in SARS-CoV-2 transmission compared to ancestral strains. The National Centre for Immunisation Research and Surveillance (NCIRS) with the support of the NSW Ministry of Health and NSW Department of Education conducted surveillance of SARS-CoV-2 transmission in NSW educational settings in 2020 and 2021. With increasing educational settings affected due to transmission of the Delta (B.1.617.2) variant from June 2021, I was asked to assist with surveillance.

My role

My role from June to December 2021 involved various tasks within the school's team. During this time, I was tasked with investigating suspected SARS-CoV-2 transmission in 13 educational settings. My primary role was to check PCR results of close contacts (using the class list with student and teacher names) for three time points: days 0–5, days 6–9, and days 10–21. For the primary case from the educational setting, other information on household members, vaccination status, and infectious period were recorded. Details of any secondary cases and their household contacts were also recorded. I was the lead author for the end of Term 3 public summary report for this surveillance work, which included writing on the epidemiology of COVID-19 outbreak in NSW, calculating the number and proportion of primary cases vaccinated across NSW educational setting, and analysing transmission by educational setting and household contacts. Preparation of this report involved a large amount of data cleaning and following up of missing data.

Lessons learnt

My experience with the schools SARS-CoV-2 transmission work taught me that surveillance is all about teamwork. I had always thought data analysis was a solitary task, but in a situation where we were dealing with a large volume of data in real-time, without a team, it would not have been possible. Looking up cases

and close contacts, entering data, ensuring data was consistent across different Microsoft Excel spread sheets was very time consuming. However, without the effort of data collection and entry, there would be no data to analyse and no findings. This was the first time I calculated attack rates and made use of pivot tables for analysis.

Acknowledgements

I would like to thank the schools team at NCIRS, especially Dr Helen Quinn and Dr Archana Koirala for the opportunity to be involved in the school transmission work. A big thank you to Helen and second year MAE, Noni Winkler, for helping me understand how to calculate attack rates, navigate through the data sets and answering all my questions. Thank you so much Evie for your assistance on data cleaning, we made a great team and thank you for your support! I acknowledge Noni's work on calculating secondary attack rates by vaccination status. Thank you, Archana and Professor Kristine Macartney, for your comments and support for the final report. And many thanks to Salema for her patience in the development of infographics. Thank you Deepika for your edits in the final process of the publication.

Communication to a lay audience

In November 2021, there was a request to write up the public facing summary for the end of Term 3 work for school transmission of SARS-CoV-2. Until Term 3, the highest number of educational settings having transmission per term was 51. But in Term 3, there were 531 exposure events, and the report ended up becoming a much bigger task than first anticipated. The summary report was for a lay audience that would have a high interest in understanding surveillance data. This report was written to fulfil the MAE competency of communicating a lay audience. The final report was published on 18 February 2022 and is available on the [NCIRS website](#). Below is a copy of the final report (Appendix A).

Appendix A – Lay summary report



COVID-19 in schools and early childhood education and care services – the experience in NSW: 16 June to 17 September 2021

Prepared by the National Centre for Immunisation Research and Surveillance (NCIRS)

18 February 2022

Overview

- This report provides an overview of SARS-CoV-2 Delta (B.1.617.2) variant transmission in all schools and early childhood education and care (ECEC) services and associated households in New South Wales (NSW), Australia during the Delta variant outbreak between **16 June 2021 and 17 September 2021** (end of school term 3).
- Data are reported for primary (first) cases in schools (between 16 June and 17 September) and ECEC services (between 16 June and 31 August), with school and ECEC close contacts and household contacts of secondary cases followed for 30 days following school or ECEC exposure.
- From 25 June 2021, stay-at-home orders (lockdown) were implemented, initially in Greater Sydney and then the entire state of NSW. Schools resumed for Term 3 on 12 July 2021 via online teaching, but remained open for students who required onsite attendance. A range of COVID-19 mitigation measures, including mandatory mask use for adults and high school students, were implemented from 12 July 2021. Vaccination rates were low in working age adults at outbreak onset (16 June 2021), but reached 73% for dose 1 and 47% for dose 2 in the population aged ≥16 years in NSW by 17 September 2021.
- In this reporting period, there were 44,734 notifications of locally acquired COVID-19 cases in NSW (population 8.1 million). Of these, 12,455 (27.8%) were among those aged 0 to ≤18 years.
- Overall, there were 531 exposure events in educational settings, with 614 individuals (380 students [61.9%] and 234 staff members [38.1%]) identified as primary COVID-19 cases, who had an opportunity to transmit SARS-CoV-2 to others in their school or ECEC service. Of these 531 events, 339 (involving 397 primary cases) were reviewed in detail and data are presented in this report. The majority of primary cases (93.7%) were unvaccinated.
- From the 339 events, 14,509 individuals (11,254 students [77.6%] and 3,255 staff members [22.4%]) were identified as close contacts of the 397 primary cases. The majority of close contacts (13,869 of 14,509; 95.6%) underwent SARS-CoV-2 nucleic acid testing; 636 were identified as secondary cases, resulting in an overall secondary attack rate among close contacts in educational settings of 4.6%. The secondary attack rate from a 1- or 2-dose vaccinated primary case was lower at 3.3%.
- For the 636 secondary cases 1,536 household contacts were identified; 914 of these became infected with SARS-CoV-2, resulting in a household contact attack rate of 59.5%.
- Transmission rates in schools and ECEC services during this SARS-CoV-2 Delta variant outbreak in NSW (4.6%) were approximately five times higher than those with the ancestral strain of SARS-CoV-2 in NSW in 2020 (0.9%), despite limited school attendance and community lockdowns (see previous NCIRS reports [here](#) and publication [here](#)).
- Increasing COVID-19 vaccination rates (including in those aged ≥12 years) and numerous social and public health measures to reduce transmission in educational settings and the community underpinned a return to face-to-face learning in Term 4 2021. For more information, refer to [NSW Health website](#).

Background

The National Centre for Immunisation Research and Surveillance (NCIRS), with the support of the NSW Ministry of Health and NSW Department of Education, has been conducting surveillance of SARS-CoV-2 transmission in educational settings (schools and early childhood education and care [ECEC] services) since the start of the COVID-19 pandemic 2020 in New South Wales (NSW), Australia. NSW has a population of 8.1 million, with about 1.8 million residents aged ≤18 years. The state has approximately 3,100 schools and 5,800 ECEC services.

NSW experienced an outbreak of the SARS-CoV-2 Delta (B.1.617.2) variant¹ from 16 June 2021 to October 2021. The first cases in schools were identified on 18 June 2021. Stay-at-home orders (lockdown) were implemented in Greater Sydney (36 local government areas [LGAs]) from 25 June 2021 and a state-wide lockdown (128 LGAs) from 14 August 2021. Stay-at-home orders were eased on 11 October 2021.

The start of the Greater Sydney lockdown coincided with the commencement of the 2-week winter school holiday period (end of Term 2). During that time, ECEC, vacation care and out-of-school-care (care before and after school) services were kept open. NSW schools commenced Term 3 on 12 July 2021 via online teaching in the Greater Sydney area, but remained open for any student who required onsite attendance (e.g. children of essential workers, vulnerable children and students who required onsite attendance). Mitigation measures were implemented using the [NSW tiered COVID-19 safe schools operation plan](#); all adults and high-school students were required to wear masks. Adults (including staff members) were required to sign in and out (using QR code system), and non-essential adults were allowed limited entry in educational settings. Primary school and ECEC children were not required to wear masks.

