Applied Epidemiology of Infectious Diseases in Western Australia

A Thesis submitted for the degree of

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Hannah Vogt

Communicable Disease Control Directorate
Metropolitan Communicable Disease Control
Government of Western Australia, Department of Health

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Field Supervisors
Dr Benjamin Scalley
Dr Paul Armstrong

Academic Supervisor
Dr Aparna Lal

Government of **Western Australia**
Department of **Health**

Australian National University

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 proportions of material which have been accepted for the award of any other degree or diploma at ANU or any other educational institution, except where due acknowledgement is made in the text. Any contribution made to the research by others, with whom I have worked is explicitly acknowledged in the thesis. 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.

Hannah Vogt

April 2021

“The moment to moment of almost anything you are doing is a grind. It is only upon completion,

in reflection where you can see the glory.”

— Brian Greene

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THESIS ABSTRACT

The Western Australian (WA) Communicable Disease Control Directorate (CDCD) is responsible for the surveillance, prevention and control of communicable diseases in WA, while Metropolitan Communicable Disease Control (MCDC) is responsible for the public health management of all communicable diseases across metropolitan Perth. From March 2019 to December 2020, I undertook my MAE field placement split between CDCD and MCDC.

This thesis presents the projects undertaken during this 21-month placement.
My projects comprise of:

- First 600 COVID-19 Cases in Western Australia: Public Health Response Effectiveness of Contact Tracing & Restrictions in WA
- Evaluation of the COVID-19 Surveillance System in Western Australia
- Measles Outbreak Investigation & Response, Perth, Western Australia
- Measles cases that have previously received any measles-containing immunisations: infectivity & reasons for an apparent rise in incidence.

This thesis also describes other experiences and public health activities undertaken during my placement, specifically an investigation of an invasive meningococcal disease serogroup C outbreak in the Pilbara and involvement in the subsequent targeted vaccination campaign.

These projects and experiences fulfil the core requirements of the Australian National University Master of Philosophy (Applied Epidemiology) program.

CHAPTER 1: INTRODUCTION TO FIELD PLACEMENTS & SUMMARY OF EXPERIENCE

OVERVIEW

I commenced as a MAE scholar split between the WA Health Communicable Disease Control Directorate (CDCD) and the Metropolitan Communicable Disease Control (MCDC) in Perth on 18 March 2019.

FIELD PLACEMENTS

COMMUNICABLE DISEASE CONTROL DIRECTORATE (CDCD)

CDCD is one of the directorates within the Public and Aboriginal Health Division. My field placement within CDCD was in infectious diseases. Units within CDCD managed immunisation, infectious disease data, influenza and other communicable diseases, sexually transmitted infections and blood-borne viruses, statutory notifications and healthcare associated infections. Within the WA Health system, there are 7 population/public health units (PHU) situated across the state, which are a part of the Western Australia Country Health Service (WACHS).

METROPOLITAN COMMUNICABLE DISEASE CONTROL (MCDC)

Across metropolitan Perth, public health management of communicable diseases is the responsibility of the MCDC team. This team is responsible for the public health management of notifiable infectious diseases to protect the community and prevent disease outbreaks, in approximately 77% of those in WA.

Under the supervision of Dr Ben Scalley and Dr Paul Armstrong, my primary role and responsibility was to gain experience as a public health epidemiologist, by conducting epidemiological research projects and also take part in outbreak control, the COVID-19 pandemic response and other public health activities arising within MCDC and CDCD such as assisting OzFoodNet during a *Salmonella* outbreak. I also attended and contributed to weekly MCDC team and surveillance meetings, as well as CDCD weekly surveillance meetings.

I was also given the opportunity to be involved in an outbreak investigation of an invasive meningococcal disease serogroup C in the Pilbara, in which I was fortunate enough to be able to spend a week in Port Hedland at the Pilbara Population Health Unit (PPHU), where I provided epidemiological and operational support during the targeted vaccination campaign (Chapter 6).

SUMMARY OF CORE ACTIVITY REQUIREMENTS

ANALYSIS OF A PUBLIC HEALTH DATASET

FIRST 600 COVID-19 CASES IN WESTERN AUSTRALIA: PUBLIC HEALTH RESPONSE EFFECTIVENESS OF CONTACT TRACING AND RESTRICTIONS IN WA

On the 11 March 2020, the World Health Organisation (WHO) declared the COVID-19 outbreak a global pandemic. In response, Australia and Western Australia (WA) implemented intertwined risk-informed strategies in the form of non-pharmaceutical interventions. A descriptive epidemiological study was undertaken, of the first 600 cases of COVID-19 notified in WA. Demographic features of cases and transmission patterns (outbreaks, secondary cases and close contacts) were described, and assessed was the impact and effectiveness of non-pharmaceutical interventions on COVID-19 in WA, over four phases of the response. Phases were defined by significant non-pharmaceutical interventions put into place by both the Australian and WA Government. It was seen that the majority of the COVID cases were acquired overseas and when local transmission occurred, the proportion of secondary cases in a household setting was significantly higher when compared to those not in a household setting. Restrictions introduced in phases 3 and 4, including mandatory hotel quarantine for return travellers and the WA hard border closure, had the greatest impact with the reported number of cases and contacts decreasing.

ESTABLISH/EVALUATE A SURVEILLANCE OR OTHER HEALTH INFORMATION SYSTEM

EVALUATION OF THE COVID-19 SURVEILLANCE SYSTEM IN WESTERN AUSTRALIA

The COVID-19 surveillance system in WA has undergone numerous changes since its commencement in early 2020, due to the constantly evolving situation of the global pandemic. The system has yet to be evaluated. Following the Centres for Disease Control and Prevention Guidelines for Evaluating Public Health Surveillance System, I engaged with key stakeholders, analysed surveillance system data and reviewed key documents to evaluate the performance of the COVID-19 surveillance system. Recommendations for the improvement of the surveillance system were made.

INVESTIGATION OF AN ACUTE HEALTH PROBLEM OR THREAT

MEASLES OUTBREAK INVESTIGATION & RESPONSE, PERTH, WESTERN AUSTRALIA

Between 20 September 2019 and 16 October 2019, 29 cases of measles were notified in WA, with 23 cases being part of the outbreak. I was part of the outbreak operations team in Metropolitan Communicable Disease Control (MCDC), with my primary role being to support the coordination of the measles outbreak response. I assisted in the collection of epidemiological data and was responsible for the data management, analysis and reporting in relation to all measles cases and their contacts within the outbreak.

DESIGN/CONDUCT AN EPIDEMIOLOGICAL STUDY

MEASLES CASES THAT HAVE PREVIOUSLY RECEIVED ANY MEASLES-CONTAINING IMMUNISATIONS: INFECTIVITY & REASONS FOR AN APPARENT RISE IN INCIDENCE

The proportion of measles cases who had been previously vaccinated increased in Western Australia (WA) in recent years, with 13 cases notified since the beginning of 2018 until January 2019, that had previously received two measles-containing immunisations. A retrospective case series analysis was undertaken, of all cases of measles notified in WA, from 1 January 2009 to 31 October 2019. From this analysis of surveillance data, it can be postulated that there may be waning immunity in those who have received two measles-containing vaccinations, in the year of birth cohort of 1995-1999, during which circulating wild type measles was less common than preceding years. A trend was also identified suggesting that measles cases in WA who have received one or two measles-containing vaccines may have reduced infectivity and therefore are less likely to result in secondary cases. It is recommended that further analysis of Australian-wide measles data be undertaken.

ADDITIONAL REQUIREMENTS

LITERATURE REVIEW

A targeted literature search and synthesis of relevant information was undertaken for each project. The search strategy conducted as part of measles cases who have been previously vaccinated, their infectivity and reasons for an apparent rise in incidence, is detailed in Chapter 5.

REPORT TO A NON-SCIENTIFIC AUDIENCE

I prepared the frequently asked questions (FAQs) as part of the WACHS Pilbara Targeted Meningococcal ACWY Vaccination Program (Chapter 6), which was developed to provide information to the public about the vaccination program. I also wrote a Situation Report for the COVID-19 pandemic response in WA (Chapter 2), which was to update all stakeholders including those within CDCD, public health units in WA, Western Australia Country Health Service (WACHS), Disaster Preparedness and Management Unit (DMPU) and numerous other external health stakeholders.

PEER-REVIEWED PUBLICATION

Upon submitting, I had prepared a late draft manuscript, related to Chapter 2 (First 600 COVID-19 Cases in Western Australia: Public Health Response Effectiveness of Contact Tracing & Restrictions in WA). Chapter 2 has therefore been presented in the structure and format determined by Communicable Diseases Intelligence (CDI) instructions to authors.

CONFERENCE PRESENTATIONS

I presented the following oral presentations at scientific conferences:

- *Are vaccinated measles cases less likely to result in secondary cases*? Communicable Diseases Control Conference 2019, Canberra, Australia, 19–21 November 2019
- *Are vaccinated measles cases less likely to result in secondary cases*? Government of Western Australia, Public Health Nurses State-wide Update 2019, WA, Australia, 27 November 2019

TEACHING OF TOPICS IN FIELD EPIDEMIOLOGY

I prepared and conducted a teaching exercise called "COVID-19: Public Health Operations (PHOps) in Western Australia" and attended Lessons from the Field prepared by MAE scholars in my cohort (Chapter 7). I also participated in teaching to first year MAE scholars.

COURSEWORK

I passed the following coursework subjects of the MAE program:

POPH8916 Outbreak Investigation

POPH8917 Public Health Surveillance

POPH8913 Analysis of Public Health Data

POPH8915 Research Design and Methods

POPH8914 Issues in Applied Epidemiology

ADDITIONAL FIELD PLACEMENT ACTIVITIES

In addition to activities related to the core program requirements, I also took part in the following activities and projects:

- provided epidemiological and operational support during an outbreak investigation of an invasive meningococcal disease serogroup C in the Pilbara and involvement in the subsequent targeted vaccination campaign (this activity is detailed in Chapter 6)
- secretariat of the WA Pre and Post-natal Syphilis Working Group
- involvement, contribution and minute-taking in the 2019 WA Influenza debrief workshop and the 2019 Measles Outbreak in Perth debrief workshop
- attended weekly MCDC team and surveillance meetings
- attended weekly CDCD surveillance meetings

FULFILMENT OF PROGRAM REQUIREMENTS

A summary of my projects and activities and how they meet the core MAE requirements is detailed in the follow table (Table 1).

Table 1: Overview of my Master of Philosophy in Applied Epidemiology program requirements, February 2019 – April 2021.

Requirements	Chapter					
	2	3	4	5	6	7
Outbreak investigation			✓			
Epidemiological study				✓		
Data analysis	✓					
Establish/evaluate a surveillance system		✓				
Literature review				✓		
Teaching activities						✓
Conference presentation				✓		
Report to a non-scientific audience	✓				✓	
Peer-reviewed publication	✓					

CHAPTER 2: FIRST 600 COVID-19 CASES IN WESTERN AUSTRALIA: PUBLIC HEALTH RESPONSE EFFECTIVENESS OF CONTACT TRACING & RESTRICTIONS IN WA

LIST OF ABBREVIATIONS

ACF	Aged Care Facilities
ANU	Australian National University
CDCD	Communicable Disease Control Directorate
CDI	Communicable Disease Intelligence
CDNA	Communicable Diseases Network Australia
COVID-19	Coronavirus disease 2019
DMPU	Disaster Preparedness and Management Unit
GP	General Practitioner
MCDC	Metropolitan Communicable Disease Control
NZ	New Zealand
NNDSS	National Notifiable Diseases Surveillance System
PHEOC	Public Health Emergency Operations Centre
PHI	Public Health Intelligence
PHOps	Public Health Operations
PHOCUS	Public Health Operations COVID-19 Unified System
POA	Place of acquisition
PHU	Public health units
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SoNG	Series of National Guidelines
SOP	Standard operating procedure
UK	United Kingdom
USA	United States of America
WA	Western Australia
WACHS	Western Australia Country Health Service
WANIDD	Western Australian Notifiable Diseases Database
WGS	Whole Genome Sequencing
WHO	World Health Organisation

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PROLOGUE

MY ROLE

I was heavily involved in the Western Australia (WA) preparedness and response activities during the COVID-19 pandemic, beginning in January 2020 and which remains ongoing. I was fortunate to work in multiple levels of the public health system in WA – beginning the pandemic response at the Public Health Emergency Operations Centre (PHEOC) within the then Operations Cell for the state government, located at the Communicable Disease Control Directorate (CDCD). I then worked within Metropolitan Communicable Disease Control (MCDC) which, during the transition of organisational functions and structure, was merged into Public Health Operations (PHOps). PHOps then became its own stream within PHEOC. Within PHOps, I worked in Public Health Intelligence Cell (PHIC), which provided analytical support, reporting and database development and support.

At the beginning of the response, I was a member of the then 'Operations Cell' within the PHEOC. This cell was responsible for clinician engagement including producing clinician alerts, responding to queries and advising on the management of suspected cases, laboratory engagement, biosecurity management (maritime procedures and airport health screenings), surveillance and reporting, engagement with healthcare settings such as hospitals, general practitioners (GPs), pharmacies and engagement with universities and schools in WA.

My main role in this area was the laboratory liaison officer. I liaised with both public and private laboratories in terms of their preparedness and implementation of procedures and processes to link in with the public health response. With the assistance of the microbiologists, I wrote the specimen collection procedures, created a specimen collection and on-call handover (in and out of business hours) standard operating procedure (SOP) for all public health units (PHUs) and physicians to follow. I also ensured all public health units and physicians had lists of current COVID-19 specimen collection locations. I also liaised with the laboratories to arrange a domiciliary service to assist with specimen collection for COVID-19 in the metropolitan area of Perth, creating a SOP for this process for PHUs and laboratories.

My other tasks included helping to optimise the WA COVID-19 surveillance and reporting system by mapping out all steps to document the flow of data and if any gaps were visible at the time. When rostered to, I provided daily reports to the National Notifiable Disease Surveillance System (NNDSS) including new case details, case counts and total number of tests in WA. I also wrote a WA Situation Report (SitRep #41, Appendix 1), which was then distributed to CDCD, all public

health units (PHUs) in WA, Western Australia Country Health Service (WACHS), Disaster Preparedness and Management Unit (DMPU) and numerous other external health stakeholders. And, although it was for only one day – I was also tasked to be Lead of the Operations Cell. I attended twice daily PHEOC meetings (8:15am daily briefing, 12:15pm meeting) and the PHEOC and all WA PHUs meetings, Operations Cell team meetings and was given the opportunity to sit on some of the Communicable Disease Control Network Australia (CDNA) COVID-19 working group meetings.

When cases began to be notified in WA (mid-late March), I was then requested to assist MCDC with the operational aspect of the response, including case and contact interviews and the subsequent follow-up. As noted previously, MCDC was then merged into PHOps, within the PHEOC structure. Within PHOps I was then working in PHI.

My role in PHI was to manage the Excel spreadsheet of all cases of COVID-19. This spreadsheet was adapted from the one used in the measles outbreak (as discussed in Chapter 4). PathWest would email positive COVID-19 case results, including names, dates of birth and any other information provided on the pathology request form. This information would be entered into the COVID-19 spreadsheet in real-time. Initially it was also used to monitor daily tasks, such as case clearance dates and flight manifest requests pertaining to specific cases. The main purpose of the COVID-19 spreadsheet was to document all cases as soon as they were notified, as well as adding required information for reporting purposes once they had been interviewed by MCDC staff. This required constant data cleaning, as well as clear and constant communication with public health physicians, registrars and nurses interviewing each case. This spreadsheet was used to provide reports, including case counts, line-lists of cases and an epidemiological curve to numerous stakeholders, including PHEOC, health service providers within WA, and importantly for public health physician on-call handovers – particularly reporting case numbers to the media and Health Minister.

At the start of the response, we were using REDCap to log all suspected cases and contacts, with forms created for case assessment, results, enhanced data and contact details and exposures. Case interviews were also recorded in detail on separate word documents. By 8 April 2020, WA had migrated data from REDCap into the Public Health Operations COVID-19 Unified System (PHOCUS). Case interview word documents, and any other documentation relating to that case was also uploaded and attached to their PHOCUS record. PHOCUS underwent many updates and modifications to its current state. When REDCap data was migrated into PHOCUS, I helped establish required fields for the place of acquisition data field, as per the National Notifiable

Diseases Surveillance System (NNDSS) data specifications, as well as arranging data cleaning guidance and data extracts for the PHOps staff to undertake. The spreadsheet continued to be used for reporting purposes when PHOCUS was first implemented. It was seen as the source of truth for the first 600 cases and was used as a quality assurance check against the data that had been migrated into PHOCUS. Throughout the process, I was also able to indicate which data fields need to be added to PHOCUS to aid and assist future analysis of close contacts and secondary cases.

The following part of the response is what the subsequent draft manuscript/chapter is based on. After mandatory hotel quarantine was implemented in WA from 28 March 2020, I was given the task to look at all cases and their close contacts, to establish whether the quarantine/isolation measures in place were resulting in less close contacts and therefore secondary cases.
As the lead investigator of this project, I was responsible for the project proposal, study design, ethics review application, data analysis plan development, data collection, cleaning and analysis. All 600 cases' infectious and incubation periods were again assessed, as per the SoNG, and analysed by their stated date of onset of illness, obtained from their interview. Within their infectious period, all of their close contacts were further analysed, and their types of contact documented. Specific definitions for these "types of contacts" were created, due to the incubation period of 14 days, some close contacts had contact with the infectious case in two settings (for example while travelling but also once they returned to their household) and it was therefore not possible to assign them one "type" of contact. Secondary cases were also further investigated and discussed with WA Public Health physicians to confirm links.