For more information on the outbreak response, visit [NSW Health website](#). Refer also to [NSW public health orders and restrictions](#).

At the beginning of the Delta variant outbreak on 16 June 2021, among those aged ≥16 years in NSW, 21% had received dose 1 and 4% had received dose 2 of a COVID-19 vaccine. In mid-July, school staff working in LGAs of concern were prioritised for vaccination² and it was mandatory for childcare workers who live or work in the LGA of concern to have their first vaccination dose by 30 August 2021.³ From 6 September 2021 all school and ECEC services staff state-wide were prioritised for vaccination.⁴ The peak number of new COVID-19 notifications in NSW occurred on 10 September 2021 and at that point 70% of the NSW population aged ≥16 years had received dose 1 and 41% had received dose 2 of a COVID-19 vaccine, with coverage in those aged 12–15 years growing since vaccination commenced in that age group from 13 September 2021. Refer to [Figure 1](#) for vaccination coverage rates in people aged ≥16 years during the period 16 June 2021 to 17 September 2021.

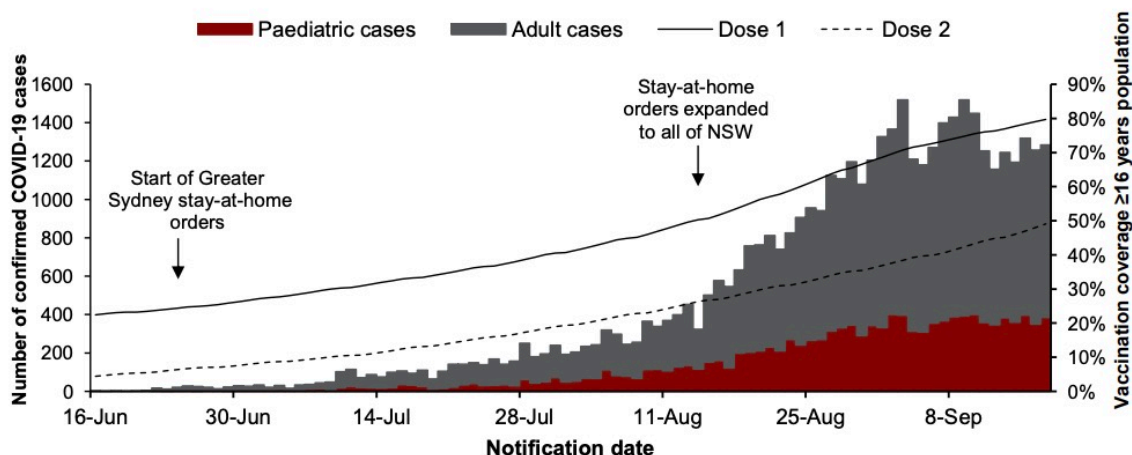
The Delta (B.1.167.2) variant of concern (VOC) became the predominant global strain throughout early-mid 2021 and was estimated to be 97% (76–117%) more transmissible than the Alpha VOC.² On 26 November 2021, the World Health Organization (WHO) announced that the Omicron (B.1.1.529) variant, first identified in South Africa, was a new VOC. The data presented in this report pre-date the emergence of the Omicron variant in Australia.

Brief overview of the epidemiology of the COVID-19 Delta variant outbreak in NSW

A total of 44,734 locally acquired COVID-19 cases were notified between 16 June 2021 and 17 September 2021. Of these, 12,455 (27.8%) cases were in children and young people (refer to [Figure 1](#)): 3,691 (29.6%) were aged 0–5 years; 4,382 (35.2%) were aged 6–12 years; and 4,382 (35.2%) were aged 13–18 years.

Of all NSW COVID-19 cases in children and young people, where the investigation of the source of infection had been completed up to 17 September 2021, 5,970/12,455 (47.9%) were reported to have acquired infection from household contacts. Forty-eight (0.4%) children and young people with COVID-19 were identified as Aboriginal and/or Torres Strait Islander. Numbers have been calculated from publicly available data on COVID-19 from NSW Health.⁵

Figure 1: COVID-19 cases in NSW, by age and notification date, 16 June 2021 to 17 September 2021 with vaccination coverage (dose 1 and dose 2) in adults aged 16 years and older*



Term 2	School Holidays	Term 3
Schools fully open Limited mitigation strategies Signing in required by non-essential adults	Greater Sydney lockdown Rural and regional local government areas in lockdown from early August 2021 All of NSW in lockdown from 14 August 2021 Schools open for vulnerable children and children of essential workers Mask use for anyone aged >12 years (excluding people who may not tolerate masks such as people with disability) No parents onsite All extracurricular activity cancelled ECEC services (childcare) fully open From 6 September 2021 all school and ECEC staff state-wide prioritised for vaccination	

* Vaccination in adolescents aged 12–15 years commenced on 13 September 2021.

Methods

All NSW schools and ECEC services that had a child or adolescent aged ≤18 years and/or adult with laboratory-confirmed COVID-19 attend while infectious (defined as 48 hours before symptom onset, based on national guidelines) were investigated to determine onward transmission in close contacts from the educational setting.

A 'close contact' was defined as a person in the same class or who had face-to-face contact with a case while infectious (i.e. during their symptomatic period and 48 hours before symptom onset). All close contacts were required to quarantine for 14 days from their last exposure date. A 'casual contact' was defined as a person who was onsite at the school or ECEC service at the same time as the case but did not meet the definition of a close contact. Casual contacts were required to quarantine for 5 days. Both close and casual contacts were required to undergo SARS-CoV-2 nucleic acid testing before de-isolation. If any casual contact tested positive, all contacts at the educational setting were upgraded to 'close contacts'.

This report includes data on all schools where a primary (first) case(s) occurred between 16 June 2021 and 17 September 2021. For ECEC services, this report covers primary cases between 16 June 2021 and 31 August 2021; data collection ceased on 31 August 2021 due to the large volume of data that had already been collected. All contacts were followed up until 15 October 2021.

Household transmission from school or ECEC secondary cases were followed up for 28 days following exposure between 16 June 2021 and 18 October 2021. Data on who infected who in households were identified by data matching and manual review of case notes collected during contact tracing interviews.

Full details of our methods can be found in our previous [reports](#) and [publication](#).⁶

Results

From 16 June 2021 to 17 September 2021, there were 531 COVID-19 exposure events in schools and ECEC services, involving 614 primary (first) cases (380 students and 234 staff members), as shown in [Figure 2](#). Nearly half of the primary cases (45%) acquired COVID-19 through household contacts, with the remainder from an unknown source or community non-household contacts. The frequency of COVID-19 exposure events increased as community incidence of COVID-19 increased over the study period.

In this reporting period (excluding ECEC services in September 2021), there were 386 COVID-19 exposure events and 454 primary cases. Contact lists were available for review for 28/28 (100%) high schools; 146/165 (88%) primary schools; 9/20 (45%) K–12 schools; 17/17 (100%) schools for specific purposes (SSP); and 139/156 (89%) ECEC services. Therefore, in total 339 exposure events from 397 primary cases were reviewed (240 students and 157 staff members) for this report.

Of the 14,509 close contacts (11,254 students and 3,255 staff members) identified for the 397 primary cases, nearly all (95.6%; n=13,869) underwent nucleic acid testing on at least one occasion following the exposure.

Secondary transmission occurred in 40.4% of the COVID-19 exposure events (137/339): there were 2 events in high schools [2/28; 7.1%]; 59 in primary schools [59/146; 40.4%]; 5 in K–12 schools [5/9; 55.6%]; 6 in SSP [6/17; 35.3%]; and 65 in ECEC services [65/139; 46.8%].

Of the 397 primary cases, a total of 636 close contacts (493 students and 143 staff members from the 13,869 close contacts) were infected with SARS-CoV-2, giving an overall secondary attack rate of 4.6% (refer to [Table 2](#)). Higher secondary attack rates occurred when the primary case was an adult staff member as compared with a child or an adolescent. The highest transmission rate occurred in ECEC services between staff members (13.4%) and from staff members to any contact (10.2%) followed by K–12 settings between staff members (16.1%).

The majority (93.7%) of primary cases at the time of this study were unvaccinated (refer to [Table 1](#)). Twenty-five staff members were vaccinated with at least one dose.

Table 1: Number and proportion of primary cases vaccinated across New South Wales educational settings followed up from 16 June 2021 to 17 September 2021

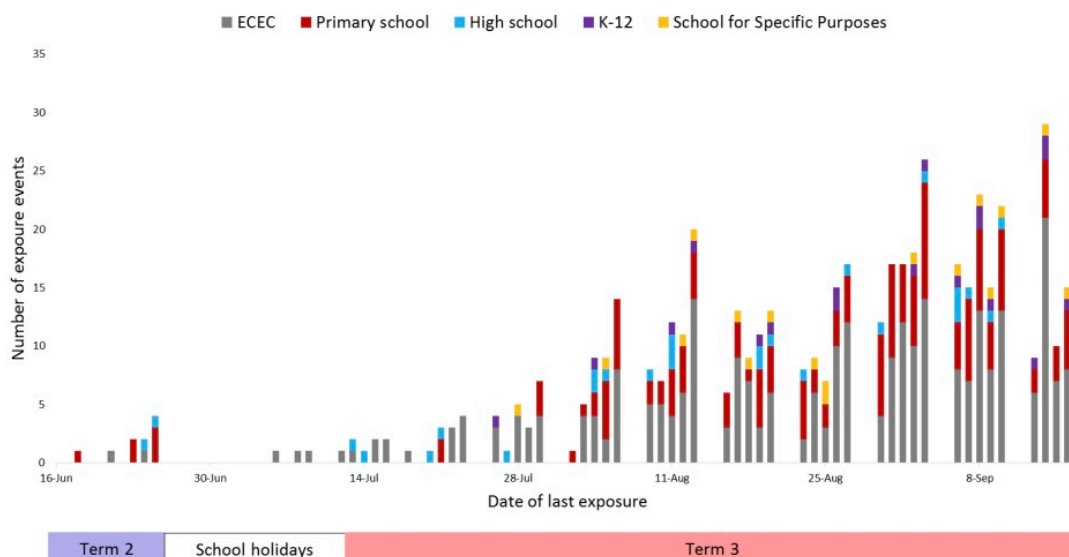
Number of primary cases per educational setting (%)						
Number of valid doses	High school	Primary school	K–12 school	Schools for specific purposes	Early childhood and education care	Total
2-Doses*	3 (10.3)	1 (0.5)	0 (0)	3 (15.0)	1 (0.6)	8 (2.0)
1-Dose†	2 (6.9)	6 (3.3)	0 (0)	5 (25.0)	4 (2.6)	17 (4.3)
Unvaccinated‡	24 (82.8)	177 (96.2)	10 (100)	12 (60.0)	149 (96.8)	372 (93.7)
Total	29 (100)	184 (100)	10 (100)	20 (100)	154 (100)	397 (100)

* 2-doses was defined as having two doses of vaccine, with the second dose at least 14 days prior to infection onset date and a minimum of 14 days between the two doses.

† 1-dose was defined by having one dose of vaccine at least 14 days prior to infection onset date.

‡ Unvaccinated was defined as having no vaccine or having 1 dose <14 days prior to infection onset date.

Figure 2: NSW schools and ECEC services with a COVID-19 event, 16 June 2021 to 17 September 2021



High schools

A total of 29 COVID-19 primary cases (19 students and 10 staff members) were identified in 28 high-school events. In one event there were co-primary cases (2 students). These 29 primary cases had 1,675 (1,414 students and 261 staff members) close contacts, 1,609 (96.1%) of whom underwent nucleic acid testing. A total of 46 secondary cases (40 students and 6 staff members) were identified across 2 schools (secondary attack rate 2.9%). Refer to [Figure 3](#).

Figure 3: Number of NSW high-school events with secondary transmission of COVID-19 between 16 June 2021 and 17 September 2021



2 out of 28 events with
secondary transmission

Primary schools

A total of 184 COVID-19 primary cases (136 students and 48 staff members) were identified in 146 primary school events. Thirty-five events had co-primary cases of students. Of the 6,196 close contacts identified (4,979 students and 1,217 staff members), 5,927 (95.7%) underwent nucleic acid testing. A total of 217 secondary cases (206 students and 11 staff) were identified in 59 of 146 events (40.4%). Refer to [Figure 4](#).

The overall secondary attack rate in primary schools was 3.7%, with the highest attack rate from student to student (4.4%). Refer to [Table 2](#).

Figure 4: Number of NSW primary school events with secondary transmission of COVID-19 between 16 June 2021 and 17 September 2021



Kindergarten to Year 12 (K–12) schools

A total of 10 COVID-19 primary cases (5 students and 5 staff members) were identified in 9 K–12 school events. One school had a co-primary case (student). Of the 182 close contacts identified (101 students and 81 staff members), 176 (96.7%) underwent nucleic acid testing. A total of 14 secondary cases (8 students and 6 staff members) were identified in 5 of 9 events (55.6%). Refer to [Figure 5](#).

The overall secondary attack rate in K–12 schools was 8.0%, the highest across all school settings. Refer to [Table 2](#) for further details. The secondary attack rate was highest (16.1%) between staff members.

Figure 5: Number of NSW K–12 school events with secondary transmission of COVID-19 between 16 June and 17 September 2021



Schools for specific purposes

A total of 20 COVID-19 primary cases (8 students and 12 staff members) were identified in 17 SSP events. Three schools had co-primary cases. These 20 primary cases had 470 (205 students and 265 staff) close contacts, 450 (95.7%) of whom underwent nucleic acid testing. A total of 25 positive secondary cases (16 students and 9 staff members) were identified in 6 of 17 events (35.3%). Refer to [Figure 6](#). The overall attack rate in SSP was 5.6%. Refer to [Table 2](#).