From this, a spreadsheet of all 600 cases (notified from 21 February to 9 June 2020) and their close contacts was created, including documentation of "type of close contact", all secondary cases and which index they were linked with. POA of all cases and secondary cases were assessed through this process and updated on PHOCUS accordingly. During this process, the connection between cases, their POA, contacts, secondaries/tertiaries and therefore outbreaks, was very evident. I therefore worked with Dr Nevada Pingault (WA's COVID-Net Epidemiologist) when COVID-Net began, to provide the data I had collected and been managing, to compare to what she was provided with from PHEOC, to establish all outbreaks that had occurred in WA. We were able to then establish critical links within outbreaks and perform quality assurance by confirming numbers within each, which was then used to report to COVID-Net. From these discussions, Whole Genome Sequencing (WGS) was then able to be requested from PathWest for specific cases within outbreaks, to contribute and substantiate the epidemiological findings.

LESSONS LEARNT

This project and involvement in the COVID-19 pandemic response in WA first and foremost expanded my capacity to be able to adapt rapidly, be extremely flexible and resilient. It provided me with a once in a lifetime opportunity to be involved in the preparedness and response activities in WA, for a global pandemic. This overall experience has provided a wealth of experience, knowledge and lessons learnt.

There were many challenges responding to a pandemic of a novel disease, particularly at the start when the situation was rapidly evolving and there were numerous unknowns about the pathogen and its characteristics. However, these challenges have continued throughout- with the COVID-19 case definition continuously updated, the COVID-19 CDNA Series of National Guidelines for Public Health Units (SoNG) constantly being updated with new information to guide best practice, changes in testing criteria, as well as changing restrictions and directions Australia-wide and within WA. These changes then directly impacted the existing protocols, SOPs and all public facing documents. I therefore learnt how to adapt quickly to the evolving situation and changes to the response.

I also learnt that unlike other outbreaks in which you can be across all aspects and the specifics of the response, in a pandemic of this nature it isn't possible. I learnt in the initial phase when it was rapidly evolving, that it was imperative to be aware of all aspects of the response and which cells/stakeholders were responsible, however it was not possible to be across every single detail. Therefore, it was imperative to have good communication with each cell undertaking the response.

Adapting rapidly and being flexible was especially highlighted during my role in PHI, when the peak of notifications occurred and during the transition between the REDCap database and use of the Excel spreadsheet to PHOCUS. I also learnt that seemingly simple data requests (such as the one I was given) can take a lot longer than initially thought. Given the speed of the COVID-19 response in WA and the urgent need for a database that could assist operationally in case and contact management, the migration of certain details of cases/their close contacts (particularly recovered cases) was also crucial. This meant the data I required for analyses didn't allow for easy extraction. I therefore spent several months collating all of the data from case interviews, lists of close contacts, REDCap forms and the PHOCUS database. From this process I learnt that databases need to be carefully designed for operational purposes, but also for data analyses and reporting purposes.

Public Health Impact

From collating all of the data on contacts and their links to cases and whole genome sequencing information, it was possible to retrospectively identify clusters and outbreaks of COVID-19. By describing these relationships and the nature of the links and outbreaks, it contributed to understanding the epidemiology of the first 600 cases notified in WA. By then examining the data on cases and contacts at each of the key time points where population-based interventions were put in place, it was possible to then determine the impact these non-pharmaceutical interventions had on the spread of COVID-19 in WA.

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I would like to thank and acknowledge all involved in the WA COVID-19 pandemic response. Specifically, a huge thanks to those in PHEOC and PHOps. From the very start of the response, to the first wave and onwards, everyone's ability to pull together and work tirelessly on this pandemic was something very special to witness and be a part of. This has truly been a bonding experience, both professionally and through the lifelong friendships that have been made.

Special thanks to Dr Clare Huppatz for making sure I was involved from the beginning and the biggest thank you to my supervisor Dr Ben Scalley, for involving me in the operational side as soon as cases started to be notified in WA (and for the request to analyse close contacts – in which this chapter was then born). And to Jenny Vo and Tracie Chong (PHOps) – for your constant technical support and overall encouragement.

NOTE: *Upon submitting, this is a late draft manuscript in the structure and format determined by Communicable Diseases Intelligence (CDI) instructions to authors. The title and author list are still to be confirmed.*

ABSTRACT

BACKGROUND

On the 11 March 2020, the World Health Organisation (WHO) declared the COVID-19 outbreak a global pandemic. In response, Australia and Western Australia (WA) implemented intertwined risk-informed strategies in the form of non-pharmaceutical interventions. I investigated the epidemiology of the first 600 COVID-19 cases notified in WA, the impact and effectiveness of the intertwined national mitigation and WA suppression strategies and the time-to-event intervals of the WA public health response.

METHODS

I undertook a descriptive epidemiological study of all laboratory confirmed and probable cases of COVID-19 in WA from 21 February 2020 to 9 June 2020. Data were extracted from the Western Australian Notifiable Diseases Database (WANIDD) and the Public Health Operations COVID-19 Unified System (PHOCUS). Demographic features of the COVID-19 cases and transmission patterns (outbreaks, secondary cases and close contacts) were described, and also assessed was the impact of non-pharmaceutical interventions on COVID-19 in WA, over four phases of the response. Phase 1 was defined as the period prior to 15 March 2020, when only travellers from China, Iran, Korea and Italy were required to self-isolate for 14 days. Phase 2 was from 15 March 2020 up to and including 27 March 2020, which saw all overseas arrivals and interstate travellers being required to self-isolate for 14 days, as well as a travel ban on all non-Australian residents and citizens coming in Australia, and an overseas travel ban effective for all Australians. Phase 3 was the period from 28 March 2020 to 4 April, which saw all people entering WA required to undertake mandatory 14-day quarantine at designated hotels. Finally, Phase 4 was defined as the period from 5 April 2020 onwards, which saw WA's hard border closure, with people no longer being able to enter WA unless granted an exemption.

FINDINGS

Between 21 February 2020 and 9 June 2020, WA was notified of 600 cases of COVID-19. Five-hundred and ninety-one cases were confirmed and nine probable cases, including 120 (20%) hospitalisations and nine (1.5%) COVID-19 deaths. The main source of infection was overseas acquisition (43.8%), closely followed by At Sea (41.2%). The last case of community transmission (where the source of infection could not be identified) was notified on 11 April 2020. There were 22 outbreaks investigated within this study period. From the 600 cases notified, 2140 close contacts were identified, with a mean of 4.26 close contacts per case (95% CI 3.75-4.77) and a median of 2 close contacts per case. Within the 600 cases, 53 were secondary cases, with 2.5% of close contacts (n=2140) becoming a secondary case. The proportion of secondary cases of COVID-19 in a household setting was significantly higher when compared to those not in a household setting (Chi-square= 28.29, p-value= <0.00001).

By exposure period, the restriction Phase 1 saw 438 (73%) cases being exposed to COVID-19 prior to 15 March 2020. Of those, their place of acquisition (POA) was largely overseas acquired, accounting for 50.7% (n=222) of all cases in Phase 1 (n=438), with At Sea (n=152) accounting for 34.7% and locally acquired- contact of a case or in a known cluster (n=44) accounting for 10%. These continued to decrease in number over all Phases, however in Phase 4 there was an increase in At Sea cases (n=21), representing 47.7% of all cases in Phase 4, followed by 45.5% of cases being acquired overseas. However, all of these cases were in quarantine (n=41) or known close contacts (n=3) at the time of being reported and did not represent a risk of onward transmission. The number of close contacts were also analysed by Phases, illustrating the highest number of close contacts was within the exposure period of Phase 1 (n=1626, 76%), then decreasing over the following Phases, except for the 18.3 contacts per case exposed in Phase 3 who could be attributed to “workplace” close contacts, including those from hotels, Aged Care Facilities (ACFs) and hospitals.

By presentation period, the most cases notified in WA was during Phase 2, with 259 cases (43.2%), which also saw the highest number of close contacts (n=1027, 48%). Within this Phase, the POA showed the highest numbers in the overseas category (n=148), accounting for 57.1% cases in that Phase, followed by 30.9% At Sea (n=80). Notifications during Phase 3 and 4 were similar with 176 cases (29.3%) in Phase 3 and 147 cases (24.5%) in Phase 4, with a large proportion of those attributed to a cruise ship of International residents (n=81) and a maritime vessel (n=21).

The number of close contacts were highest within the presentation period of Phase 2 (n=1027), which then decreased over the following Phases. Numbers of close contacts were however still high due to large numbers attributed to "workplace" close contacts from hotels, ACFs and hospitals. The average number of close contacts remained consistent throughout all presentation period Phases.

Times from date of notification to isolation date was an average of 0.38 days, with 477 cases only isolated once notified of their positive result, while 62 cases were already in isolation for an average of 2.87 days before being notified of their positive result. These cases were already in quarantine due to having arrived from overseas, or due to being identified as a close contact of a confirmed case.

CONCLUSIONS

The majority of the COVID-19 cases reported in the first half of 2020 in WA were acquired overseas. When there was local transmission, the proportion of secondary cases of COVID-19 in a household setting was significantly higher when compared to those not in a household setting. Restrictions introduced in phases 3 and 4, including mandatory hotel quarantine for return travellers and the WA hard border closure, had the greatest impact with the reported number of cases and contacts decreasing.

KEY WORDS: COVID-19, Western Australia, Australia, non-pharmaceutical interventions, restrictions, public health response

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the infective agent that causes coronavirus disease 2019 (COVID-19). SARS-CoV-2 is a novel coronavirus, first identified in humans in Wuhan, China, in December 2019, with the predominant mode of transmission being exposure to infectious respiratory droplets and particles, transmitted either via, inhalation of respiratory droplets and aerosolised particles, or deposits of respiratory droplets on mucous membranes(1). The World Health Organisation (WHO) declared COVID-19 a worldwide pandemic on 11 March 2020(2). Since then, it has caused enormous health, economic and societal impacts throughout Australia and around the world (3).

Initially, it was seen that the chains of human-to-human transmission of COVID-19 in China were successfully interrupted by using rigorously applied non-pharmaceutical public health measures. The measures included rapidly enhancing and expanding surveillance through rigorous case finding and isolation, immediate testing, thorough contact tracing and quarantine of close contacts, as well as community engagement and education (4). Following on, recommendations from the WHO-China Mission published in February 2020 included the need for immediate and decisive government leadership, which needed to continuously evolve, specifically in terms of making current evidence and risk based decisions combined with the rapid employment of non-pharmaceutical public health measures (4).

Evidence from New Zealand (NZ) has also indicated that national COVID-19 suppression strategies which were implemented early in the response, based on the WHO-China Mission recommendations, were successful. These strategies were effective in limiting the spread of the virus and impact on the health system. This evidence is an important lesson learnt, particularly for high-income or island nations (5).

Before the WHO declared a worldwide pandemic on 11 March 2020, Australia implemented measures aimed at mitigation (slowing the spread) of COVID-19 into and within the country, and to therefore prepare healthcare services and laboratories for a targeted response (6).The first risk-based Australian border restrictions were employed on 1 February 2020, with a ban on foreign national passengers arriving on flights from China and Australian passengers on flights arriving from China, to self-isolate for 14 days. The restrictions were further enhanced, with a

travel ban on all non-Australian residents and citizens coming into Australia on 20 March 2020, followed by “Stay home” restrictions imposed in Australia on 29 March 2020(7).

On 18 March 2020, the Australian Government declared a “human biosecurity emergency” under the *Biosecurity Act 2015*, given the risks COVID-19 posed to human health and the need to control its spread in Australia. The declaration was recommended by the Chief Medical Officer in his capacity as the Director of Human Biosecurity and allowed the state and territory Health Ministers to issue targeted, legally enforceable directions and requirements to combat the virus as required.

Consequently, all Australian states and territories set their own directions and requirements, which would be intertwined with the Australian Government’s. The major non-pharmaceutical intervention made by the WA Government was that of restrictions for people entering the state from all other jurisdictions, unless an exemption was granted. WA State Border controls under the *Emergency Management Act 2005* were implemented on 5 April 2020, with a focus on suppression (stopping further introduction and community spread of COVID-19). These border restrictions were in place for the entirety of this data collection period.

The aims of this study were to describe the epidemiology of the first 600 COVID-19 cases notified in WA, investigate the impact of the national mitigation and WA suppression strategies, and assess the time-to-event intervals of the WA public health response.

METHODS

STUDY POPULATION & TIME PERIODS

This descriptive epidemiological study assessed the first 600 COVID-19 cases, confirmed and probable, in WA. The first case notified in WA was on the 21 February 2020, with case 600 being notified on 9 June 2020. The case definitions applied were those defined by the Communicable Diseases Network Australia (CDNA). During this study period, the case definitions for both cases and contacts were updated frequently as they are based on knowledge about the clinical and epidemiological profile of COVID-19 cases presenting in Australia and worldwide. Therefore, the data in this study reflects the case definition at the time of case/contact investigation.

OUTBREAKS

As defined by the Australian Government Department of Health's network "COVID-Net", an outbreak is "two or more cases (who don't reside in the same household) among a specific group of people and/or over a specific period of time where illness is associated with a common source (such as an event or within a community)".

CLOSE CONTACTS

Those who were deemed as "close contacts" of the 600 notified COVID-19 cases in WA, as defined by the COVID-19 CDNA National guidelines for public health units (1), were further classified in this study by the specific type of contact they had with an infectious case (see Table 1).

SECONDARY CASES

"Secondary cases" were defined as a person who acquired COVID-19 from the index case by being epidemiologically related in time, place or person. Dates of exposure to the infectious index case (i.e. exposure occurred within 14 days of illness onset) and the type of close contact as defined in Table 1, were used to determine who secondary cases were.

Table 1: Definitions of close contacts of COVID-19 cases by "type of close contact", 21 February to 9 June 2020, Western Australia

Contact classification	Description of the type of close contact
Health care associated	Close contact with the infectious case during health care associated exposure: e.g. patients, including locations of ACF, hospitals, support care (e.g. at home health care)
Workplace	Close contact with the infectious case while in the workplace e.g. colleagues, contactors. This also includes those who are health care workers e.g. if a Dr is a case and they worked, their fellow HCW colleagues are classified as "workplace"
Household	Close contact with the infectious case within the household only
Household/workplace	Close contact with the infectious case while at home AND at work
Travel	Close contact with the infectious case whilst travelling only
Travel/Household	Close contact with the infectious case while travelling AND while in the household
Travel/Hotel	Close contact with the infectious case while travelling AND while in hotel quarantine
Hotel	Close contact with an infectious case while in hotel quarantine only
Hotel/Household	Close contact with an infectious case while in hotel quarantine AND while in the household
Other	Close contact with an infectious case while in a different location than above: in an uber/taxi, Tafe/school, social events (dinners, lunches etc)
Unknown	Close contact listed but type of contact information not clear

RESTRICTION PHASES

Four restriction phases were defined by using significant dates and activities during the pandemic response, undertaken by the Australian Government and the WA Government, outlined in Table 2. Over these four phases, we considered the effects of the intertwined national mitigation and WA suppression strategies, along with key non-pharmaceutical measures taken to protect the community, on the epidemiology of WA's first 600 COVID-19 cases.

Phase 1 was defined as the period prior to 15 March 2020. At the beginning of this period, 'Human coronavirus with pandemic potential' was declared an urgently notifiable disease in WA under Part 9 of the *Public Health Act 2016*. Prior to this date, only returned travellers from China, Iran, Korea and Italy were required to self-isolate for 14 days.

Phase 2 was defined as the period from the 15 March 2020 up to and including 27 March 2020. On 15 March and 17 March respectively, a Declaration of State of Emergency through s.56 *Emergency Management Act 2005* and a Declaration of Public Health, State of Emergency Public Health Act 2016, Part 12, Division 3, section 167, section 171 was enacted.
From 15 March, all overseas arrivals and interstate returned travellers were required to self-isolate for 14 days. During this period, a travel ban was placed on all non-Australian residents and non-Australian citizens coming into Australia, and an overseas travel ban effective for all Australians. WA also put local restrictions in place such as closure of all non-essential businesses. This period saw rapid acceleration of non-pharmaceutical interventions.

Phase 3 was defined as the period from 28 March 2020 to 4 April 2020, which saw all people entering WA required to undertake mandatory 14-day quarantine at designated hotels. "Stay at home" restrictions were imposed in Australia and WA on 29 March, with WA also introducing intrastate regional travel restrictions on 1 April.

Phase 4 was defined as the period from the 5 April 2020 onwards. In WA, under the *Emergency Management Act 2005*, State Border controls were implemented. This saw people no longer being able to enter WA unless an exemption had been granted. This hard border remained during this study period, however other restrictions within WA eased.

Table 2: Restriction phases, key dates and activities of non-pharmaceutical interventions in Australia & Western Australia

PHASE	DATE	AGENCY	Key activity
PHASE 1 PRIOR TO 15 MARCH 2020	1/02/2020	AUS	Ban on foreign national passengers on flights from China arriving in WA
			Australian passengers on flights from China and arriving in WA to self-isolate for 14 days
	5/03/2020	WA	Returned travellers from Iran, Korea required to self-isolate for 14 days from date of departure
	11/03/2020	WHO	WHO declared worldwide pandemic
		WA	Travellers from Italy required to self-isolate for 14 days from date of departure
PHASE 2 BETWEEN 15 MARCH 2020 AND 27 MARCH 2020	15/03/2020	AUS	All overseas arrivals required to self-isolate for 14 days and cruise ship arrivals banned
	18/03/2020	WA	Indoor gatherings limited to <100 people
	20/03/2020	AUS	Travel ban on all non-Australian residents & non-Australian citizens coming into Australia
		WA	Non-essential outdoor organised gatherings should be limited to fewer than 500ppl. Major events cancelled
	23/03/2020	WA	Closure of non-essential businesses
	24/03/2020	WA	Interstate arrivals required to self-isolate for 14days Border controls apply to all road, air, rail and sea access points
	25/03/2020	AUS	Overseas travel ban is effective for all Australians
PHASE 3 FROM 28 MARCH 2020 TO 4 APRIL 2020	28/03/2020	WA	ALL people entering WA required to undertake mandatory 14day quarantine at designated hotels
	29/03/2020	AUS/WA	Restrictions imposed (WA and AUS wide) "stay home"
	1/04/2020	WA	Intrastate regional travel restrictions introduced
PHASE 4 FROM 5 APRIL ONWARDS	5/04/2020	WA	STATE BORDER CLOSURE No longer be able to enter Western Australia after 11.59pm, on Sunday, 5 April 2020 unless an exemption has been granted.
	27/04/2020	WA	Phase 1 restrictions eased
	18/05/2020	WA	Phase 2 restrictions eased
	6/06/2020	WA	Phase 3 restrictions eased
	27/06/2020	WA	Phase 4 restrictions eased

Data Sources

All confirmed and probable cases notified from 21 February 2020 to 9 June 2020 (case 1 to 600) were extracted from PHOCUS. This system worked in conjunction with the Western Australia Notifiable Infectious Disease database (WANIDD), which transmits WA case data to the National Notifiable Diseases Surveillance System (NNDSS). Case interviews, which at the start of the COVID-19 response were initially documented in the REDCap database and on individual word documents, separately to the WANIDD and PHOCUS databases, were also accessed to enable a detailed analysis of close contact information.

Outcome Measures

Demographic characteristics of all 600 cases and their contacts were described. The number of secondary cases were assessed and described. The number of outbreaks and the average/median size of the outbreaks were calculated.

The National Notifiable Diseases Surveillance System (NNDSS) data field specifications for COVID-19 require a "place of acquisition" (POA) field to be completed for each case, to indicate where the disease is known to have been acquired during their incubation period, either locally or overseas. Therefore, if the case had been overseas in the 14 days before their onset, they were classified as "overseas acquired". "At Sea" was used for cases who had been on a maritime vessel (cruise ship or cargo vessel) during their incubation period, while if the case had not travelled, further investigation would occur as to whether they had acquired the infection locally via "locally acquired - contact with a known case and/or in a known cluster", via "locally acquired - contact not identified interstate travel" or "locally acquired no contact identified" with a confirmed case. Each cases POA was examined and data cleaned throughout the response.

To measure the public health response performance, time-to-event intervals were calculated. Average days were calculated between onset date and specimen collection date, onset date and notification date, date of notification to isolation date and date of isolation to result notification.

Cases were then assigned to four restriction phases to assess different impacts of the national mitigation and WA suppression strategies, along with key measures taken to protect the community during the pandemic response.

Within these four restriction phases, cases were firstly assigned to a phase based on their estimated exposure period (estimated date of SARS-CoV-2 infection). The "exposure period" date was defined as occurring one incubation period before symptom onset, thus cases onset date minus the 14-day incubation period. The "exposure period" assigned was then used to assess the impacts of the non-pharmaceutical intervention phases on the number of cases, close contacts and place of acquisition.

Finally, cases were assigned to a phase based on their "presentation period", defined as their notification date. The "presentation period" assigned was then used to assess the impacts of the non-pharmaceutical intervention phases on the number of cases, close contacts and place of acquisition.

There were cases excluded throughout the different outcome measures. Within the contact analysis, close contacts of cruise ships and a maritime vessel were excluded due to limited data. Similarly, close contacts included in flight manifests, hospital contacts and interstate/international contacts listed within the interview were also excluded from the analysis. Within the key time-to-event measures, probable cases were excluded due to being historical (past infection) cases.

Ethical Considerations

Ethics approval for this study was obtained from the Department of Health WA Human Research Ethics Committee (PRN: RGS0000004359, Protocol number: 0215122020) and the Australian National University (ANU) confirmed Notification of Prior Approval (human Ethics) on 23 April 2021.

Statistical Analysis

Microsoft Excel was used for data input. R (3.6.1) statistical program and Microsoft Excel were used for statistical analyses. Excel was used to calculate proportions, medians and 75^{th} and 90^{th} percentiles. 2x2 contingency tables and Chi-squared calculations were undertaken on the CDC Epi Info (8) mobile application, to compare proportions.

The mean, median and interquartile range for key time-to-event intervals were calculated using R packages "base", "stats" and "eeptools". R package, "plotly", was used to generate an epidemic curve of confirmed cases in WA and outline the four phases of WA's public health response.

RESULTS

DEMOGRAPHIC CHARACTERISTICS OF THE FIRST 600 COVID-19 CASES IN WA

The first 600 cases of COVID-19 in WA were notified between 21 February and 9 June 2020 (Figure 1). Of the notified cases, 591 cases were confirmed (98.5%) and only nine were probable (1.8%). One-hundred and twenty (20%) cases were admitted to hospital, with 31 (5.2%) admitted to the intensive care unit (ICU) and nine (1.5%) died (Table 3). Cases were predominately female (55.2%), with the highest number of cases in the 60-69yr age group (n=111). The Kimberley and Metropolitan regions of WA had the highest rate of infection (41.9 and 16.9 cases per 100,000 population respectively).

The number of cases notified in WA peaked in phase 2 (n=259, 43.2%), with 26 cases having a notification date of 20 March 2020. This was followed by a decrease of notified cases in both phase 3 and 4 (Figure 1).

The main source of infection was overseas acquisition (43.8%) closely followed by At Sea (41.2%) (Figure 1, Table 3). These imported cases continued to decline in each restriction period, however during phase 4 there was a slight increase, due to a maritime vessel arriving in WA (n=21, 24%) and the remaining cases from a cruise ship (n=26) first notified during phase 2 (Figure 1). In terms of locally acquired cases, the last case of community transmission where the source of infection could not be identified was notified on 11 April 2020.

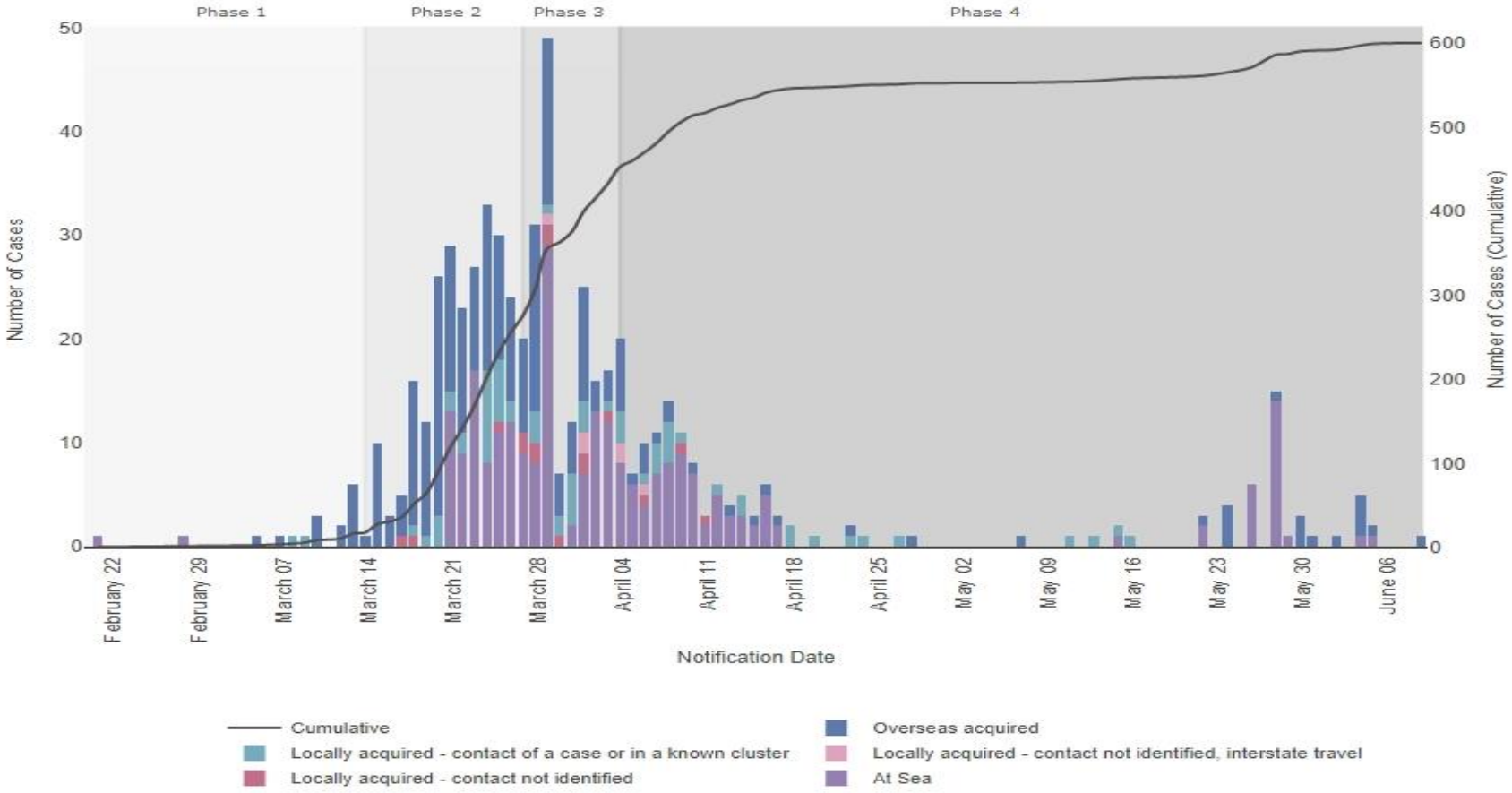

Figure 1: Epidemiological curve for COVID-19 cases, by place of acquisition and phase of restriction, 21 February to 9 June 2020, Western Australia

Table 3: Demographic characteristics of COVID-19 cases, 21 February to 9 June 2020, Western Australia

Description		Total	Proportions
Confirmation status	Confirmed	591	98.5%
	Probable	9	1.5%
Sex	Male	269	44.8%
	Female	331	55.2%
Indigenous status	Indigenous (Aboriginal but not TSI origin)	1	0.2%
	No	598	99.7%
	Not stated	1	0.2%
Age groups	0-9y	9	1.5%
	10-19y	6	1%
	20-29y	92	15.3%
	30-39y	106	17.6%
	40-49y	71	11.8%
	50-59y	88	14.6%
	60-69y	111	18.5%
	70-79y	101	16.8%
	80+	17	2.8%
Outcome	Hospitalised – Yes	120	20%
	Hospitalised – No	480	80%
	ICU admission	31	5.2%
	Deaths	9	1.5%
Place of acquisition	At sea	247	41.2%
	Overseas acquired	263	43.8%
	Locally acquired - contact of confirmed case and/or in a known cluster	68	11.3%
	Locally acquired - contact not identified interstate travel	6	1%
	Locally acquired - contact not identified	16	2.7%

OUTBREAKS

From January to June 2020, there were 22 COVID-19 outbreaks that were investigated in WA consisting of 295 confirmed and 16 probable cases, with the majority of outbreaks investigated in March (n=15) and April (n=4). The median number of confirmed cases per outbreak was 3.5 (range 0-81). There were 83 hospitalisations and 9 associated deaths amongst cases linked to outbreaks.

The most common outbreak setting in the first 600 COVID-19 cases was cruise ships (n=10, 45.5%), accounting for 75% (221/295) of all confirmed cases. Of these, 92% (76/83) of total hospitalisations and 89% (8/9) of deaths. Six of these cruise ship outbreaks were multi-jurisdictional, meaning there were also cases notified in other Australian states or territories, linked to the same cruise ship. Table 4 shows the outbreak settings, number of outbreaks associated with each setting and the number of confirmed cases linked to outbreaks in each setting.

Of the 22 outbreaks, the first known case to have acquired their infection from overseas was related to 15 outbreaks, while in seven outbreaks the first known case acquired their infection in Australia. Whole Genome Sequencing (WGS) was pivotal later in determining many outbreaks' transmission dynamics, with cases in settings being able to be included or excluded based on genomic variation. Since this chapter write-up, there have been further WGS results made available which have altered total numbers within some outbreaks.

Table 4: COVID-19 outbreak settings by the number of outbreaks and cases, 21 February to 9 June 2020, WA

Outbreak setting	Number of outbreaks (%)	Number of confirmed cases (%)
Cruise ships	10 (45.5%)	221 (75%)
Hospital	2 (9.1%)	7 (2.4%)
Accommodation	1 (4.5%)	3 (1%)
Community	1 (4.5%)	12 (4.1%)
Event	1 (4.5%)	3 (1%)
Maritime vessel	1 (4.5%)	21 (7.1%)
Residential Aged Care	1 (4.5%)	3 (1%)
Other transport	1 (4.5%)	3 (1%)
Workplace	2 (9.1%)	7 (2.4%)
Transport – Airline flight	2 (9.1%)	14 (5%)
Total	22	295

CONTACTS

From the first 600 cases notified in WA, there were 2,140 close contacts identified. All contacts were identified through traditional contact tracing methods, with none having been identified through the COVIDSafe app (9).

Of the 600 cases, 50 cases had no close contacts identified. A mean of 4.26 close contacts were identified per case (95% CI 3.75-4.77) (Table 5).

Table 5. Close contacts of COVID-19 cases by total number, mean and median, 21 February to 9 June 2020, Western Australia

Close contacts of cases	Number
Number of close contacts	2140
Mean number of close contacts (95% CI)	4.26 (3.75-4.77)
Median number of close contacts per case (75th percentile, 90th percentile)	2 (4,7)

By contact type, 514 were household only contacts and 1626 were non-household contacts (Table 8). Further analyses into specific types of contacts was also undertaken, with the highest number of close contacts resulting from workplaces (30.5%), followed by the household (24%) (Table 6).

Table 6: Close contacts of COVID-19 cases by contact type, 21 February to 9 June 2020, Western Australia

Contact type	Total	%
Workplace	653	30.5%
Household	514	24.0%
Health care associated	180	8.4%
Travel	134	6.3%
Travel/Household	113	5.3%
Hotel	66	3.1%
Travel/Hotel	37	1.7%
Unknown	16	0.7%
Hotel/Household	1	0%
Household/Workplace	1	0%
Other	425	19.9%
Total	**2140**	**100%**

SECONDARY CASES

Secondary cases within the first 600 were also analysed, with 53 resulting. Overall, 2.5% of close contacts (n=2140) became secondary cases. All secondary cases were analysed further to classify their specific type of contact (Table 7). The "Workplace" category included secondaries from health care settings (n=6) and a non-healthcare setting (n=3). The "Other" category includes all others with less than 10 in a category, including Healthcare associated and Hotel.

Table 7. Secondary cases identified by specific contact type, 21 February to 9 June 2020, Western Australia

Contact type	Number of contacts who became secondary cases
Household only*	29 (54.7%)
Workplace**	10 (18.9%)
Other***	14 (26.4%)

*Household contacts: contact with the infectious case within the household only
**Workplace contacts: Close contact with the infectious case while in the workplace
***Other: all other types of contacts

Of the close contacts, 5.6% were household only contacts compared to 1.5% who were non-household contacts (Table 8). The proportion of secondary cases of COVID-19 in a household setting was significantly higher when compared to those not in a household setting (Chi-square= 28.29, p-value= <0.00001). While the proportion of secondary cases of COVID-19 in a workplace setting was not significantly higher when compared to those not in a workplace setting (Chi-square=3.43, p-value= 0.064).

Table 8. Secondary cases: new cases previously identified as contacts by contact type, 21 February to 9 June 2020, Western Australia

Contact type	Number of contacts	Number of contacts who became secondary cases	Proportion of contact type that became a secondary case
Household only*	514	29	5.6%
Non-Household**	1626	24	1.5%
Overall	**2140**	**53**	**2.5%**

*Household contacts: contact with the infectious case within the household only
**Non-household contacts: all other types of contacts. These can also include those who have had "mixed" type of contact with an infectious case (e.g. contact with the infectious case while travelling AND while in the household)

KEY TIME-TO-EVENT INTERVALS: MEASURE OF PUBLIC HEALTH RESPONSE

Key time-to-event intervals were also evaluated (Table 9). The average days between the cases onset date and their specimen collection date was 4.13 days (median=3 days), while onset date to their notification date to public health was an average of 5.23 days (median=4 days).

Case notification date to isolation date was a mean of 0.38 days, with those 477 cases not being in isolation prior to their positive result and resulting notification to public health. There were 62 cases who were already in isolation for an average of 2.87 days (median= 2 days) before a positive result was notified. In data not shown, dates stratified by restriction phase were analysed, however due to numerous caveats it was extremely difficult to interpret.

EXPOSURE PERIOD RESULTS

During the "exposure period", calculated by onset date minus 14-day incubation period (Table 10), the numbers of cases was highest in Phase 1 (n=438, 73%). Those cases with their exposure period within Phase 1 saw their place of acquisition (POA) largely being overseas acquired, accounting for 50.7% (n=222) of all cases in Phase 1 (n=438), with At Sea (n=152) accounting for 34.7% and locally acquired- contact of a case or in a known cluster (n=44) accounting for 10%. These continued to decrease in number over all Phases, however in Phase 4 there was an increase in At Sea cases (n=21), representing 47.7% of all cases in Phase 4, followed by 45.5% of cases being acquired overseas. However, all of these cases were in quarantine (n=41) or known close contacts (n=3) at the time of being reported and did not represent a risk of onward transmission.

The POA of At Sea in Phase 1 and 2 were attributed to acquiring their infection on cruise ships, while particularly during Phase 4, infections were acquired on a maritime vessel.
The number of close contacts were also placed into phases, which illustrates the highest number of close contacts within the exposure period of Phase 1 (n=1626, 76%), then decreasing over the following Phases. Except for the 18.3 contacts per case exposed in Phase 3, attributed to "workplace" close contacts, including those from hotels, ACFs and hospitals.

PRESENTATION PERIOD RESULTS

During the "presentation period" (Table 11), calculated by notification date, the peak of cases notified in WA was during Phase 2 (n=259, 43.2%), which also saw the highest number of close contacts (n=1027, 48%). Phase 2 POA showed the highest numbers in the overseas category (n=148), accounting for 57.1% cases in that Phase, followed by 30.9% At Sea (n=80). Those with a POA as Locally acquired increased during Phase 2 and remained consistent throughout Phase 3 and 4. Notifications during Phase 3 and 4 were similar with 176 cases (29.3%) in Phase 3 and 147 cases (24.5%) in Phase 4, with a large proportion of those attributed to a cruise ship of International residents (n=81) and a maritime vessel (n=21).