Figure 6: Number of NSW schools for specific purposes events with secondary transmission of COVID-19 between 16 June 2021 and 17 September 2021



ECEC services

A total of 153 COVID-19 primary cases (75 children and 78 staff members) were identified in 139 ECEC events until 31 August 2021. Fourteen events had co-primary cases. These 153 primary cases had 5,986 (4,555 children and 1,431 staff members) close contacts, 5,707 (95.3%) of whom underwent nucleic acid testing. A total of 334 secondary cases (223 children and 111 staff members) were identified in 65 of 139 events (46.8%). Refer to [Figure 7](#). The overall attack rate was 5.9% and the highest attack rate was between staff members (13.4%). Refer to [Table 2](#).

Figure 7: Number of NSW Early childhood education and care (ECEC) events with secondary transmission of COVID-19 between 16 June 2021 and 31 August 2021



Transmission in household contacts from secondary cases

A total of 1,536 household contacts were identified from the 636 secondary cases (493 students and 143 staff members) who came from 489 households. Of the 1,536 household contacts, 914 were infected with SARS-CoV-2 in 368 of the households, resulting in an attack rate of 59.5%. In two thirds of the households (234/368; 63.6%), all household members acquired SARS-CoV-2 infection. Refer to [Figure 8](#).

Figure 8: Household cases resulting from a secondary case in NSW educational settings between 16 June 2021 and 17 September 2021 (excluding early childhood and care services in September 2021)

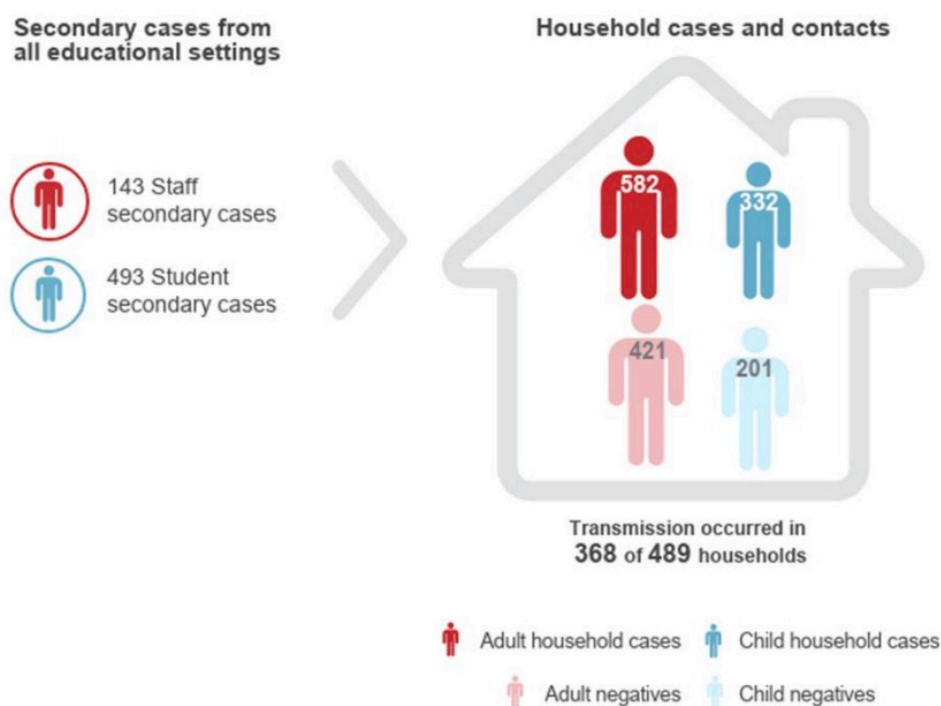


Table 2: Secondary attack rates of COVID-19 in educational settings, by primary and secondary case type and educational setting type, between 16 June 2021 and 17 September 2021*

Primary case type	Close contact type	Number of positive cases / total number of tested cases	Attack rate (%)
All settings			
Any	All	636/13869	4.6%
Adult	All	337/4759	7.1%
Adult	Adult	106/1317	8.0%
Adult	Child	231/3442	6.7%
Child	All	312/9405	3.3%
Child	Adult	41/1942	2.1%
Child	Child	271/7463	3.6%
K-12			
Any	All	14/176	8.0%
Adult	All	6/42	14.3%
Adult	Adult	5/31	16.1%
Adult	Child	1/11	9.1%
Child	All	8/134	6.0%
Child	Adult	1/50	2.0%
Child	Child	7/84	8.3%
High School			
Any	All	46/1609	2.9%
Adult	All	0/52	0.0%
Adult	Adult	0/49	0.0%
Adult	Child	0/3	0.0%
Child	All	46/1557	3.0%
Child	Adult	6/209	2.9%
Child	Child	40/1348	3.0%
Primary School			
Any	All	217/5927	3.7%
Adult	All	17/1054	1.6%
Adult	Adult	5/285	1.8%
Adult	Child	12/769	1.6%
Child	All	186/5020	3.7%
Child	Adult	8/939	0.9%
Child	Child	178/4081	4.4%
SSP			
Any	All	25/450	5.6%
Adult	All	17/301	5.6%
Adult	Adult	5/163	3.1%
Adult	Child	12/138	8.7%
Child	All	8/149	5.4%
Child	Adult	4/93	4.3%
Child	Child	4/56	7.1%
ECEC			
Any	All	334/5707	5.9%
Adult	All	337/3310	10.2%
Adult	Adult	106/789	13.4%
Adult	Child	231/2521	9.2%
Child	All	64/2545	2.5%
Child	Adult	22/651	3.4%
Child	Child	42/1894	2.2%

Note: For five primary schools and two ECEC services where both a staff member and student were co-primary cases, the close contacts have been counted in attack rate calculations for both categories of primary cases.

* Excluding ECEC services in September 2021.

The secondary attack rate from a fully (2.8%) or partially vaccinated (3.5%) primary case was lower than from an unvaccinated individual (4.6%). Refer to [Table 3](#).

Table 3: Secondary attack rates of COVID-19 in educational settings, by vaccination status of the primary case type and educational setting type, between 16 June 2021 and 17 September 2021*

Primary case type	Close contact type	2-Dose [†]		1-Dose [‡]		Unvaccinated [§]	
		Number of positive cases / total number of tested cases	Attack rate (%)	Number of positive cases / total number of tested cases	Attack rate (%)	Number of positive cases / total number of tested cases	Attack rate (%)
Any	All	3/107	2.8%	13/371	3.5%	617/13301	4.6%
Adult	All	3/107	2.8%	13/371	3.5%	318/4191	7.6%
Adult	Adult	2/44	4.5%	1/125	0.8%	103/1111	9.3%
Adult	Child	1/63	1.6%	12/246	4.9%	215/3080	7.0%
Child	All	0/0	—	0/0	—	309/9315	3.3%
Child	Adult	0/0	—	0/0	—	41/1905	2.2%
Child	Child	0/0	—	0/0	—	268/7410	3.6%

* Excluding ECEC services in September 2021. One primary school was excluded due to having co-primary cases with different vaccination status

† 2-Dose was defined as having two doses of vaccine, with the second dose at least 14 days prior to infection onset date and a minimum of 14 days between the two doses.

‡ 1-Dose was defined by having one dose of vaccine at least 14 days prior to infection onset date.

§ Unvaccinated was defined as having no vaccine recorded, or 1 dose <14 days prior infection onset date.