The number of close contacts were again placed into phases, by the cases notification date, which illustrates the highest number of close contacts within presentation period of Phase 2 (n=1027) and then decreased over the following Phases. Numbers of close contacts were however still high due to large numbers attributed to "workplace" close contacts from hotels, ACFs and hospitals. The average number of close contacts remained consistent throughout all presentation period Phases.

Table 9: Key time-to-event intervals: measure of public health response: 21 February to 9 June 2020, Western Australia

Measure	Total (cases)	Mean (days)	Median (days)	IQR (days)
Onset date to specimen collection date	587*	4.13	3	1-6
Onset date to notification date	593*	5.23	4	2-7
Date of notification to isolation date	477**	0.38	0	0-1
Date of isolation to result notification	62***	2.87	2	1-3

*Probable cases excluded due to being past infections
**477 cases who went into isolation after positive result was notified. These 477 cases were not in isolation before notification)
***62 cases who were already in isolation for an average of 2.87 days before positive result was notified

Table 10: Overall picture by restriction dates, by onset date minus 14-day incubation period (EXPOSURE PERIOD), 21 February to 9 June 2020, Western Australia

		Total	PHASE 1	PHASE 2	PHASE 3	PHASE 4
Number of cases		600	438 (73%)	104 (17.3%)	14 (2.3%)	44 (7.3%)
Number of close contacts		2140	1626 (76%)	192 (9%)	256 (12%)	66 (3.1%)
Average number of close contacts per case			3	2	18	2
Place of acquisition (POA)	At Sea	247	152	67	7	21
	% within this POA		61.5% (n=247)	27.1% (n=247)	2.8% (n=247)	8.5% (n=247)
	% within Phase		34.7% (n=438)	64.4% (n=104)	50% (n=14)	47.7% (n=-44)
	Overseas	263	222	19	2	20
	% of all O/S cases		84.4% (n=263)	7.2% (n=263)	0.8% (n=263)	7.6% (n=263)
	% within Phase		50.7% (n=438)	18.3% (n=104)	14.3% (n=14)	45.5% (n=44)
	Locally acquired – contact of a case or in a known cluster	68	44	16	5	3
	% within this POA		64.7% (n=68)	23.5% (n=68)	7.4% (n=68)	4.4% (n=68)
	% within Phase		10.0% (n=438)	15.4% (n=104)	35.7% (n=14)	6.8% (n=14)
	Locally acquired – contact not identified, interstate travel	6	5	1	-	-
	% within this POA		83.3% (n=6)	16.7% (n=6)		
	% within Phase		1% (n=438)	1% (n=104)	-	-
	Locally acquired – contact not identified	16	15	1	-	-
	% within this POA		93.8% (n=16)	6.3% (n=16)	-	-
	% within Phase		3.4% (n=-438)	1% (n=104)		

Table 11: Overall picture by restriction dates, by notification date (PRESENTATION PERIOD), 21 February to 9 June 2020, Western Australia

		Total	PHASE 1	PHASE 2	PHASE 3	PHASE 4
Number of cases		600	18 (3%)	259 (43.2%)	176 (29.3%)	147 (24.5%)
Number of close contacts		2140	64 (3%)	1027 (48%)	523 (24.4%)	526 (24.6%)
Average number of close contacts per case			4	4	3	4
Place of acquisition (POA)	At Sea	247	2	80	78	87
	% within this POA		0.8% (n=247)	32.4% (n=247)	31.6% (n=247)	35.2% (n=247)
	% within Phase		11.1% (n=18)	30.9% (n=259)	44.3% (n=176)	59.2% (n=147)
	Overseas	263	14	148	67	34
	% within this POA		5.3% (n=263)	56.3% (n=263)	25.5%(n=263)	12.9% (n=263)
	% within Phase		77.8% (n=18)	57.1% (n=259)	38.1% (n=176)	23.1% (n=147)
	Locally acquired – contact of a case or in a known cluster	68	2	26	18	22
	% within this POA		2.9% (n=68)	38.2% (n=68)	26.5% (n=68)	32.4% (n=68)
	% within Phase		11.1% (n=18)	10% (n=259)	10.2% (n=176)	15% (n=147)
	Locally acquired – contact not identified, interstate travel	6	-	-	5	1
	% within this POA		-	-	83.3% (n=6)	16.7% (n=6)
	% within Phase		-	-	2.8% (n=176)	0.7% (n=147)
	Locally acquired – contact not identified	16	-	5	8	3
	% within this POA		-	31.3% (n=16)	50% (n=16)	18.8% (n=16)
	% within Phase		-	1.9% (n=259)	4.5% (n=176)	2% (n=147)

DISCUSSION

The graduated non-pharmaceutical public health strategies and restrictions put in place by the Australian Government and the WA Government, which were implemented throughout the study period (21 February to 9 June 2020), indicated that these measures were effective in containing the spread of COVID-19 in WA.

AIM 1: DESCRIPTIVE ANALYSIS

For this study period, as of 9 June 2020 Australia had recorded a total of 7,267 cases of COVID-19(10), 600 of those having been notified in Western Australia. Australia had recorded 102 deaths, nine of those reported in WA. WA cases consisted predominantly of females (55.2%), with 18.5% of all cases being within the 60-69 year age group, followed by 17.7% in the 30-39 year age group. This was consistent with what Australia was experiencing during the same period, with 75.9% of all cases being within the 18-64 year age group (11). The numbers within these age groups being largely driven, in both WA and nationally, by outbreaks on cruise ships and by overseas travel. Recognising the time period NZ used for their descriptive epidemiological study was less than this study, they also reported the majority of their cases were female (56%), however the age group with the most cases reported was 20-34 years (34%). Likewise, it was seen in both WA and nationally, the lowest numbers and rates of disease were among children and young adults, which is also consistent with international reports from NZ(5), China and the United States of America (USA), indicating a low rate of infection among children(11). Conversely, from January to May 2020 Hong Kong had a different demographic profile from what was being reported worldwide by the WHO (12), with a higher male to female ratio and 66.7% of cases being under the age of 45 years of age (13).

Among the 600 cases notified in WA, 2140 close contacts were identified, with a mean of 4.26 close contacts per case. While there was community transmission occurring in WA, the proportion of secondary cases in a household setting was significantly higher when compared to those not in a household setting (Chi-square= 28.29, p-value= <0.00001),

Internationally, a study was undertaken on the risk of SARS-CoV-2 infection among contacts of individuals with COVID-19 in Hangzhou, China. This study found that household contacts had 41.7 times higher risk of acquiring COVID-19 and the incidence rate of close contacts who lived in the same residence was 17.9% significantly higher than those who had different types of contact (14).

A literature search conducted failed to find any Australian data to compare this study's results to. Therefore, these findings could contribute to strengthening COVID-19 knowledge about household transmission in Australia. Further investigations into understanding these transmission dynamics within the household compared to those outside the household could help inform future control strategies and public health interventions to reduce the risk of further COVID-19 within the household (15).

From January to June 2020, WA investigated 22 COVID-19 outbreaks, associated with 295 confirmed cases and 16 probable cases. There were an additional nine probable cases included in this count due to these cases being linked to known outbreaks after serological testing and interview after this study period date. The only comparison with Australia available was from the COVID-19 National Incident Room Surveillance Team's Epidemiology Report 28 (fortnightly reporting period ending 25 October 2020) (16). It must be noted that this includes an additional 4 months to the comparison. It was reported that since the beginning of the epidemic, 826 outbreaks associated with 13,199 cases. In March 2020, fifteen outbreaks were investigated in WA, which was also reported to be the first peak Australia-wide. The median number of confirmed cases per outbreak in WA was 3.5 (range 0-81), which was low compared to national statistics, with the median being 6 (range 2-260), with the largest proportion of outbreaks (39%) having 6-24 cases (16).

Internationally, NZ found that 67% cases of locally acquired outbreak-related cases occurred before their "lockdown" (5). This is similar to WA with locally-acquired cases ("contact of a case or in a known cluster", "contact not identified interstate travel" or "contact not identified") occurring in Phase 1 and Phase 2 (Table 10), before mandatory hotel quarantine measures and WA's hard border closure was in place. There was no comparison between outbreaks occurring in WA/Australia to those having occurred in the USA and United Kingdom (UK), as COVID-19 transmission, healthcare infrastructure, testing criteria and control strategies were vastly different (17).

Of the 600 cases notified in WA, 43.8% acquired their infection from overseas, closely followed by 41.2% from "At Sea". This was also seen nationally during the same time period with 62% considered to have acquired their infection overseas, however this is difficult to interpret as further breakdown nationally for "At Sea" wasn't available, with all cruise-ship and maritime vessels being accounted for within the category of 'overseas-acquired"(11).

AIM 2: ASSESS THE TIME-TO-EVENT INTERVALS OF THE WA PUBLIC HEALTH RESPONSE

Early and rapid case identification is known to be crucial during a pandemic to be able to promptly isolate cases and to identify and quarantine their close contacts. This has been shown to reduce the further spread of COVID-19(18).

Analyses on the first 600 cases notified in WA showed that between the case onset date and specimen collection date was an average of 4.13 days and onset to notification date an average of 5.23 days. Once the case was notified of the positive COVID-19 result by public health, it was an average of 0.38 days between notification and isolation, indicating rapid public health response by PHOps. It was also seen that 62 cases were already in isolation for an average of 2.87 days before being notified of a positive result. These cases were across all restriction Phases and were in quarantine already due to being a close contact of a confirmed case or having arrived from overseas or were from a cruise ship (Table 9).

It is important to recognise that these intervals can be difficult to reduce, given they are highly dependent on the public's response. Possible impacts on these intervals, particularly early in the response could include public awareness and education of COVID-19's symptoms and the need to be tested, as well as specimen collection and therefore notification, potentially being impacted due to the narrow testing criteria. Widespread testing for COVID-19 did not become possible until 2 April 2020(19). Further analysis by phase was attempted, however due to the small numbers in some categories and various caveats including the addition of Day 12 mandatory hotel testing introduced on 12 May 2020, these findings were difficult to draw any meaningful conclusions from.

A literature search failed to find any Australian data to compare this study's results to. While NZ were able to analyse key time-to-event intervals by phases and saw these decrease over time. Within 2 weeks of their national lockdown, the data showed a reduction in not only daily case numbers but an improvement in key intervals, such as case onset to notification reducing from 9.7 days to 1.7 days, and average isolation intervals from 7.2 days to -2.7 days (with negative days signifying isolation before onset)(5). In WA, across the entire first 600 cases, the average time from notification to isolation was 0.38 days which means that there were sufficient public health resources, and that the system was able to get cases into isolation within hours. Imposing restrictions on social gatherings from 18 March 2020 and maintaining quarantine for overseas

arrivals means that potential cases were already in isolation before or around the time of onset, which limits the spread of the virus.

AIM 3: INVESTIGATE THE IMPACT OF THE INTERTWINED NATIONAL & WA STRATEGIES

Between nations and States and Territories within Australia, approaches to the suppression and/or mitigation of the impact of the COVID-19 pandemic have varied evidently (20). As experienced in China early in the COVID-19 pandemic response, chains of human-to-human transmission could successfully be interrupted by implementing non-pharmaceutical public health measures (4, 20).

When comparing the trajectory and scale of both Australia and WA's COVID-19 epidemic during this time period, to other countries such as NZ, South Korea and Taiwan, all saw a phase of exponential growth, followed by a levelling of the curve (5, 11, 20). Figure 1 and Table 11 show that the increase in cases notified in WA was highest from Phase 1 through to the end of Phase 3 (March to the start of April). In comparison, the incidence of COVID-19 in Australia also peaked during this time, and then noticeably decreased, which could be due to combination of the non-pharmaceutical public health interventions that were put in place at the start of the pandemic (see Table 2) such as border closures having been effective in slowing the spread of COVID-19. Other effective measures taken included early and rigorous case finding and isolation, immediate testing, thorough contact tracing and quarantine of close contacts and public education and engagement about physical distancing (4, 11).

To investigate the impact of the intertwined national mitigation and WA suppression strategies, cases were assigned to two different periods, by each restriction phase. This included their "exposure period" based on their onset date minus a 14-day incubation period (Table 10), and their "presentation period" based on their notification date (Table 11). Each restriction phase (Phase 1-4) differed in time period length, as these were dictated by significant non-pharmaceutical public health interventions declared nationally or exclusively within WA.

Table 10 shows cases assigned to each restriction phase by their "exposure period" to COVID-19 and then used to assess the impacts of the non-pharmaceutical intervention on disease transmission. This analysis shows a decrease in the number of cases and contacts throughout Phases 1 to 4. The POA, particularly in Phase 1 and 2 also highlights that COVID-19 transmission was occurring predominantly Overseas and At Sea (cruise ships), which then decreased dramatically due to the travel restrictions put in place by the Australian Government. WA

residents acquiring the infection locally was highest in Phase 1 and 2, however also noticeably decreased afterwards. Importantly, those 44 cases in Phase 4 were mostly in hotel quarantine or a known close contact of a confirmed case, therefore did not present a risk of onward transmission.

Although there were different timeframes of Phase distinction, NZ also saw a decrease in cases over their 5 Phases (dictated by their national COVID-19 suppression strategies), with POA of imported, import related and locally acquired cases also being high throughout Phase 1-3 (2 February through to 10 April 2020) but then, similar to WA, decreasing due to border restrictions, movement restrictions including the "stay at home" orders and implementing mandatory state-managed quarantine for all returning travellers to NZ on 10 April 2020(5).

Cases were also assigned to "presentation periods", using notification date, to assess what impact COVID-19 notifications were having within WA, by the number of cases and their resulting close contacts. Table 11 illustrates the peak of COVID-19 notifications during Phase 2, which was also seen nationally (11). This not surprisingly, also coincided with the highest number of close contacts. Notifications during Phase 3-4 were similar, with a large proportion of those cases being attributed to a POA of At Sea, which consisted of 81 international residents being on a cruise ship and a separate maritime vessel (n=21), as well as a POA of "Overseas" which was attributed to returning Australian citizens arriving in WA. Importantly during these phases, mandatory hotel quarantine was in place or cases on ships were managed appropriately on the vessel and therefore not putting the WA public at further risk of COVID-19. Close contacts travelling to WA with these cases, were also in mandatory quarantine, limiting the potential spread of the virus.
The highest number of close contacts were seen during Phase 2 and importantly declined during Phase 3-4. Numbers were still elevated during Phase 3 and 4 due to large numbers attributed to "workplace" close contacts, including those from hotels, ACFs and hospitals (Table 6)

During Phase 2, the POA of cases was highest for the Overseas category which could be attributed to Australian residents returning from overseas. Also high during this period were the locally acquired – contact of a case or in a known cluster and At Sea. Throughout Phases 2-4, the notification of those cases defined as being "locally acquired" remained consistent, with most being a contact of a case or in a known cluster. This also coincides with most outbreaks in WA being investigated in March and April 2020.

Overall, the number of cases and contacts notified over the restriction Phases decreased, which could be attributed to all restrictions, including social restrictions, the public being more educated

about COVID-19, international and state border closures and mandatory hotel quarantine measures. This then allowed the relaxation of WA's social restrictions to ease from 27 April 2020 onwards, while the WA hard border closure and international border closures remained in place.

A literature search conducted failed to find any Australian data to compare these results to. Similar studies have been undertaken internationally however, specifically in NZ and Hong Kong. Hong Kong assessed their overall effectiveness of various public health measures including enhanced surveillance and testing, border control, mandatory quarantine and social distancing measures. These measures were implemented throughout the period of January to May 2020. Hong Kong reported 1084 cases in this time period. The Phases had differing time periods compared to this study; however, they also reported a similar trend of a stable number initially being reported, followed by a surge and then an eventual drop. Their highest case numbers (n=925) were reported in Phase 3 (4 March to 19 April 2020), a similar time to WA's peak of notifications in Phase 2-3 (15 March to 4 April 2020). Hong Kong also noted an alike trend of initially imported infection (in their instance from China), to local transmission, to imported infection from overseas countries associated with local transmission, to controlled imported infection with limited local transmission. The surge they experienced, similar to WA and Australia was due to imported cases from people returning from overseas and also an increase in local cases (13). New Zealand also saw their peak between 16 March and 10 April 2020 (their defined Phase 2 and 3), with case notifications gradually decreasing thereafter. Likewise, it was also seen that the proportion of imported cases declined after their rapid escalation of non-pharmaceutical interventions, including their "lockdown" and border controls (5).

ADVANTAGES

This study has the advantage of having used PHOCUS, in which all data related to notified COVID-19 cases and contacts in Western Australia are entered, including every positive SARS-CoV-2 test and case/contact questionnaires. Another advantage was that the data analysed in this study had also been through the quality assurance process which facilitated high data quality and completeness.

LIMITATIONS

There are also limitations to this study. The dataset analysed is small which therefore poses statistical limitations. Furthermore, the testing criteria for COVID-19 constantly changed throughout the response as new information about the virus was discovered. Therefore, especially early in the response, there would be an under-representation of the true number of cases in WA, as many would not have been eligible for testing according to the criteria that were in place at the time.

Given the rapid pace of the non-pharmaceutical interventions being implemented and also eased within WA, whilst also overlapping with national response measures, it is difficult to distinguish the impacts of individual non-pharmaceutical interventions.

Similarly, the categorisation of the "restriction date phases", the exposure and presentation periods, all included assumptions. For instance, the "exposure period" date categorisation of cases was calculated with the assumption that the incubation period is 14 days, as is stated in the COVID-19 SoNG. This therefore could have seen some cases incorrectly assigned to an exposure period phase.

As this study used surveillance data and with the rapidly changing national case definitions and data specifications for both cases and contacts, coupled with the changes in operational processes and the introduction of the new PHOCUS in WA, the data collected, recorded, stored and analysed was inevitably susceptible to errors, one example being differing interpretations by the user and therefore potential misclassification of cases place of acquisition, or the type of contact they had with their close contacts. Similarly, particular contact data wasn't able to be analysed due to it not being available and therefore excluded from this study, as noted in Methods.

CONCLUSION

WA's response to COVID-19 up to June 2020 had resulted in relatively low case numbers and mortality. Overall, the combination of national and state-wide COVID-19 non-pharmaceutical public health interventions including border closures, mandatory hotel quarantine and social distancing, were able to stabilise, decrease and limit disease importation from overseas and interstate, and therefore limit local transmission in WA.

With continual learnings and evolving understanding about the COVID-19 virus in Australia and world-wide, which so far has shown to be capable of causing enormous health, societal and economic impacts, non-pharmaceutical public health interventions should be continuously evaluated (13). WA and Australia's capacity to be extremely agile and able to rapidly adapt non-pharmaceutical public health measures is vital (4).

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APPENDIX

APPENDIX 1: WA SITUATION REPORT #41

Government of **Western Australia**
Department of **Health**

Situation Report

Sitrep 41: COVID-19 – WA Response

Sunday, 1 March 2020 14:00 Hours (new information since previous sitrep in red font)

This sitrep has been authorised by the PHEOC Coordinator, Dr Donna Mak

Key sources of information

- Interim recommendations for surveillance, infection control, laboratory testing and contact management for COVID-19 have been developed by the Communicable Disease Network Australia (CDNA). These are available on the Australian Government Department of Health website.
- WA Health has information on COVID-19, including information for clinicians and patients.

Current Situation

International

- As of 20 February 2020, China has removed the classification of "clinically diagnosed". Cases are now reported as "suspected" or "confirmed", with all confirmed cases requiring laboratory confirmation. Some previously reported "clinically diagnosed" cases are thus expected to be discarded over the coming days as laboratory testing is conducted and some are found to be negative.
- According to the most recent WHO Situation Report dated 29 February 2020, in the past 24 hours:
  - Worldwide: 1,753 new confirmed cases were reported (85,403 total);
  - In China: 435 new confirmed cases were reported (79,394 total); 47 new deaths were reported (2,838 total);
  - Outside of China: 1,318 new confirmed cases were reported (6,009 total). Two new countries (Mexico and San Marino) reported cases. Nineteen new deaths outside of China were reported (86 total).
- On 30 January 2020, the WHO International Health Regulations Emergency Committee declared the outbreak of COVID-19 a Public Health Emergency of International Concern (PHEIC).
- On 28 February 2020, the WHO increased the assessment of the risk of spread and risk of impact of COVID-19 to very high at the global level.
- The Australian Government has assisted 170 passengers of the Diamond Princess to depart Japan. These passengers are in quarantine at the Howard Springs Accommodation Village, Darwin. The Australian Embassy in Tokyo continues to provide consular support to 47 passengers who tested positive to COVID-19, those who chose to remain behind in Japan, and those who have opted to finish quarantine on the Diamond Princess. Any Diamond Princess passengers were not on the assisted flight will not be allowed on other flights to Australia before Wednesday 4 March 2020 and will need to complete a 14-day quarantine period before travelling to Australia. Australians who are medically cleared from the Japanese health system will be provided a medical clearance form for presentation to officials upon arrival at the Australian border.

National

- As of 15:00 29 February 2020, 25 confirmed cases have been detected in Australia. Of the 25 confirmed cases, there have been four cases from NSW, nine cases from QLD, three cases from SA, seven cases from VIC, and two cases from WA. The initial 15 cases had either a direct or indirect link to Wuhan, Hubei Province, China, and all have now cleared their infection. Nine cases have been reported among passengers who were on the Diamond Princess cruise ship repatriation flight from Japan. All these cases have returned to their home jurisdictions for isolation and care.
- The CDNA is meeting frequently to discuss clinical advice, guidelines, fact sheets and research work relating to COVID-19.
- Department of Foreign Affairs and Trade (DFAT) travel advice levels related to COVID-19 as of 29 February 2020:
  - China: 'do not travel';
  - Iran: "do not travel";

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- Japan, Mongolia and South Korea (Republic of Korea): 'exercise a high degree of caution'. It is also advised that travellers reconsider the need to travel to Daegu and Cheongdo due to significant outbreaks of COVID-19 in those cities;
- The Lombardia and Veneto regions in northern Italy: 'exercise a high degree of caution'.

- The following travel restrictions are in place for people entering Australia having left mainland China on or after 1 February 2020:
  - foreign nationals (excluding permanent residents of Australia) will not be allowed to enter Australia until 14 days after they have left or transited through mainland China (excluding Hong Kong, Macau and Taiwan);
  - Australian citizens, permanent residents and their immediate family will still be able to enter Australia, as well as airline crews who have been using appropriate personal protective equipment;
  - all travellers who have left or transited through mainland China (excluding Hong Kong, Macau and Taiwan) on or after 1 February 2020 must isolate themselves until 14 days after leaving China.
- The following travel restrictions are in place for people entering Australia having left Iran on or after 1 March 2020:
  - foreign nationals (excluding permanent residents of Australia) will not be allowed to enter Australia until 14 days after they have left or transited through Iran;
  - Australian citizens, permanent residents and their immediate family will still be able to enter Australia, as well as airline crews who have been using appropriate personal protective equipment;
  - all travellers who have left or transited through Iran on or after 1 March 2020 must isolate themselves until 14 days after leaving Iran.
- As of 22 February 2020, Year 11 and 12 students who remain in China (outside Hubei Province) due to Australian travel restrictions have been offered a strict pathway to resume their studies. This is in recognition of the importance of the final two years of school. Students who are completing their senior secondary schooling can apply for an exemption to the 1 February 2020 COVID-19 travel restrictions applied to foreign nationals who have been in mainland China (except Hubei Province). The exemptions will be considered on a case by case basis.
- As of 3 February 2020, biosecurity officers from the Australian Government Department of Agriculture, Water and the Environment, with the support of WA Health staff, have been meeting all passengers arriving in Australian airports who have travelled to mainland China in the past 14 days, undertaking assessment and providing information on isolation as appropriate.
- As of 3 February, the National Coronavirus Health Information Line is live on **1800 020 080**. The line provides public health and situation information on the COVID-19 outbreak.
- On 27 February 2020, the Prime Minister announced the activation of the 'Australian Health Sector Emergency Response Plan for Novel Coronavirus (COVID-19)'.

State

- As of 1 March 2020, there are two confirmed cases in WA, associated with the Diamond Princess cruise ship. On 1 March the first coronavirus related death in Australia was reported, in a 78-year-old man from WA, who was a passenger on the Diamond Princess cruise ship. An additional 594 people tested for COVID-19 in WA have had a negative result.
- As of 29 January 2020, 'Human coronavirus with pandemic potential' has been declared an urgently notifiable disease under Part 9 of the *Public Health Act 2016*.
- As of 28 February 2020, the Chief Health Officer has formally escalated the Infectious Disease Emergency Management Plan to INITIAL ACTION PHASE and the State Hazard Plan Human Biosecurity has been activated to STANDBY PHASE.
- Briefings and meetings being held on 1 March 2020:
  - A media briefing was held by the Chief Health Officer regarding the first coronavirus related death in WA.

Actions Required

- As of 21 February 2020, the case definition for COVID-19 in Australia has been revised to:

  Confirmed case

  A person who tests positive to a validated specific SARS-CoV-2 nucleic acid test or has the virus identified by electron microscopy or viral culture.

  Suspect case

  Epidemiological criteria:
  - Travel to (including transit through) mainland China in the 14 days before the onset of illness

OR

- close or casual contact in the 14 days before illness onset with a confirmed case of COVID-19.

AND

Clinical criteria:

- Fever

OR

- Acute respiratory infection (e.g. shortness of breath or cough) with or without fever

- Clinicians who identify any patients who meet the criteria above should immediately contact a WA Health Public Health Physician. Please refer to the Population Health Units phone list during work hours; after hours contact the CDCD Public Health Physician on-call at 9328 0553. The WA Health Public Health Physician can provide guidance on testing and management.
- It is recommended that clinicians should consider testing people with a clinically compatible illness who travelled to any of the following countries in the 14 days before onset of symptoms: Cambodia, Hong Kong, Indonesia, Iran, Italy, Japan, Singapore, South Korea, Thailand. The recommendation does not apply to passengers who have only been in transit through an airport in these countries.
- All other **non-urgent** requests for information on COVID-19 should be referred to PHEOC at pheoc@health.wa.gov.au or visit health.wa.gov.au/coronavirus.
- Health Service Providers (HSPs) should ensure that there are no financial barriers for people to be evaluated for potential COVID-19 infection.
- All WA Emergency Departments should display signage directing ill persons with recent overseas travel to identify themselves at triage. Masks should be provided to persons presenting with acute febrile respiratory illness as soon they are identified.
- Maintain situational awareness. This is a dynamic situation and health services in WA should continue to monitor email and other communication systems for potential updates.

Further Situation Reports

- The next sitrep will be distributed on 2 March 2020, unless there are significant developments in the interim.

Sitrep prepared by: Hannah Vogt, CDCD
T: +61 8 9222 0221 | E: pheoc@health.wa.gov.au | I: www.health.wa.gov.au

CHAPTER 3: EVALUATION OF THE COVID-19 SURVEILLANCE SYSTEM IN WESTERN AUSTRALIA

LIST OF ABBREVIATIONS

CALD	Culturally and linguistically diverse
CDC	Centers for Disease Control and Prevention
CDCD	Communicable Disease Control Directorate
CDNA	Communicable Diseases Network Australia
COVID-19	Coronavirus disease 2019
HSS	Health Support Services
HWB	Health and Wellbeing service
ICU	Intensive Care Unit
LDR	linked data repository
NNDSS	National Notifiable Diseases Surveillance System
nCoV	novel coronavirus
NCS	National Surveillance Committee
NOK	next of kin
PCR	Polymerase chain reaction
PHEOC	Public Health Emergency Operations Centre
PHEIC	Public Health Emergency of International Concern
PHIC	Public Health Intelligence Cell
PHOps	PHEOC Operations (Public Health Operations)
PHOCUS	Public Health Operations COVID-19 Unified System
QA	Quality assurance
REDCap	Research Electronic Data Capture
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SES	Socio-economic status
SHICC	State Health Incident Coordination Centre
SWICC	The State Welfare Incident Control Centre
VOC	variant of concern
WA	Western Australia
WACHS	Western Australia Country Health Service
WANIDD	Western Australia Notifiable Infectious Diseases Database
WHO	World Health Organisation

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PROLOGUE

MY ROLE

From the beginning of the COVID-19 pandemic in Western Australia (WA), I have been working within both the Public Health Emergency Operations Centre (PHEOC), PHEOC Operations (PHOps) and within the Public Health Intelligence Cell (PHIC).

Before organisational functions were further advanced, I was within the Operations Cell of PHEOC. My roles pertinent to this chapter included:

- laboratory liaison between PHEOC and all laboratories within WA, arranging specimen collection procedures, liaising with clinical microbiologists, facilitating domiciliary services to assist with COVID-19 collection in metropolitan Perth with a private laboratory, creating a standard operating procedure (SOP) for specimen collection during business hours and while public health physicians were on-call
- liaison between PHEOC and Metropolitan Communicable Disease Control (MCDC) regarding the use of REDCap for suspected cases, people under investigation and contact tracing
- a member of the surveillance and reporting arm of the Operations Cell, therefore assisted in mapping out the current surveillance system in WA to identify all processes, writing WA Situation Reports and reported WA COVID-19 data daily to the National Notifiable Disease Surveillance System (NNDSS).

During the transition of organisational functions, I worked within MCDC, which was then merged into PHOps. Within PHOps, I worked in PHIC and performed data analytics, reporting, and database development and support. Initially, my role in PHIC was to manage the Excel spreadsheet of all cases of COVID-19. This spreadsheet was adapted from the one used in the measles outbreak (as discussed in Chapter 4). The main purpose of the COVID-19 spreadsheet was to document all cases as soon as they were notified, as well as adding required information for reporting purposes once they had been interviewed by MCDC staff. This data, of all cases and their contacts, was entered into REDCap which was initially used as the case and contact management system.

The Excel spreadsheet required constant data cleaning, as well as clear and constant communication with public health physicians, registrars and nurses that interviewed each case. This spreadsheet was used to provide reports, including case counts, line-lists of cases and an epidemiological curve to numerous stakeholders, including PHEOC, health service providers within WA, and importantly for public health physician on-call handovers – particularly reporting case numbers to the media and Health Minister.

By 8 April 2020, data from REDCap was migrated into the Public Health Operations COVID-19 Unified System (PHOCUS). PHOCUS underwent many updates and modifications to its current state. Prior to the migration of the REDCap COVID-19 data, I helped establish the required fields for the place of acquisition data field, as per the NNDSS data specifications, as well as arranging data cleaning guidance and data extracts for the PHOps staff to undertake. The Excel spreadsheet continued to be used for reporting purposes when PHOCUS was first implemented. It was seen as the source of truth for the first 600 cases and was used as a quality assurance check against the data that had been migrated into PHOCUS. Throughout the process, I was also able to indicate which data fields needed to be added to PHOCUS to assist future analysis of close contacts and secondary cases.

Continuing from this role during my MAE, I was then officially employed by WA Health to work in PHIC in January 2021, working specifically within the surveillance system I was to evaluate. My role within the team included the following tasks:

- daily reporting of COVID-19 data, including case/contact data, testing data to internal and external stakeholders (locally and nationally)
- data management of both cases and contacts
- liaising with the State Health Incident Coordination Centre (SHICC) for hotel quarantine case and contact clearances
- producing daily COVID-19 Situation Reports
- producing weekly epidemiological COVID-19 presentations to internal stakeholders
- identifying PHOCUS and WANIDD data issues, reviewing data flow, QA, maintenance, management and reporting of COVID-19 data.

For this project, extraction of the study data was undertaken by the PHIC. To complete the stakeholder engagement process, I developed the interview guide, coordinated, facilitated and transcribed the interviews.

Lessons learnt

This project expanded my capacity to be flexible and adapt to new challenges. This project was commenced at the beginning of 2020 when the COVID-19 pandemic was just beginning. I started to critically evaluate the WA surveillance system and how it was being adapted for the COVID-19 pandemic. I then adjusted this project to compare the surveillance system that was first put in place, to the new system (PHOCUS) which was implemented on the 8 April 2020. This was also the basis of my Lesson from the Field. However, given the pace of the pandemic response and the evolving and ever-growing COVID-19 surveillance system in WA, recommendations I was preparing (which also linked in from my data analysis project) had already been incorporated into the numerous PHOCUS updates. I therefore adapted my previous work into this project.

I am grateful for being able to engage with all stakeholders, and to witness how the project has evolved and its outcome, especially as I have been an active participant in all versions of the COVID-19 WA surveillance system since the commencement of the pandemic. The stakeholder consultation also gave me a great opportunity to learn about questionnaire design and from this I gained an appreciation for the value and power of qualitative research methods. It also highlighted to me the importance of having close working relationships with all stakeholders.

Public Health Impact

This is the first evaluation of the COVID-19 surveillance system in WA. As a result of the evaluation, a series of recommendations were made to help improve and strengthen the current system. These recommendations have been provided to PHEOC, PHOps, Communicable Disease Control Directorate (CDCD) for their consideration and further action. Importantly, several of these recommendations can also be applied to all other notifiable conditions and their surveillance in WA.

Acknowledgments

I am very grateful to the number of people who have given me their support and time. I would specifically like to thank the following people who provided their expertise, knowledge and experiences: Dr Ben Scalley, Dr Clare Huppatz, Dr Suzanne McEvoy, Brenda Kamau, Paul Hughes, Carolien Giele and Andrew Jardine. I would also like to acknowledge the tireless work all staff within PHEOC, PHOps and CDCD have done, and continue to, undertake in their roles within WA's COVID-19 surveillance system.

ABSTRACT

BACKGROUND

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the infective agent that causes coronavirus disease 2019 (COVID-19). The COVID-19 global pandemic was declared on 11 March 2020 by the World Health Organisation (WHO), triggering public health action in many parts of the world. COVID-19 surveillance in WA has evolved throughout the pandemic and since its establishment in January 2020, however the COVID-19 surveillance system has not yet been evaluated. The purpose of this evaluation is to provide an assessment of the system's performance and provide recommendations for its improvement.

METHODS

This evaluation followed the US Centres for Disease Control and Prevention *Guidelines for Evaluating Public Health Surveillance Systems*. Engagement with stakeholders, document review, and analysis of surveillance system data were used to assess the performance of the system against key attributes.

RESULTS

The current COVID-19 surveillance system in WA, in the current climate of minimal COVID-19 cases, performs well and meets its defined objectives. Throughout all of the changes to COVID-19 surveillance and the system in WA, it has been adequate for monitoring, detecting, reporting and informing public health response during the COVID-19 pandemic response. The current system is undoubtedly useful and is currently effective, however, there are concerns held if case numbers were to dramatically increase.

CONCLUSION

Based on evaluation findings, minor and major recommendations were made. These included the addition of specific data fields, continual education and training of staff involved in the surveillance system and automation of data flow from notification to reporting.

BACKGROUND

This chapter describes and evaluates the COVID-19 surveillance system in Western Australia (WA). Firstly, it will examine and describe the public health significance and epidemiology of COVID-19. Following this there will be a description of the public health surveillance system for COVID-19 in WA. The evaluation of this system undertaken will also be described to ensure it meets the intended objectives. Recommendations will then be made to conclude this chapter.

PUBLIC HEALTH SIGNIFICANCE & EPIDEMIOLOGY OF COVID-19

On the 31 December 2019, the World Health Organisation (WHO) China Country Office learnt of cases of pneumonia with an unknown aetiology first identified in Wuhan City, Hubei Province of China. A new type of coronavirus was isolated on 7 January 2020 and, as of 20 January 2020, there were 282 confirmed cases, including six deaths, of novel coronavirus (nCoV) (temporarily named 2019-nCoV) reported across four countries (China, Thailand, Japan and the Republic of Korea)(1). On 30 January 2020, the WHO declared the outbreak to be a Public Health Emergency of International Concern (PHEIC) (2) and further declared the COVID-19 outbreak a global pandemic on 11 March 2020 (3).