Discussion

During the reporting period, NSW experienced a large COVID-19 outbreak caused by the SARS-CoV-2 Delta (B.1.617.2) variant, which commenced on 16 June 2021, with most cases occurring in Greater Sydney (population 5.7 million).⁵ The Delta variant infects people at a higher rate than the ancestral strain of SARS-CoV-2.

Delta variant transmission rate (4.6%) seen in NSW schools in Term 3 2021 was consistent with the rates reported in our last schools report,⁷ despite higher rates of community transmission. Schools with higher rates of attendance did not necessarily have higher rates of transmission; some schools in regional areas had one case attend and no secondary transmission. However, this observation may have been confounded by the fact that during this period, high school attendance occurred in areas of the state where there was low or no local COVID-19 transmission and a low likelihood of multiple simultaneous attendances of COVID-19 cases at schools or ECEC services.

Overall, there was a five-fold higher rate of transmission (secondary attack rate 4.6%) in educational settings during this outbreak period than in 2020 (secondary attack rate 0.9%). Transmission was highest between K–12 staff members (16.1%) and ECEC staff members (13.4%). These high transmission rates led to the prioritisation of staff vaccination in areas of high community circulation of the virus in NSW, which ultimately contributed to a very high vaccination rate.

The vast majority of primary cases were unvaccinated. Among the vaccinated primary cases, secondary attack rates were lower than in the unvaccinated cases. This suggests that the COVID-19 vaccine may have an effect on preventing infection (thus introductions into schools) and reducing transmission from those who were infected.

The study also showed the Delta variant was also more easily transmitted among household members (59.5%), regardless of age, than previous SARS-CoV-2 variants, with approximately 11-fold higher transmission seen in households than in schools and ECEC services.

Conclusion

This report provides insight into the transmission of the Delta variant in NSW schools and ECEC services between 16 June 2021 and 17 September 2021. Our findings remain consistent with our previous report and showed that transmission in educational settings was five-fold higher with the Delta variant (4.6%) than with the ancestral strain (0.9%). Transmission among household members was also found to be higher than in school settings.

Term 4 2021

While this report presents data from Term 3 2021, our study continued in Term 4 2021 (5 October 2021 to 17 December 2021).

In Term 4, students returned to face-to-face learning from 18 October 2021 and attendance rates were more than 85% in schools from 24 October 2021. All schools were required to follow on-site mitigation measures as per NSW Education COVID-Safe measures Level 3 setting and all NSW educational staff members were required to be vaccinated by 8 November 2021. Adolescent (12–19 years) vaccination rates for dose 2 saw an increase from 49.5% on 18 October 2021 to 79.4% on 17 December 2021.

As COVID-19 continued to circulate in the community, exposure events in schools and ECEC services also continued to occur during Term 4: there were a total of 985 exposure events in schools between 18 October 2021 and 17 December 2021, the majority of which (61%) were within the primary school setting, reflecting infection among an unvaccinated population. However, for the majority of Term 4, daily NSW state-wide COVID-19 case numbers were low, ranging from 129 to 300 notifications per day.

Case notifications started to rise rapidly, primarily among those aged over 19 years, from 27 November 2021. This coincided with the introduction of the SARS-CoV-2 Omicron variant in NSW. Cases infected with the Omicron variant also attended some schools; data on both Delta and Omicron variant transmission in Term 4 2021 in NSW will be reported separately.

Numerous mitigation measures have been shown to be effective and are important to ensure uninterrupted face-to-face learning among students. One of these, rapid antigen testing for close contacts, commenced in NSW schools on 26 October 2021 as a method to return students into the classroom earlier in their isolation period. Data on the NSW rapid antigen home testing 'test to stay' program in Term 4 will be reported separately. In addition, vaccination using the Pfizer COVID-19 vaccine (Comirnaty) among 5–11 year olds commenced on 10 January 2022.

School participation is vital for children's education and social and mental wellbeing. NCIRS, NSW Health and NSW Education will continue to study and understand the transmission of SARS-CoV-2 in educational settings to ensure that robust scientific evidence is available to inform policy and practices to maximise face-to-face learning while reducing harm from COVID-19.

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Glossary

Community non-household contact	a person in close contact of a COVID-19 case who does not live in their household
ECEC	Early childhood education and care: all forms of education for children under school-age, including childcare and preschool
High school	a secondary school (Year 7 to 12) that caters for children aged 12 to ≤18 years
Household tertiary case	a person who lives within the same household as a secondary case and gets infected with SARS-CoV-2 from exposure to that secondary case
K-12 school	a school (Kindergarten to Year 12) that caters for children aged 4 to ≤18 years in which contacts were not restricted to the primary or secondary school
LGA	Local Government Area
NSW	New South Wales
Primary case	a person who has SARS-CoV-2 infection and brings it into a school or ECEC
Primary school	an elementary school (Kindergarten to Year 6) that caters for students aged 4 to ≤12 years
SARS-CoV-2	Severe Acute Respiratory Syndrome-Coronavirus-2: the name of the coronavirus that causes COVID-19 disease
SARS-CoV-2 nucleic acid test	a test that detects the SARS-CoV-2 genome
Secondary attack rate	a measure of the frequency of new cases of COVID-19 among the contacts of primary cases
Secondary case	a person who gets infected with SARS-CoV-2 in a school or ECEC setting from exposure to a person with COVID-19
Secondary transmission	transmission of SARS-CoV-2 from a primary case to exposed contacts
SSP	Schools for Specific Purposes
VOC	Variant of Concern

References

1. NSW Health. Public health alert – COVID-19 case. 16 June 2021. Available from: https://www.health.nsw.gov.au/news/Pages/20210616_01.aspx. Accessed 8 January 2022
2. NSW Government. Teacher vaccinations prioritised in South Western Sydney. Available from: <https://education.nsw.gov.au/news/latest-news/teacher-vaccinations-prioritised-in-south-western-sydney>. Accessed 8 January 2022
3. NSW Health. New protections and compliance rules to carry NSW through vaccination targets. Available from: https://www.health.nsw.gov.au/news/Pages/20210820_02.aspx. Accessed 8 January 2022
4. Community Colleges Australia. NSW mandates vaccination for all school staff and identifies opening date. Available from: <https://cca.edu.au/nsw-mandates-vaccination-for-all-school-staff-and-identifies-opening-date/>. Accessed 8 January 2022
5. NSW Government. NSW COVID-19 data. Available from: <https://data.nsw.gov.au/nsw-covid-19-data>. Accessed 8 January 2022
6. Macartney K, Quinn HE, Pillsbury AJ, Koirala A, Deng L, Winkler N, Katelaris AL, O'Sullivan MVN, Dalton C, Wood N, and the NSW COVID-19 Schools Study Team. Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. *The Lancet Child and Adolescent Health*. 2020;4: P807-816.
7. National Centre for Immunisation Research and Surveillance (NCIRS). COVID-19 transmission in NSW schools and ECEC services in Term 4, 2020. Available from: <https://www.ncirs.org.au/covid-19-in-schools>. Accessed 8 January 2022.

Chapter 7

Teaching experiences

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MAE teaching experience

The MAE program requires scholars to fulfil two teaching competencies:

- 1) Teaching to first year scholars
- 2) Develop and participate in “Lessons from the Field” (LFF).