Even before the WHO declared the pandemic, Australia had implemented measures aimed at slowing the spread of COVID-19 into and within the country. The first Australian border restrictions was employed on 1 February 2020, with a ban on foreign national passengers arriving on flights from China, and enforced Australian passengers on flights arriving from China, to self-isolate for 14 days. The restrictions continued to be further enhanced throughout the pandemic response (4). On 18 March 2020, the Australian Government declared a "human biosecurity emergency" under the *Biosecurity Act 2015*, given the risks COVID-19 posed to human health and the need to control its spread in Australia. The declaration allowed the state and territory Health Ministers to issue targeted, legally enforceable directions and measurements to combat the virus, as required (5).

In WA, the Public Health Emergency Operations Centre (PHEOC) was activated on 23 January 2020 to coordinate the State response to the COVID-19 pandemic. Shortly after, on 29 January, "Human coronavirus with pandemic potential" was declared an urgently notifiable disease under Part 9 of the *Western Australia Public Health Act, 2016*, and on 15 March 2020, the Minister for

Emergency Services in WA declared a State of Emergency in respect of the pandemic caused by COVID-19, pursuant to section 56 of the *Emergency Management Act 2005* (WA). The WA public health response to COVID-19 consists of an all of government approach under this Act (6).

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the infective agent that causes coronavirus disease 2019 (COVID-19). SARS-CoV-2 is a novel coronavirus with evidence suggesting bats being the reservoir and an intermediate host is yet to be determined (7, 8). The predominant mode of transmission of SARS-CoV-2 is human-to-human, via droplets and fomites from an infected person (9) . The current incubation period is estimated to be a range of 1 to 14 days, with the majority of people becoming symptomatic 5 to 6 days after becoming infected (9, 10).

Based on current evidence, pre-symptomatic and asymptomatic transmission of COVID-19 can occur. Pre-symptomatic transmission can occur 1-3 days before the onset of symptoms (11, 12), with the viral load of throat swabs being the highest at the case's symptom onset and decreasing within 7 days (13, 14). Following the establishment of the Communicable Diseases Network Australia (CDNA) Series of National Guidelines (SoNG) for the purposes of routine contact tracing, cases were considered infectious from 48 hours prior to symptom onset and required immediate isolation until certain criteria have been met.

Symptoms of COVID-19 range from mild symptoms to severe illness, with fever and cough being the most commonly reported symptoms. Other less common symptoms include tiredness, myalgia, loss of taste or smell, headache, sore throat, conjunctivitis and runny nose. Serious symptoms can include shortness of breath and difficulty breathing, chest pain/pressure and loss of speech or movement (9, 15, 16). Most infected people develop mild to moderate illness and do not require hospitalisation. However, people with underlying medical conditions, such as cardiovascular disease, diabetes, cancer and chronic respiratory disease, are more likely to develop serious illness.

Laboratory testing for SARS-CoV-2 is important for diagnosis and public health investigations. The main types of samples collected and tested are upper and lower respiratory tract samples. Nucleic acid testing using reverse transcription polymerase chain reaction (RT-PCR) to detect SARS-CoV-2 during the acute illness is the diagnostic test of choice (9, 17).

The use of non-pharmaceutical public health interventions and prevention activities have been implemented and recommended since the start of the pandemic in an attempt to prevent and slow down the spread of COVID-19(7). Non-pharmaceutical interventions in Australia have included Australian border closures, within-Australian State and Territory border closures, travel bans to overseas countries, lockdowns, mandatory hotel quarantine for returned overseas travellers, and contact tracing of confirmed cases of COVID-19.

Simultaneously, prevention activities for COVID-19 have also been advised, including maintaining and practicing physical distancing (keeping at least 1.5m from each other), practising good hand hygiene (washing hands often with soap and water, or hand sanitiser and covering coughs and sneezes with a tissue or use your elbow), staying at home if you are unwell and getting tested for COVID-19 if you have flu-like symptoms(18). While writing this chapter, the Australian and Western Australian COVID-19 vaccination program was rolled out on 22 February 2021(19).

At the time of chapter write up (as of 10 February 2021), globally there were a total of 106,555,206 confirmed cases of COVID-19, with a total of 2,333,446 deaths (20). Nationally, there were 28,871 confirmed cases reported in Australia, with a total of 909 deaths. The largest number of cases were reported in Victoria, with 20,458 confirmed cases and 820 deaths. 62.1% of cases notified in Australia were locally acquired (contact of a confirmed case), 22.6% having acquired the infection overseas and 15.3% acquiring their infection locally, however, with no contact identified (21).

HISTORY OF COVID-19 SURVEILLANCE IN WA

In WA, "Human coronavirus with pandemic potential" was declared an urgently notifiable disease under Part 9 of the *Western Australia Public Health Act, 2016* on 29 January 2020.
Given COVID-19 was an emerging disease, there were no clear or specific protocols for the response or its surveillance, therefore these needed to be developed and the surveillance system needed to adapt, both nationally and within WA.

COVID-19 surveillance in WA has evolved throughout the pandemic. From the beginning, it was recognised that the existing surveillance system (known as the Western Australian Notifiable Infectious Diseases Database, WANIDD) would not be sufficient, capable or flexible enough for the demands of the operational aspect of an emerging infectious disease and its response. Furthermore, WANIDD did not have any existing case or contact tracing management capabilities.

Therefore, MCDC created a COVID-19 case and management system at the beginning of the pandemic response, using the Research Electronic Data Capture (REDCap) database (22), which is a free and secure web application, in which you can build, alter and manage online surveys.

REDCap was used to log all suspected cases and contacts, with forms created for case assessment, results, enhanced data and contact details and exposures. Case interviews were also recorded in detail on separate word documents. In regard to case and contact follow-up and management, REDCap was used in conjunction with the statistical package R and the SMS business provider Essendex, to send text messages to all cases and contacts being managed as part of the COVID-19 response.

REDCap was also used in conjunction with two COVID-19 Excel spreadsheets, one in MCDC and one in PHEOC. The MCDC spreadsheet, at the beginning was also used to monitor daily tasks, such as case clearance dates and flight manifest requests pertaining to specific cases. The spreadsheet was also used to provide reports, including case counts, line-lists of cases and an epidemiological curve to numerous stakeholders, including PHEOC, health service providers within WA, and importantly for public health physician on-call handovers – particularly reporting case numbers to the media and government.

By 8 April 2020, WA had migrated data from REDCap into the new Public Health Operations COVID-19 Unified System (PHOCUS), based on the Salesforce platform (a customer relationship management service) (23). Case interview word documents, and any other documentation relating to that case, was also uploaded and attached to the cases PHOCUS record. PHOCUS underwent many updates and modifications to its current state.

PHOCUS, as a data management system, is used to document a summary of all episodes of communication, including interviews, phone calls, messages, meetings, as well as tasks, test results, handovers and actions related to individuals. The system functionality includes:

- documentation of individuals as an ‘entity’ with an ability to create a “record” of activity
- links to cases and contacts, and track and trace capability
- system generated emails and SMS text messages
- ability to log daily monitoring calls separately
- ability to log and document calls, meetings and actions
- storage of related documents as attachments e.g., COVID-19 PCR laboratory results
- provision of ‘lists’ for daily calls

- ability to set ‘tasks’ for individuals or team queues
- documentation of an outbreak setting as an ‘entity’
- identification of specific cases through check boxes and extra fields (e.g. outbreaks, hotel cases, cases in high-risk settings).

At the time of this chapter write-up, the WA COVID-19 response was still functioning with two systems, as will be further described in the Results section. PHOCUS is the data management system for all cases and contacts, while WANIDD is in place to report to the National Notifiable Disease Surveillance System (NNDSS), on the required COVID-19 Dataset Field Specifications.

EVALUATION OBJECTIVES

The objective of the COVID-19 surveillance system in WA was to rapidly identify cases as early as possible in the course of the persons infection and isolate them, identify their contacts as early as possible and quarantine them, and to minimise the risk of local transmission within WA’s community and health sector.

The COVID-19 surveillance system in WA has not yet been evaluated. Therefore, the primary aim of this evaluation is to provide an assessment of the system, with the scope being if there was a breach in hotel quarantine, would the current system identify this, and would it have the capacity to scale up and deal with potential local transmission.
The objectives of the evaluation are to:

- describe the COVID-19 surveillance system in WA
- assess how effectively and efficiently COVID-19 surveillance meets its defined objectives
- provide recommendations for surveillance system improvement.

METHODS

For this evaluation of the COVID-19 surveillance system in WA, the United States Centers for Disease Control and Prevention (CDC) Updated Guidelines for Evaluating Public Health Surveillance Systems framework (24) was used. This included engaging stakeholders, describing the surveillance system under evaluation, and assessment of its performance. Evaluation findings were used to inform surveillance system recommendations.

DESCRIPTION OF THE SURVEILLANCE SYSTEM

The objectives of the surveillance system and COVID-19 case definitions were sourced from the publicly available *Communicable Diseases Network Australia (CDNA) Coronavirus Disease 2019 (COVID-19) National Guidelines for Public Health Units* (9). The system structure, operation, resource requirements and use of surveillance system data were obtained through review of relevant documents, discussions with PHEOC, PHOps, Communicable Disease Control Directorate (CDCD) staff, and stakeholder interviews.

ANALYSIS OF SURVEILLANCE DATA

Notifications from the PHOCUS and the WANIDD from the first case of COVID-19 notified in WA (21 February 2020) to case number 910 (notified on 10 February 2021), were described by: age, sex, indigenous status, confirmation status, hospitalisation, death, notification date, specimen collection date, laboratory result notification date and place of acquisition.

STAKEHOLDER ENGAGEMENT

Key stakeholder groups, relevant to each cell within the WA COVID-19 surveillance system were identified to ensure a range of perspectives were captured in the evaluation (Table 1). Individuals from these groups were invited to participate in a semi-structured interview. Interview questions were tailored to the specific role of each stakeholder and captured their experiences and opinions on the operation and performance of the COVID-19 surveillance system in WA (Appendix 1). The questions were emailed to the stakeholder prior to the interview, which were conducted face to face, recorded for playback purposes and also transcribed post-interview. After the recording was reviewed, it was deleted.

Based on relevant functions and roles within the surveillance system, key stakeholder groups included:

Table 1: Stakeholders and their role in the WA COVID-19 surveillance system

Stakeholders' role in WA's COVID-19 surveillance system
PHOCUS & WANIDD data custodian, PHEOC Strategy Coordinator
Public Health Physician, Head of PHEOC Operations (PHOps)
Epidemiologist, Surveillance and Disease Control Program, WANIDD WA member on National Surveillance Committee (NSC)
Public Health Physician, PHEOC Operations (PHOps) & Contact tracing leadership
PHEOC Operations (PHOps) Education and Training Lead
Epidemiologist, Public Health Intelligence Cell (PHIC)
PHEOC Operations (PHOps) Clinical Nurse Manager

** Note: Laboratories play a vital role in this system, however this evaluation is focussed on what WA Health (specifically PHEOC/PHOps) can control and therefore were not interviewed.

EVALUATION OF SURVEILLANCE SYSTEM PERFORMANCE & USER EXPERIENCE

This evaluation used a mixed methods approach. Evidence regarding system attributes and usefulness were collected through the analysis of surveillance data (quantitative) and/or stakeholder interviews (qualitative).

The performance and user experience of the system was evaluated by describing the following system attributes: flexibility, simplicity, acceptability, representativeness, data quality, timeliness and stability (Table 2). The descriptions of these attributes were then used to indicate the overall usefulness of the COVID-19 surveillance system in meeting its defined objectives.

Two system attributes, sensitivity and predictive value positive (PVP) were not included in this evaluation. To calculate sensitivity and predictive value positive, it is required to have cases detected by the surveillance system and the number of true cases. It can be said with a degree of certainty, given at the time of writing, WA's last case due to community transmission where the source could not be identified was 11 April 2020, that this surveillance system detected most cases of COVID-19 in WA. However, given that there was no data source containing the true number of cases, it was not possible to determine the sensitivity nor PPV.

Table 2: Methods used to evaluate the COVID-19 surveillance system and against selected attributes

Attribute	Evaluation definition (24)	Evaluation methods
Flexibility	How well the system can adapt and accommodate changing information needs or operating conditions.	Evidence for how well the system has responded and adapted to changing demands were reported and described (e.g. how quickly COVID-19 became notifiable, the use of WANIDD and the development and use of PHOCUS). Stakeholder interview.
Simplicity	The structure and ease of operation of the surveillance system.	The surveillance system flowchart was used to describe the structure. Stakeholder interview. Stakeholders were asked to describe their role and how they perceived the ease and operation of the system.
Acceptability	Willingness of stakeholders to participate in the surveillance system.	Stakeholder interview. Stakeholders were asked to describe, as relevant to their role, the strengths and weaknesses of the system.
Representativeness	Accuracy of the described health-related event over time and its distribution in the population by place and person.	Stakeholder interview Stakeholders identified any groups of people that may be under-represented in the system. Evidence of any active surveillance measures in place (for hotel workers) is also described.
Data quality	Completeness and validity of data collection.	Surveillance system data from both PHOCUS and WANIDD was analysed. Stakeholder interview.
Timeliness	The time taken between key steps in the surveillance system process.	Surveillance system data from PHOCUS, specimen collection date to result notification date. Stakeholder interview.

Attribute	Evaluation definition (24)	Evaluation methods
Stability	The reliability and availability of the surveillance system.	Stakeholder interview. Stakeholders identified any past, current or potential issues to the availability or reliability of the surveillance system.
Usefulness	How well the system meets its defined objectives.	Stakeholder interview. Overall evaluation of the surveillance system attributes and the stakeholder's views regarding how well the system meets the objectives.

ETHICAL CONSIDERATIONS

Protocol 2017/909: Request for waiver of consent for use of data in research for Master of Applied Epidemiology students for 'Outbreak Investigation' and 'Surveillance in Public Health' projects was approved by the ANU Human Research Ethics Committee on 7 February 2018.

RESULTS

COVID-19 SURVEILLANCE SYSTEM STRUCTURE & ITS SIMPLICITY

COVID-19 is a nationally notifiable disease. In WA on 29 January 2020, "Human coronavirus with pandemic potential" was declared an urgently notifiable disease under Part 9 of the WA *Public Health Act, 2016*.

As described in the COVID-19 SoNG, there are four main objectives of surveillance of COVID-19, which are to rapidly (9):

1. identify, isolate and manage cases
2. identify, quarantine and provide relevant information to contacts.
3. detect and manage clusters and outbreaks, and
4. characterise the epidemiology of COVID-19 in Australia to inform the public health response including:
    - o analysing the progression of the epidemic in time, person and place,
    - o describing the transmission dynamics, and
    - o identifying groups at special risk of infection.

The national case definition for COVID-19, as per the CDNA SoNG, is presented in Box 1. Laboratories are required to notify on laboratory definitive and/or laboratory suggestive evidence. Under Sections 157(1)(k) and 190(l)(p) of the WA *Public Health Act, 2016*, all pathology laboratories undertaking COVID-19 testing notify the Chief Health Officer of all positive and negative tests (25).

Box 1: Communicable Disease Network Australia national case definition for COVID-19, as of SoNG Version 4.2 (29 January 2021) (9).

Confirmed case

A confirmed case requires laboratory definitive evidence.

Laboratory definitive evidence:

1. Detection of SARS-CoV-2 by nucleic acid testing,
   OR
2. Isolation of SARS-CoV-2 in cell culture, with confirmation using a nucleic acid test,
   OR
3. SARS-CoV-2 IgG seroconversion or a significant increase in SARS-CoV-2 neutralising or IgG antibody level (e.g. four-fold or greater rise in titre)

Historical case

A historical case requires laboratory suggestive evidence supported by either clinical evidence OR epidemiological evidence, and is not a confirmed case

Laboratory suggestive evidence:

Detection of SARS-CoV-2 neutralising or IgG antibody2

Clinical evidence:

1. History of measured (≥37.5°C)3 or self-reported fever (e.g. night sweats, chills)
   OR
2. History of an acute respiratory infection (e.g. cough, shortness of breath, sore throat).

Epidemiological evidence:

1. Contact with a known COVID-19 case (confirmed or historical), involving a plausible mode of transmission, at a time when the case was likely to have been infectious.
   OR
2. International or domestic travel in a geographically localised area with elevated risk of community transmission, including travel on a cruise ship with known COVID-19 transmission on board.

SIMPLICITY

Interviewed stakeholders perceived the overall structure of the COVID-19 surveillance system in WA to be quite complex, given there are essentially two databases (PHOCUS and WANIDD) involved. The surveillance system is described in more detail below and summarised in Figure 1.

TESTING CRITERIA

Testing criteria for SARS-CoV-2 in Western Australia are guided by the COVID-19 Testing Directions (WA *Public Health Act 2016*, Sections 157(l)(k) and 190(1)(p)) (25, 26) and the CDNA National Guidelines. All people who meet the testing criteria should be tested, including those who are symptomatic (and meet specific clinical and/or epidemiological criteria) and, under certain conditions, asymptomatic people. Asymptomatic testing is permitted in several settings and scenarios. For the purpose of this chapter, this includes all international arrivals into WA who must undertake mandatory quarantine in a State Quarantine Facility and are given a Centre Quarantine Direction to be tested on days 2 and 12, people participating in the DETECT Borders initiative, quarantine centre workers as specified in the Presentation for Testing (Quarantine Centre Workers) Directions (No 2)(27).

The WA Department of Health's DETECT Borders program (28) is not mandatory, however it invites asymptomatic people working at WA's points of entry to be tested, with the aim to identify any transmission from infected travellers in those most at risk, at the earliest possible opportunity. Testing can occur as often as every 7 days. Eligible groups include workers in State Health Incident Control Centre (SHICC) quarantine hotels, Perth Airport, Sea ports and Eucla and Kununurra border crossings.