This chapter outlines the two teaching experiences and key lessons learnt. It also includes my experience as a co-facilitator at a pre-conference workshop at the 11th Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET) Global Scientific Conference, Panama, 4 September 2022.

Teaching first-year scholars

Background

The teaching session to first-year MAE students took place during their course block 1 (March 2022). Each teaching session was led by 4–5 scholars of the 2021 MAE cohort. As a cohort we first identified several topics we believe would benefit the first-year students, then each teaching session group chose a topic to teach based on our preference and experience. My group chose to teach on surveillance of notifiable conditions in Australia. We decided on this topic as we felt an understanding of notifiable disease surveillance is fundamental to all scholars. My group consist of Yasmin Lisson, Hayley Dyke and Al Gomez and myself.

The objectives of our teaching session were based on the following:

- 1) Understand how notifiable diseases and conditions are reported to the National Notifiable Diseases Surveillance System (NNDSS)
- 2) Describe how surveillance data inform public health action
- 3) Identify some important public health responses to surveillance signals
- 4) Understand how COVID-19 responses differ to other notifiable disease responses

The teaching session was conducted online via Zoom. At the beginning of the session, I taught on the NNDSS, what it is and how diseases and conditions are

reported, and its relevance to public health. We then split into four break-out rooms for a case study on syphilis; we facilitated discussions on what public health responses should be undertaken in response to the surveillance report data on syphilis. The four groups re-convened for discussion after 15 minutes. Then AI led a case study of COVID-19 and how it differs to other notifiable diseases. Then finally, teaching session was concluded with a short evaluation of the teaching session.

Teaching evaluation

There were 20 first-year scholars participating in the session, and 100% (20/20) agreed that our session met all the stated learning objectives, and 80% (18/20) agreed that the teaching session was useful in their current stage of their MAE journey. The scholars' overall feedback was positive; they appreciated the interactive components (the discussions and case studies) in our teaching session. One improvement two scholars suggested was to provide handouts of the case study before the session so they could prepare ahead of time.

Lessons learnt

Our focus was to make the teaching session informative and applicable; providing practical examples that would be useful to first years in their own placements. To achieve this, our team reflected on our experiences and thought of ways of to make the content more suitable for the first-years, which included, using different case studies, notifiable conditions, and discussion points. This took time as it was a trial and error. Through this process we learnt the value of teaching and appreciate the teaching-skill of transferring knowledge through practical means.

Another lesson learnt was to consider different interactive approaches to training online, on a web platform. In our preparation of the teaching session, we had not considered online tools, such as 'Padlet' which allows users to express their ideas anonymously in an online shared space. We only considered using 'Poll Everywhere', a live online-poll application, however it did not work as intended. If I had to do this teaching session again, I would investigate other online tools to make the teaching on Zoom more interactive and engaging.

Lessons from the Field

Background

The Lessons from the Field (LFF) component of the MAE program was developed to increase opportunities for peer-to-peer teaching and learning based on the challenges faced in the field. Our cohort split up into two groups to complete the LFF task.

With my background and experience, I chose to focus my LFF on epidemiology and immunisation policy in Australia. It is often difficult to bridge the gap between how epidemiology is relevant to bigger policy questions, for example, those relevant to the National Immunisation Program (NIP). As the only scholar placed at the National Centre for Immunisation Research and Surveillance, there was an opportunity for me to share the processes required for a vaccine to be funded under the NIP and how epidemiological data are applied in this process.

The three learning objectives of the LFF were to:

- 1) Describe the role of different stakeholders in the process of adding a new vaccine to the NIP
- 2) Describe the different considerations when developing immunisation policies
- 3) Give examples of the role of epidemiology in making decisions for the NIP

For my LFF, I prepared a case study worksheet with questions for scholars to complete two weeks before the LFF (see Appendix A). On the day of the session (13 July 2022), I had prepared a presentation to explain the role of key stakeholders in the Australian immunisation policy, such as the Australian Technical Advisory Group on Immunisation, the Pharmaceutical Benefits Advisory Committee, and the Therapeutic Goods Administration. I also described the different considerations for policy decisions, such as, vaccine characteristics, feasibility, equity, and ethical considerations.

For the second half of the LFF presentation, I provided two case studies where changes were made to the NIP immunisation policy. The first case study was on a change in the pneumococcal vaccination schedule for infants. The second case

study was on the expansion of the NIP to funding to Aboriginal and Torres Strait Islander people < 2 years for routine vaccination of meningococcal B vaccination. In addition, epidemiological data were provided to scholars for interpretation and discussion.

During the presentation, I ensured all the necessary content contained within the worksheet was presented, allowing the scholars to answer all questions within the worksheet. To conclude my LFF, I also prepared a survey via REDCap so peers could evaluate the presentation and the contents provided.

Lessons learnt

Preparing for my LFF session taught me the importance of having a clear teaching focus and knowing how to target the teaching material effectively to your audience. I had to ensure I wasn't being vague in the ideas that were being presented, and that required a lengthy process of choosing the right case studies. It was difficult to determine the level of knowledge and understanding my peers had, then providing case studies that would be challenging and interesting for them.

For my next opportunity to teach, I would like to trial my lesson to another peer or student to see areas of improvement. I would also send a short poll to my peers before choosing the focus area.

There were five scholars that attended the LFF and 100% strongly agreed that:

- 1) The LFF session was clear and easy to follow,
- 2) The learning objectives were met,
- 3) The content was useful to expand their understanding on this topic, and
- 4) They learnt something new or interesting through the session.

Co-facilitator experience

Background

When my abstract was accepted for a poster presentation at the 11th TEPHINET Global Scientific Conference (4–9 September 2022), I was invited by Matt Griffith, a PhD candidate at the Australian National University, to be a co-facilitator at a pre-conference workshop on “Beyond Principles: How do we use learning theories to facilitate learning experiences for field epidemiology training program (FETP) trainees?” Another fellow MAE, Aidan Yuen, also joined me as a co-facilitator.

Matt is an epidemiologist and has worked for the World Health Organisation, United States Centres for Disease Control and Prevention and Japan’s National Institute for Infectious Diseases. He has developed and led training for epidemiologists and FETP supervisors and trainees from various countries around the world. His PhD is on how training and learning occur in applied epidemiology programs. As the TEPHINET Global Scientific Conference is a platform for FETPS fellows, alumni, and mentors to come learn and experience the latest in applied epidemiology, this workshop was very suitable for the conference. It was a perfect opportunity for Aidan and myself, as MAE scholars to learn about learning principles and apply how we have learnt as FETP trainees.

Process

In preparation for the pre-conference workshop, Matt, Aidan, and I met online, fortnightly, over a span of two and a half months. During these sessions, Matt led us in ice breaker activities to get to know each other, we also reviewed facilitating methods, considered what is the role of a trainer, and explored different learning theories (andragogy and experiential learning theory). Aidan and I wrote and prepared responses for homework provided by Matt, and we gradually built our knowledge in facilitating, andragogy and experiential learning theory. As we drew closer to the date, Matt, Aidan, and I together, designed the full-day workshop. We designed the workshop in a way that reflected the learning theories we had discussed. Designing the workshop was a rigorous process as we worked to get

the order, content, examples, and timing of sessions right. We were given different roles for the workshop such as, practice co-leading, and preparing training content and presentation slides.