At the time of finalising this chapter, on 18 February 2021, Presentation for *Testing (Quarantine Centre Workers) Directions* (No 6) were signed, requiring quarantine workers to comply with daily shift and seven-day COVID-19 testing protocols. Testing requirements include presenting to a COVID Clinic for a nasopharyngeal swab every seven days and the collection of a mouth swab prior to completing each shift worked at a quarantine centre (27).

Testing in WA is available at COVID clinics, regional public hospitals and health services, remote health clinics, private pathology centres (including drive through options) and if required domiciliary services are available. Once the specimen has been collected and processed, under Sections 157(1)(k) and 190(l)(p) of the WA *Public Health Act, 2016*, all pathology laboratories

undertaking COVID-19 testing must notify the Chief Health Officer of all positive and negative tests as soon as practicable, and in any event, within 24 hours of obtaining each positive or negative test result, in order to prevent, control or abate the serious public health risk presented by COVID-19(25).

Reporting to WANIDD and PHOCUS

As soon as a specimen returns a positive result, the clinical microbiologist will immediately email a designated distribution email list consisting of staff from PHOps and PHEOC. This email will state the cases demographic details, location, strength of PCR result and have their request form attached. Once received, this is actioned by PHOps as soon as possible, including an acknowledgment of receipt to the testing laboratory.

This method of notification by the laboratories to PHOps via email, was set up at the start of the response and has remained in place. It managed to be successful even during the height of WA's case numbers, with the highest number of cases notified in one day being 44. Concerns were raised by interviewed stakeholders over this process, if case numbers were to significantly increase.

Reporting to WANIDD

Both positive and negative COVID-19 laboratory results from public and private laboratories are transmitted to CDCD. This occurs either via a laboratory feed (from between midnight and 7am), resulting in an encrypted email being sent to CDCD, or CDCD having the ability to download these results from the laboratory server. Once the file is manually un-encrypted, it is then saved onto the Department of Health network server (W: drive). Positive files (positive cases of COVID-19) are also saved into a folder on the secure network location drive, on the Department of Health's network server, and uploaded into WANIDD as a WANIDD record. Each record contains a WANIDD identification number, with the cases name, date of birth, address, requesting doctor details, laboratory ID, patient ID, specimen and report date.

It was indicated that this specific process was simple and straightforward for the staff undertaking this task, given they know the process extremely well. At the time of the evaluation, only 3 staff members have the administrative access to WANIDD required to complete this task and were only able to do the task from Monday to Friday. From this saved data file/s with all positive and negative results from all laboratories across WA, a STATA code is run to combine all results into

one Excel spreadsheet by PHIC. This spreadsheet is then used as a source for multiple reporting purposes.

REPORTING TO PHOCUS

A laboratory feed into PHOCUS only includes results from the public laboratory and is not an instant feed. A “mirror image” of the list of names and results are received, which then requires staff to create a new entity & record for the persons test result. Any results from private laboratories either need to be entered manually into PHOCUS or can be manually bulk uploaded. It was noted by stakeholders that the current process is not viewed as being simple, nor would it suffice if case numbers significantly increased in WA.

Within the laboratory notification process to WANIDD, PHOCUS and PHOps, all interviewed stakeholders perceived the role they undertake to be simple, as they have the experience in said area. However, all stakeholders agreed that overall, there are many complexities and areas for improvement. Notably, integration of automated processes was frequently mentioned as an advantageous improvement necessary in this part of the system.

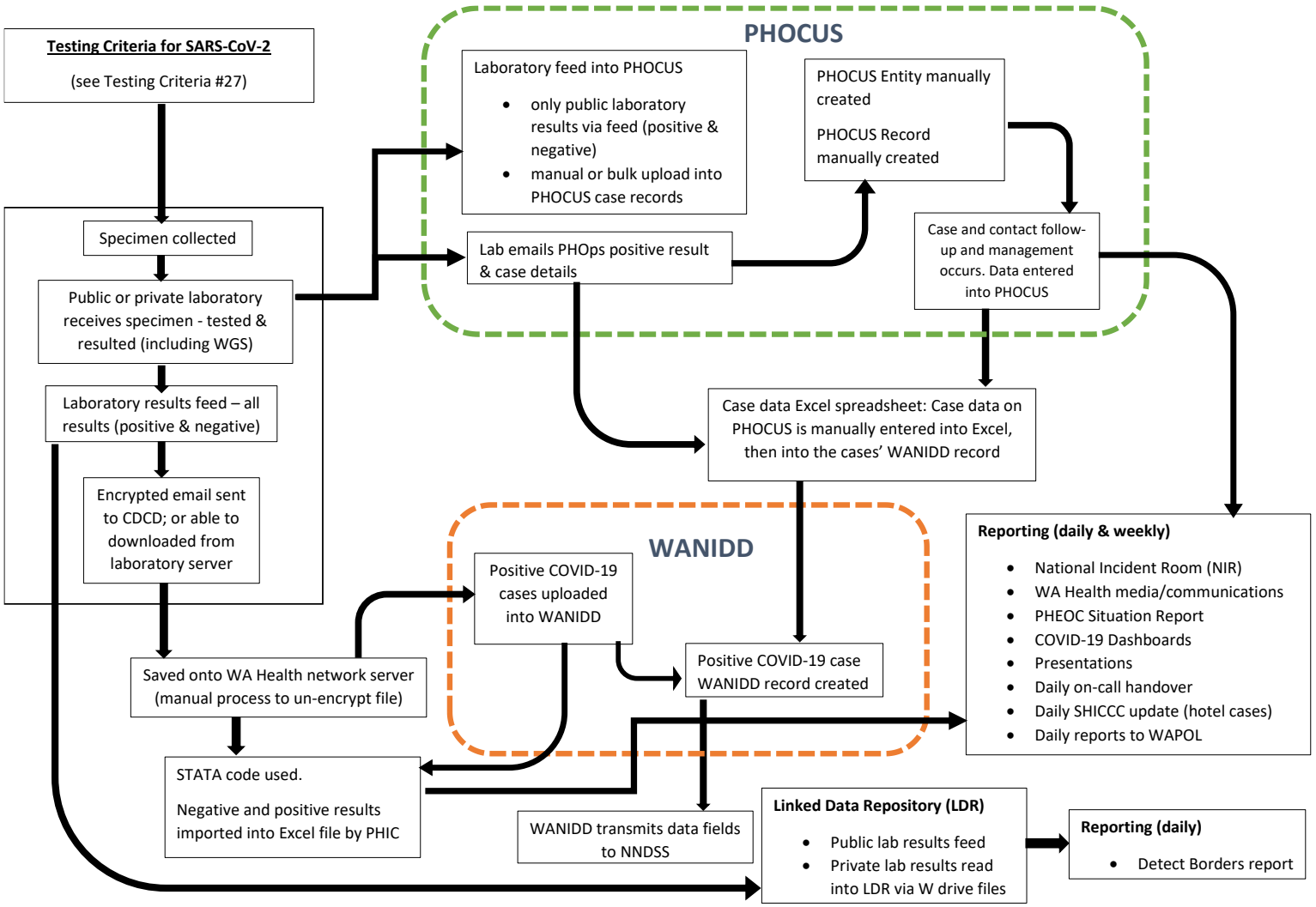

Figure 1: COVID-19 Surveillance system flow chart in Western Australia

CASE, CONTACT & OUTBREAK MANAGEMENT

The public health follow-up of cases includes case interview and contact tracing to isolate cases and quarantine close contacts in timely manner to reduce the spread of COVID-19 (Figure 2).

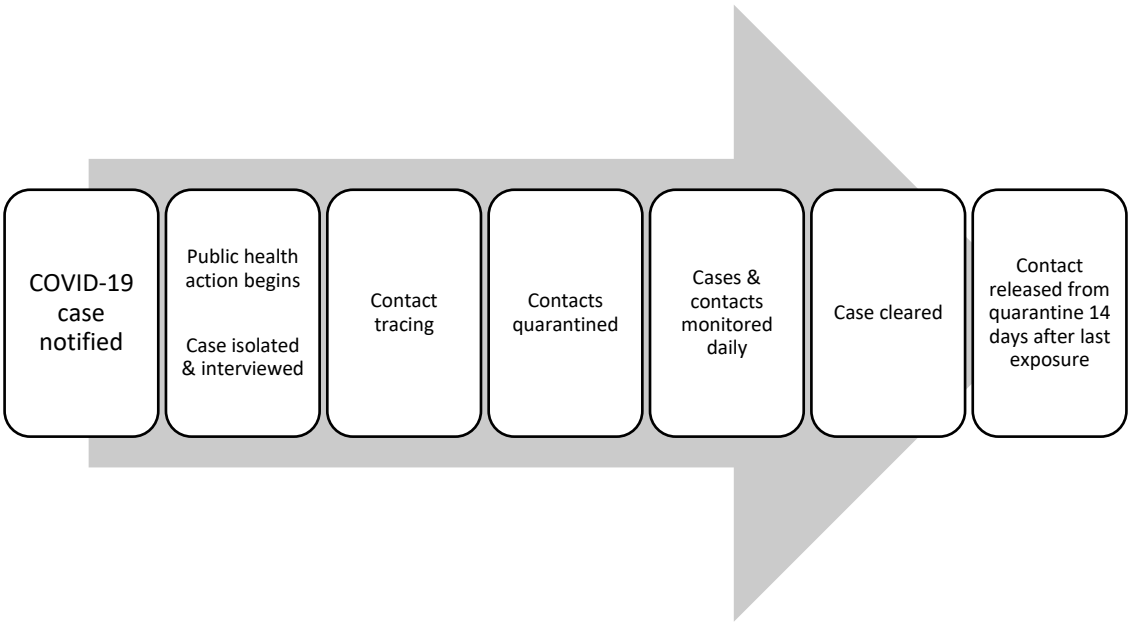

Figure 2: COVID-19 case, contact tracing and monitoring process in WA, as of January 2021

Once the email from the laboratory has been received, an email is sent back as an "acknowledgement of receipt". All laboratory results are then reviewed by the PHOps public health physician/nurse manager, to ascertain if the case meets the case definition, before being assigned to a surveillance officer to interview the case. The case is constantly reviewed as new information becomes available, for instance, from information provided by the laboratory regarding the strength of the PCR result, or via the case interview for example, the background/reason for testing (e.g. Day 2 hotel swab or if the case reported that had been previously positive overseas). Public health follow-up is conducted according to the SoNG (9) and the COVID-19 Public Health Operations Standing Operating Procedure (SOP).

As described in the COVID-19 Public Health Operations SOP, the functions undertaken by the Contact Tracing Team within PHOps include the following:

1. to inform cases of their diagnosis
2. to interview cases (or next of kin if appropriate or required)
3. to advise the case about isolation requirements.
4. to assess whether isolation can be maintained using the risk assessment tool, inform the case of what to do if they deteriorate clinically
5. to identify all close and casual contacts who have been exposed to the case while infectious. Close contacts are interviewed
6. to determine whether household/hotel contacts can be appropriately quarantined
7. to advise close contacts about the need to isolate and what to do if they develop symptoms (including testing and assessment)
8. to enter all information and communications about the case and contacts onto the PHOCUS data management system (Table 3). In addition, uploading relevant attachments, including a copy of the final pathology result as the initial notification via email is not adequate.

The case and contacts are then handed over to the PHOps Ongoing Management Team, which undertake the following functions within the system:

1. review automated daily monitoring of cases and close contacts through specific lists set up in PHOCUS
2. complete daily monitoring calls for cases and close contacts that are not on automated daily monitoring
3. liaise with close contacts who develop symptoms and arrange testing if required
4. support the monitoring of cases and contacts who are quarantined within hotels
5. liaise with hospitals regarding patient discharges and transfers
6. undertake clearance of cases.

Table 3 : PHOCUS data tabs for both COVID-19 cases and contacts

CASE	CONTACT
Person tab Case assessment, exposure history, occupation	**Person tab** Contact tracing assessment, exposure history, checklist, occupation
Health tab Assessment, symptoms, comorbidities, hospitalisation, testing	**Health tab** Assessment, symptoms, comorbidities, hospitalisation, testing
Travel tab Returned travellers questions, quarantine questions – if relevant	**Travel tab** Returned travellers questions, quarantine questions – if relevant
Movement tab Incubation and infectious period, Track and Trace	**Movement tab** Incubation and infectious period, Track and Trace
Daily monitoring tab Daily monitoring details, related – record activities, attachments	**Daily monitoring tab** Daily monitoring details, related – record activities, attachments
Case notes	**Case notes**
Engage Log daily call, email, new task	**Engage** Log daily call, email, new task

In terms of the public health follow-up and management of cases and contacts, these were both perceived as being simple overall with guidelines in place, however, the PHOCUS allows for complexity. Similarly, the management of cases and contacts can differ in intricacy depending on the type of case, their contacts and the cases clearance from isolation.

The ability to identify clusters and outbreaks was reported to be simple, particularly while cases numbers are low, but was also achieved during the "first wave" of COVID-19 in WA. The use of rapid sanger sequencing and whole genome sequencing (WGS) enabled the assignment of SARS-CoV-2 lineages and the identification of transmission events. The provision of WGS data is an advantage, which wasn't available early in the response. Also, the addition of the "Track and Trace" feature in PHOCUS, in which all exposure sites visited by the infectious case are listed in their record by place name, event name, location address and both date and times (start and end). This is then able to be analysed against other cases, to identify any linked exposures. At the time of writing, this feature had not yet been used to identify any outbreaks in WA, as there had been no community transmission.

THE STEP BETWEEN PHOCUS, WANIDD AND REPORTING TO STAKEHOLDERS

There is also an Excel spreadsheet used as a step in the surveillance system, in which it combines the laboratory result, PHOCUS case details and is then is used to manually update WANIDD. This is maintained by the PHI Cell. When the laboratory notification is received, the case is recorded on the spreadsheet. Once the interview has been completed and data has been entered in PHOCUS, specific fields are then used to update the spreadsheet. Once the positive result from the laboratory feed has been uploaded into WANIDD and a case record has been created (typically the next day), the PHIC then go into the case record on WANIDD and manually enter the details obtained from the case interview (both core and enhanced fields). This also occurs when the case is cleared and has recovered. Currently, PHOCUS and the data collected within the database is not set up to transmit data directly into WANIDD, nor to NNDSS.

This is another step with which concerns were raised by interviewed stakeholders. Currently, it is manageable with low cases numbers, but would be difficult to sustain if case numbers were to significantly increase.

REPORTING TO STAKEHOLDERS

NNDSS dataset fields for core and enhanced data are specified and have undergone numerous revisions since the beginning of the pandemic response (Table 4). Deidentified data are automatically transmitted daily from WANIDD to the NNDSS every night. There can therefore be a slight delay in reporting to NNDSS. Core data are collated (for all notifiable diseases) into a fortnightly report for the CDNA and published on the Department of Health website.

Table 4: National Notifiable Disease Surveillance System (NNDSS) 2019-nCoV Dataset Field Specifications

Existing core NNDSS fields	Enhanced data fields
State	Country of birth
Notification ID	Main language spoken at home
Disease code	Date died
Confirmation status	Intensive case admission
Laboratory diagnosis method	Ventilated
True onset date	Symptoms reported
Specimen date	Symptoms & Other symptoms
Notification date	Comorbidities & Other comorbidities
Notification received date	Gestation
Age at onset	Exposure setting & Other exposure setting
Sex	Source of infection
Indigenous status	Occupation & Other occupation
Died	Healthcare role & Other healthcare role
Place of acquisition	Healthcare setting & Other healthcare setting
Hospitalised	Quarantine status
Outbreak reference	Other quarantine facility
Case found by	Date entered quarantine or isolation

As discussed previously, all cases and contacts from both metropolitan Perth and regional WA are followed up and monitored by PHOps who solely work on COVID-19. Some of the public health action may be conducted by staff in the Western Australian Country Health Service (WACHS) if cases are in regional WA.

PHIC is responsible for the daily and ongoing monitoring of data and trends of all COVID-19 cases in WA, with the WA COVID-Net epidemiologist monitoring potential clusters and outbreaks. COVID-Net is an Australian government funded network of epidemiologists in each state and territory health department, serving as a valuable way of rapidly sharing information and expertise between the Commonwealth and all other jurisdictions.

Reporting to internal and external stakeholders about the current COVID-19 situation in WA occurs daily. This reporting is undertaken by PHEOC and PHOps, specifically PHIC. There is a mixture of automation and manual processes undertaken to collate data for reporting, however, most are still currently manual. The data collated is from numerous sources including laboratory

information (positive and negative results), PHOCUS information about cases and contacts and Excel spreadsheets.

The data is then manipulated through statistical computing software packages such as STATA and R, by running pre-written codes to extract data directly from these sources (the linked data repository (LDR), Microsoft Excel files). R then creates relevant COVID-19 epidemiological curves and tables in a completed report, such as the DETECT Borders report. In other instances, once pre-written codes are "run", excel files are subsequently manipulated using pivot tables, to complete existing reporting templates. These are manual processes which also require PHIC staff to email through templates to specific stakeholders, seven days a week.

All cases associated with an outbreak are assigned an Outbreak ID in WANIDD, which is also used as the Outbreak Reference within the PHOCUS record. Both databases allow for extraction by this data field, to be able to view and analyse those linked to each outbreak. Detailed case line lists in Microsoft Excel of each outbreak are also created to be used for reporting purposes to stakeholders, including the COVID-Net Working Group.

Interviewed stakeholders acknowledged that reporting in the current climate is simple and meeting all requirements, however again, if case numbers were to increase significantly, the monitoring and reporting, specifically the manual components would be an issue. It was noted that more automated processes are required using data linkages and a LDR. The LDR is currently being used to produce a report for the DETECT Borders testing program.

An ideal data flow from source systems (pathology, hospital admissions and discharge data, case and case/contact data and mortality data), loading, transformation and linkage (LDR), to analytics and reporting has been mapped out, with work currently being undertaken to see this completed.