Learning theories

Andragogy in short are principles on how adults learn, differing from how children learn. For example, adults prefer to lead themselves in the learning process and want to understand the why they need to learn something. This means that when adults learn it is important for the teacher to facilitate the learning process and experience rather than conduct a typical lecture style learning. We considered these Andragogy principles in our workshop, by creating an environment for self-led learning.

Experiential learning theory states that knowledge is created by transformative experience. There are four steps in the experiential learning cycle (Kolb¹): concrete experience, reflective observation, abstract conceptualisation, and active experimentation (Figure 1).

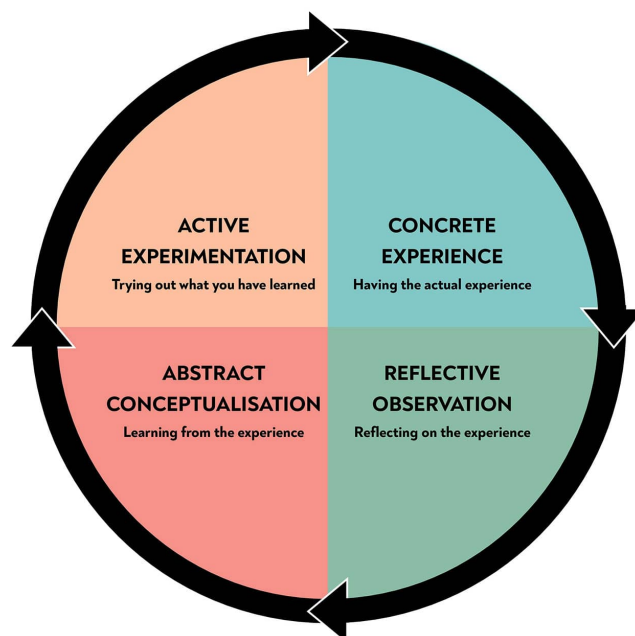


Figure 2. (Experiential Learning Cycle) Kolb's Learning Cycle

¹ Kolb, D.A. (2015) *Experiential Learning: Experience as the Source of Learning and Development*. 2nd Edition, Pearson Education, Inc.

All four steps must be taken to experience the complete learning process. Therefore, we designed the workshop so participants can experience the full experiential learning cycle.

Output

On the day of the workshop, Aidan and I assisted Matt by preparing the workshop room, acted as a co-facilitator and scribe; ensuring the workshop to run as effectively as possible. I also had the opportunity to lead a 1.5-hour session on the ‘experimental’ stage of the experiential learning cycle, allowing the participants to design an element of a FETP curriculum. This session incorporated an ‘energiser’ (a short activity to increase group energy levels), reflective discussions, as well as a final feedback time. The overall response was very positive, as it was a dynamic workshop with engaging activities, thoughtful discussions, and interesting learnings. During the workshop we had eight attendees, with four of the participants were FETP National Directors. Below is the workshop schedule:

Time	What	Who	Explanation
08:30am	Introduce session	Matt Griffith	Welcome and introduction to everyone in the room
08:45am	Ice breaker		Get to know each other about their background and experiences
9:15am	Learning contract		Create together a “contract” of what we want to learn today
9:45am	Roles and norms		Discuss role of facilitators and participants
10:15am	Break		
10:45am	Demonstration (Experience)	Martyn Kirk	Listen to a lecture on an introduction to epidemiology An example of “experiencing” a typical part of the FETP curriculum
11:45am	Think-Pair-Share (Reflect)	Matt Griffith	Get participants to pair up to reflect and share their experience of listening to a lecture (a list of questions was given)
1:00pm	Lunch		
2:00pm	Teach-back (Conceptualise)	Aidan Yuen	Provide groups handouts on andragogy and experiential learning theory. Groups were asked to create a poster answering specific questions and then teach the other group on the learning theories.
3:30pm	Design a curriculum (Experiment)	Zoe Joo	Ask groups to design FETP curriculum by incorporating learning theory principles. Groups present their curriculum design and provide feedback.
4:30pm	Evaluation	Matt Griffith	Close the workshop and feedback time

Lessons learnt

Preparing and co-facilitating this workshop was challenging, fun, and an eye-opening experience for me. I obtained knowledge on adult learning theories and received hands-on experience in co-facilitating a workshop at an international platform.

Facilitating was much harder than expected because it was different to my previous lecture style teaching experiences. Part of being able to facilitate a workshop includes the ability to read the energy level in the room, adapting to the level of understanding based on the responses of the participants, effective time-management, and the ability to appropriately encourage and challenge the participants – all to help participants to learn.

One of the most surprising things I learnt was the amount of time, energy and resources required to prepare for a workshop. Aidan and I read and assessed several readings prior to the workshop. We had to think carefully about the workshop objective and rehearse in our minds what the workshop would look like. The final workshop design had to go through several iterations before we were ready to conduct it with the resources we had. It was definitely hard work but also rewarding in seeing the participants keen to hear more from us.

Another lesson learnt was how the little things can add to the value of the training and create a welcoming, cross-cultural atmosphere. We employed several tools such as quiet jazz music, pipe cleaners to fiddle with, and an assortment of snacks from Australia to share with our international participants. These things greatly helped in creating a comfortable and welcoming space.

Furthermore, I realised the importance of building trust and relationship in the context of learning. I saw how Matt built rapport with Aidan and myself throughout the entire process. We learnt to do the same on the day of the workshop with the participants. We learnt to be trusting so the participants would feel confident to discuss and share their personal experiences and thoughts.

As a student, I realised how I like to learn, and that I enjoy the reflective process of my learning. I became aware that I placed high importance on practical learning experiences rather than theoretical learning. When designing the workshop, I would think about how certain examples were relevant to me as an MAE and reflected on how the workshop could be improved for the participants.

Overall, this experience gave me new a paradigm for learning, helped me gain knowledge and skills in facilitating, and refreshed my passion for learning. I would like to use what I have learned to help the next field epidemiologists to excel in their learning and training.

In this workshop we discussed how most [#field_epi](#) never learn how to train and how [#andragogy](#) and [#experiential_learning](#) can help [#fetsp](#) training and learning experiences.
[@tephinet](#) [@ANUPopHealth](#)
[@fieldepi_action](#) [@tephinet](#) [@zoe_joo](#)
[@KirkMartyn](#)



11:51 pm · 5/9/2022 · [Twitter for iPhone](#)

Figure 3. A Tweet about “Beyond Principles: How do we use learning theories to facilitate learning experiences for field epidemiology training program (FETP) trainees?” workshop at TEPHINET.

Appendix A – Lessons from the Field

Lessons from the Field: Epidemiology and immunisation policy in Australia

Learning objectives (including session):

- To describe the role of different stakeholders in the process of adding a new vaccine to the National Immunisation Program
 - To describe the different considerations when developing immunisation policies
 - To give examples of the role of epidemiology in making decisions for the National Immunisation Program
-

There are many considerations for immunisation policy, especially for vaccines that are to be included to the National Immunisation Program (NIP). The Australian NIP provides free vaccines to eligible people to help reduce diseases that can be prevented by vaccination.

What could be some considerations for immunisation policy? (E.g., cost-effectiveness)

- Strength of the immunisation program and health system
- Acceptability
- Feasibility
- Ability to evaluate
- Equity
- Ethical considerations
- Conformity of programs
- Political considerations
- Immunogenicity of vaccine
- Efficacy of the vaccine
- Effectiveness of the vaccine
- Safety of the vaccine

Epidemiological studies provide information on burden of disease and vaccine characteristics (immunogenicity, efficacy, effectiveness, and safety) for decision making.

Case Study 1

We are going to look at a change to the Australian NIP regarding pneumococcal vaccination schedule for infants.

History:

- In 2005, the 7-valent pneumococcal conjugate vaccine (7vPCV) was introduced
- In 2011, 7vPCV was replaced with 13vPCV
- The 13vPCV schedule for infants in Australia, the United States, and the United Kingdom (2015) is shown in Figure 1 below.

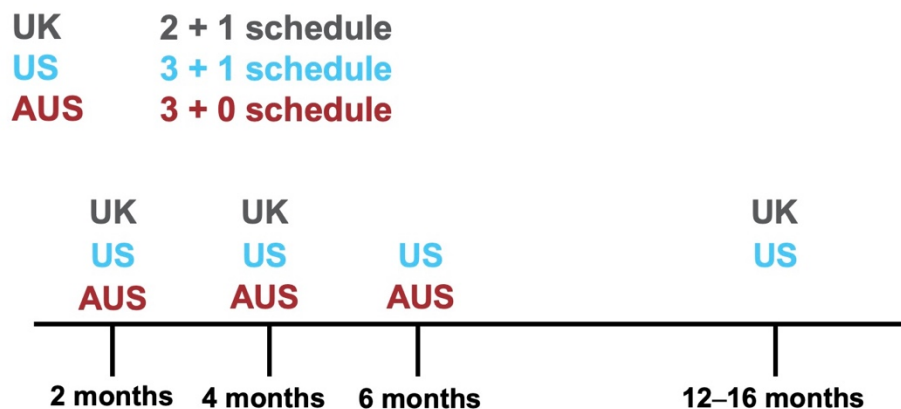


Figure 1. Infant 13-valent pneumococcal conjugate vaccine (13vPCV) schedule in the United Kingdom (UK), United States (US) and Australia (AUS) in 2015.

Although all three countries had an infant schedule for 13vPCV, Australia was the only country seeing an increase in toddlers with invasive pneumococcal disease despite being fully vaccinated (this is vaccine failure). Both the United States and United Kingdom observed lower rates of breakthrough cases.

What age groups experienced vaccine failures with the 13vPCV (3+0 schedule) in Australia (with 19F serogroup)? See Table 3 below

12–<24 months and 24–<36 months age group

Table 3: Age groups and serotypes of 13vPCV (3+0 dose) vaccine failures up to 31 December 2015

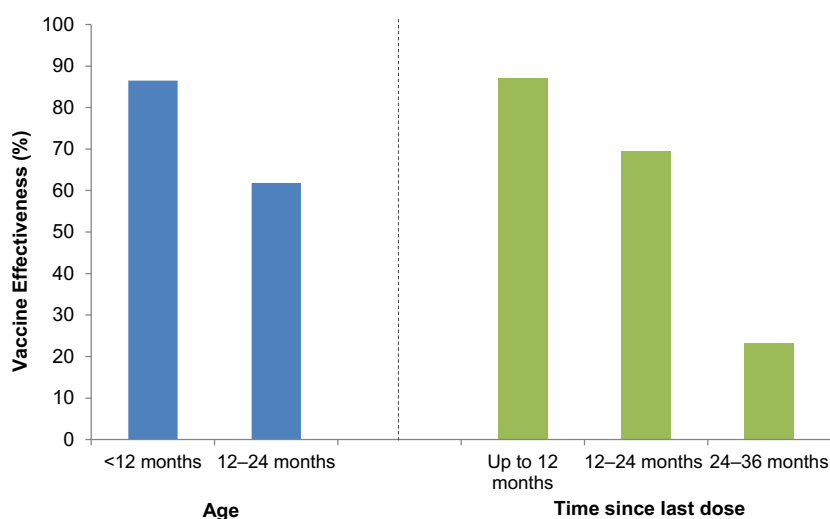
Serotype	Age group (months)					Total
	<12	12–<24	24–<36	36–<48	48–<60	
1	–	–	1	–	–	1
3	3	15	8	3	–	29
6A	–	–	1	–	–	1
7F	–	1	–	–	–	1
19A	2	38	14	6	2	62
19F	2	9	3	–	–	14
Total	7 (6%)	63 (58%)	27 (25%)	9 (8%)	2 (2%)	108 (100%)

What could be the reason why Australia experienced breakthrough cases? (Refer to Figure 1)

This could be due to the switch to the 13-valent vaccine from the 11-valent vaccine for infants. The schedule for Australia is also different to the United States and the United Kingdom, which have a +1 schedule. Australia has a 3+0 schedule.

To account for the differences in breakthrough cases, a case-control study was conducted to assess the vaccine effectiveness of the 13vPCV vaccine in children in Australia who received the vaccine at 2-, 4- and 6-month schedule.

What do you observe when you see the figure below?



In this figure, vaccine effectiveness is on the y-axis and age is on the x-axis. There was a lower vaccine effectiveness in children in the second year of life, shown by the green bars on the right. There is a progressive decrease in vaccine effectiveness with increasing time since the third dose of vaccine (which is at 6 months). In the bar graph on the left, in the blue bars, we can observe how vaccine effectiveness decreased from about 85% in the first 12 months to 70% between 12 and 24 months and down to 20% between 24- and 36-months post-dose 3.

Do you think the schedule may have changed for 13vPCV in Australia for infants?
If so, how?

Yes, the schedule would most likely have changed by moving the third dose from 6 months to 12 months, like the US and UK schedule.

If you are keen to see a comparison of Australia and the UK, you can see Table 4 below that modelled observed counts and imputed figures of severe and all invasive pneumococcal disease.

Table 4: Breakthrough cases of 13vPCV IPD in the UK and Australia* – observed case counts from both populations, and imputed figures for the anticipated Australian experience using a 2+1 schedule based on UK incidence data

Schedule	Age <12 months		Age ≥12 months		Total	
	Severe IPD [†]	All IPD	Severe IPD [†]	All IPD	Severe IPD [†]	All IPD
AUS (observed, 3+0 schedule)	1	7	24	101	25	108
UK (observed, 2+1 schedule)	19	41	18	28	37	69
AUS (imputed, 2+1 schedule [‡])	8	18	8	12	16	30
AUS (difference between imputed and observed)	+7	+11	−16	−89	−9	−78

* Observation periods: for UK 2011–2014; for Australia 2012–2015

[†] Includes pneumococcal meningitis and pneumonia with empyema/effusion

[‡] Crude extrapolation to estimate number expected if 2+1 schedule was used instead of 3+0 schedule in this period by accounting for the difference in birth cohort sizes of 700,000 in the UK and 300,000 in Australia [$n \times \frac{3}{7}$], rounded to nearest whole number

You can refer to the Public Consultation Document by the Australian Technical Advisory Group on Immunisation on the infant pneumococcal vaccination schedule Click [here](#)