ANALYSIS OF SURVEILLANCE SYSTEM DATA

From 21 February 2020 to 11 February 2021 in WA, there had been a total of 962 COVID-19 cases notified in WA (Figure 3). Of those, 910 were classified as confirmed cases and 52 were classified as historical cases. Of the 910 confirmed cases, 548 (60%) were male and 362 (40%) were female, with a median age of 44 years (age range of 0.5 years to 86 years). One case identified as being of Aboriginal or Torres Strait Islander origin. A total of 133 cases were admitted to hospital, with 36 of those admitted into the Intensive Care Unit (ICU) and nine deaths had been reported.

There were 57% of cases who acquired their infection 'Overseas', 32% 'At Sea', 8.8% 'Locally acquired – contact of a confirmed case', 1.4% 'Locally acquired- contact not identified' and 0.8% 'Locally acquired – interstate travel'.

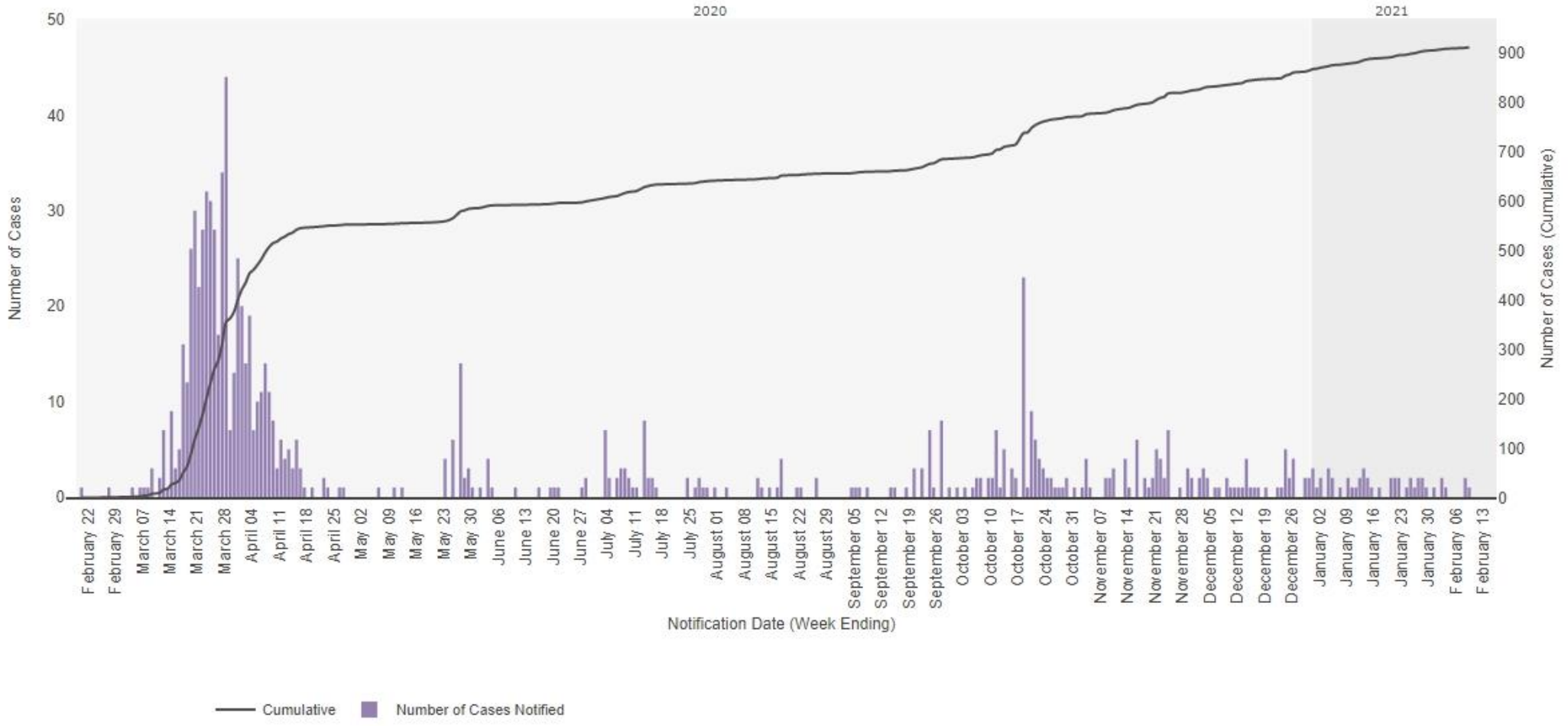

Figure 3: Epidemiological curve of COVID-19 cases, by notification date (week ending), 21 February 2020 to 10 February 2021, Western Australia

SYSTEM ATTRIBUTES

DATA QUALITY

Data quality is a composite measure of completeness and validity of the data recorded by the system (24). There are processes for data quality assurance (QA) at each step of the COVID-19 surveillance system in WA.

The first would be the transmission of laboratory results to PHOCUS and WANIDD, as well as the email sent from laboratories as soon as there is a detection of SARS-CoV2 by PCR or serology. As discussed previously, the quickest notification of a case is via an email from the laboratory. This email contains the cases demographic details, location (residential address, including quarantine hotel information), specimen type/result and strength of PCR. This email also includes an attached pathology request form. The electronic laboratory feeds to PHOCUS and WANIDD include key demographic information, specimen type and test result. The information provided by the laboratory at this stage of the process, is then validated via the case interview, where PHOps staff will check all demographic information with the case or their next of kin (NOK).

The validity and completeness of data is also checked once notifications are reported to PHOCUS, cases are interviewed, and the extra information obtained via interview is entered into PHOCUS. Another QA process, as discussed previously, is the manual check of the data entered into PHOCUS and the subsequent entry of that data into the Excel spreadsheet and then into WANIDD. Continual quality assurance is conducted by PHOps staff, including the public health physicians and PHIC staff. Any discrepancies are followed up immediately, particularly as there are handovers and reporting occurring before close of business. This was seen as a strength by some stakeholders, but noted this process is currently possible while case numbers are low in WA.

Other QA on the validity and completeness of WA COVID-19 data can occur via the NNDSS checking data transmitted from WANIDD, as well as stakeholders receiving daily reports can highlight any inconsistencies with the data, for instance the NIR querying when WA testing numbers decreased significantly from one day to the next, which was due to an issue with the WA Health drives being updated without warning.

Data quality is "influenced by the clarity of surveillance forms, the quality of training and supervision of persons who complete surveillance forms, and the care exercised in data management (24)". In the previous iteration of PHOCUS, data entry of case and contact interview data was difficult and illogical. Although PHOCUS has been upgraded and the system is currently more intuitive, stakeholders noted there are more improvements they believe should be made to improve data quality, in terms of automation, pre-populated fields, missing data field flags and

branching logic. The PHOps staff work from the COVID-19 Public Health Operations SOP, which details all processes needing to be undertaken, including scripts for interviews and data entry instructions. However, it was reported by stakeholders that there are still instances where there is varying data quality, including incompleteness or inconsistent entry, with continued training and education required.

PHOCUS also has the ability to create "Data cleaning dashboards" which enable PHOps staff to visually see which important data fields require QA. These dashboards can be manipulated to choose which data fields are incomplete. Table 5 shows which data fields are currently on a data cleaning dashboard, which are important both operationally and for surveillance and reporting purposes, to ensure validity and completeness.

Table 5: PHOCUS data fields included on a data cleaning dashboard, as of February 2021

PHOCUS data fields included on a data cleaning dashboard	
Entity fields missing	Positive cases missing test results
Travel fields	Positive cases missing indigenous status
Records fields missing	Missing clearance dates
Exposure history	Variant of concern (VOC) information missing
Daily monitoring SMS	Case cleared but still being monitored
Quarantine fields missing	Occupation fields missing
Daily monitoring fields	Incubation fields missing
Comorbidities	Medications

At the time of writing, WA was still experiencing low case numbers, almost all of which were in hotel quarantine and posing no risk to the community. Analysing the completeness of the surveillance data was attempted, however, several issues were encountered. Firstly, given low case numbers, there has been sufficient time to go back to previously notified cases since February 2020 and data clean all required fields. Data completeness was also difficult to assess due to the change and integration from REDCap to PHOCUS, which saw all cases from before 8 April 2020 have the same record creation date, data fields have changed overtime with old fields being hidden and no longer required, while new fields have been added. Older cases have information stored in the "Details" tab on PHOCUS, due to not all data being integrated into the new variables during a PHOCUS upgrade in September 2020. Furthermore, the NNDSS data specifications underwent several revisions during the response thus, the completeness of some fields were poor. Nonetheless, there has been a concerted effort for all core and enhanced data fields (Table 4) in WANIDD, which are reported to NNDSS, to be completed.

The recent case 903 (as noted previously) highlighted some data quality issues. Hundreds of contacts were identified and required follow-up. This instantly saw data quality decrease, due to the number of contacts but also the in-experience of staff entering the data. The PHIC team were heavily involved in the data cleaning aspect of the response to this case (validity of the contacts status, the type of contact and Track and Trace Events), given daily reporting was still required, but also given the sensitivity of the situation, extra and timely reporting required.

This case follow-up, along with this surveillance evaluation also highlighted issues and potential risk associated with the "Occupation" field in both PHOCUS and WANIDD. On PHOCUS, the field "At risk occupation" includes a picklist in a drop-down format, from which the options also included in WANIDD. At the time of Case 903 and writing this chapter, there were no options for "quarantine worker" or "quarantine hotel security worker". Case 903 was entered as "Other occupation", with other free text fields stating their occupation and location. Again, this doesn't cause an issue when case numbers are low, however it was noted by stakeholders that it is a risk if case numbers were to dramatically increase. Furthermore, with the only cases being notified from hotel quarantine in WA currently, the most "at risk" occupations are within the hotel quarantine setting.

There is no way to quantitatively assess that when case numbers increase, the data quality and completeness would decrease. However, all interviewed stakeholders stated that knowing the system and also from their previous experience during the "first wave" of cases in WA, as the number of cases and contacts increase, even if there were enough human resources to undertake the public health follow-up and management, the data quality would inevitably decrease. With the current system, collection and reporting of data may have to be altered, for instance only core data fields required operationally and in terms of surveillance may be collected. WANIDD fields and reporting to NNDSS may change to core fields only. All stakeholders noted that if more of the current system was automated, the hope is that this scaling back may not have to occur, or just on a lesser scale.

TIMELINESS

Timeliness is the amount of time between steps in a surveillance system (24). At the time of writing, COVID-19 was still extremely politically sensitive and therefore timeliness of the surveillance system in WA is a critical attribute. The timeliness of all surveillance system objectives, as discussed previously, but particularly the identification of cases and contacts, their isolation/quarantine and public health management is vital, to decrease the likelihood of community transmission.

Stakeholders considered one of the current strengths of the system to be the timeliness of the public health action. It was noted, however, this is possible given the small case numbers, of which they were already in hotel quarantine.

As discussed previously, Testing Criteria for SARS-CoV-2 in Western Australia has broadened, encompassing not only those who are symptomatic and/or meet epidemiological criteria, but also those who are high risk workers or returned travellers. All residents of WA meeting these criteria are encouraged to get tested for COVID-19, with COVID clinics and drive-thru testing clinics available to all.

Timeliness of specimen collection time to result notification time was assessed. Data was extracted from PHOCUS, LDR and Microsoft Excel spreadsheet containing all testing data, and further analysed. Figure 4 shows PathWest and all other private laboratories by the average days from specimen collection to notification. Apart from the long turnaround times early in the response when laboratories were establishing their processes and there were known shortages with reagents, the average time between specimen collection and result notification was 1.2 days (range 0.8-2.7 days). Figure 5 illustrates PathWest COVID-19 specimen collection time to result notification time to PHOps, by metropolitan and regional specimens. Similarly, there were longer turnaround times in February and March 2020 due to the same reasons mentioned above, however since then the times have been consistently around 24 hours. As expected, the turnaround time for regional specimens compared to metropolitan specimens is consistently slower, due to longer transport requirements.

PathWest are currently the only laboratory that provides specimen collection date and time. Therefore Figure 6 depicts the average time between specimen collection and result notification time to PHOps by hour, for all PathWest specimens. Likewise, there were larger turnaround times in February 2020, but since have been consistently under or just over a 24hour turnaround time between specimen collection and result notification.

At time of writing, the laboratory notification process, with small case numbers, ensures any positive result being immediately notified to PHOps.

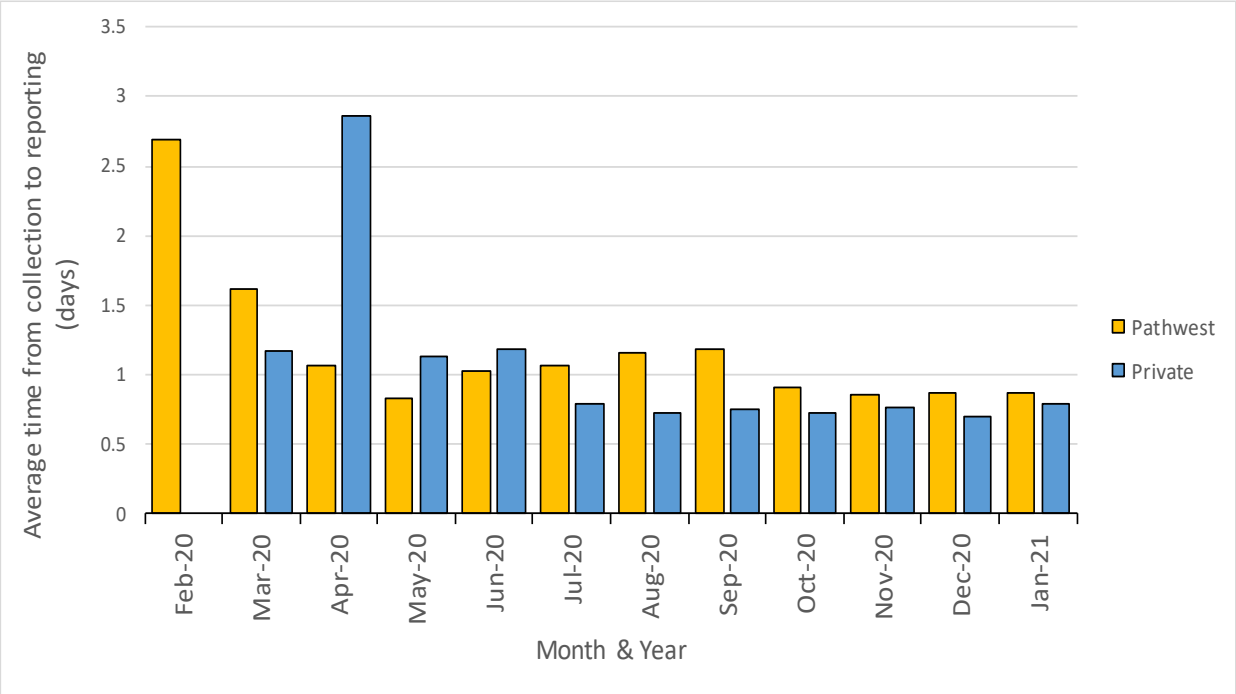

Figure 4: Epidemiological curve of COVID-19 specimen collection date to result notification to PHOps, PathWest and all private laboratories, February 2020 to January 2021, Western Australia

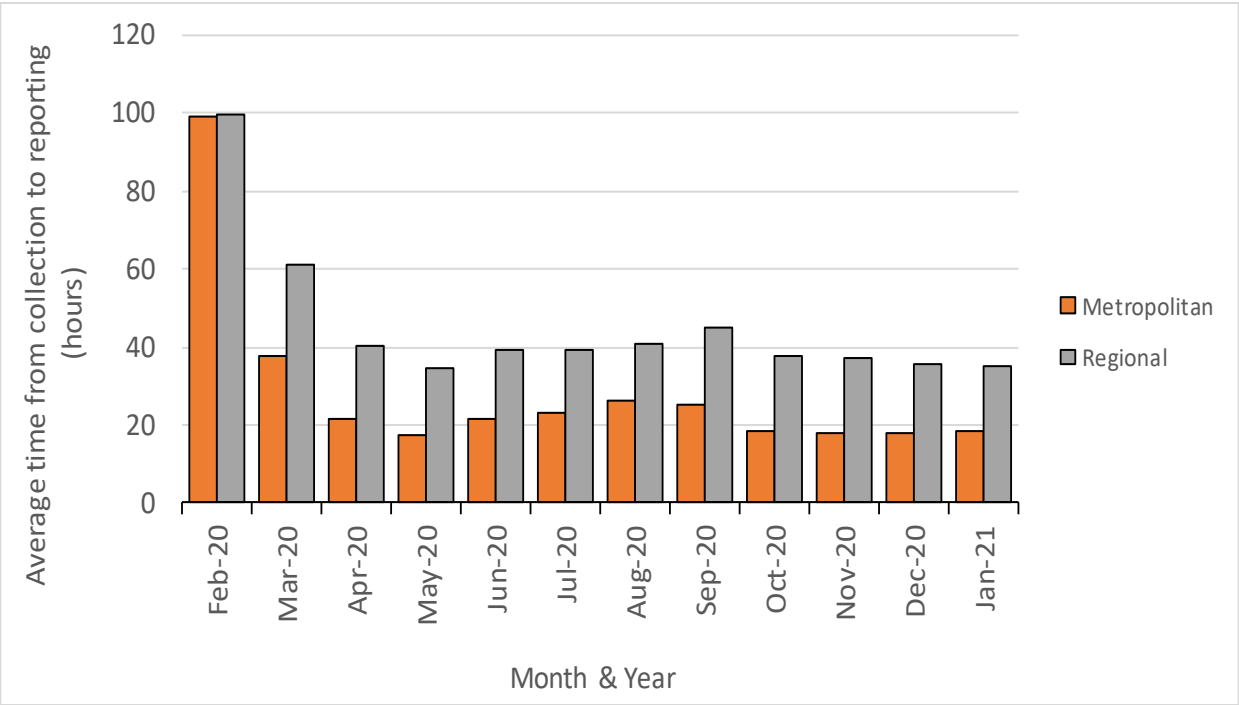

Figure 5: Epidemiological curve of PathWest COVID-19 specimen collection time to result notification time to PHOps, by metropolitan vs regional specimens, February 2020 to January 2021, Western Australia

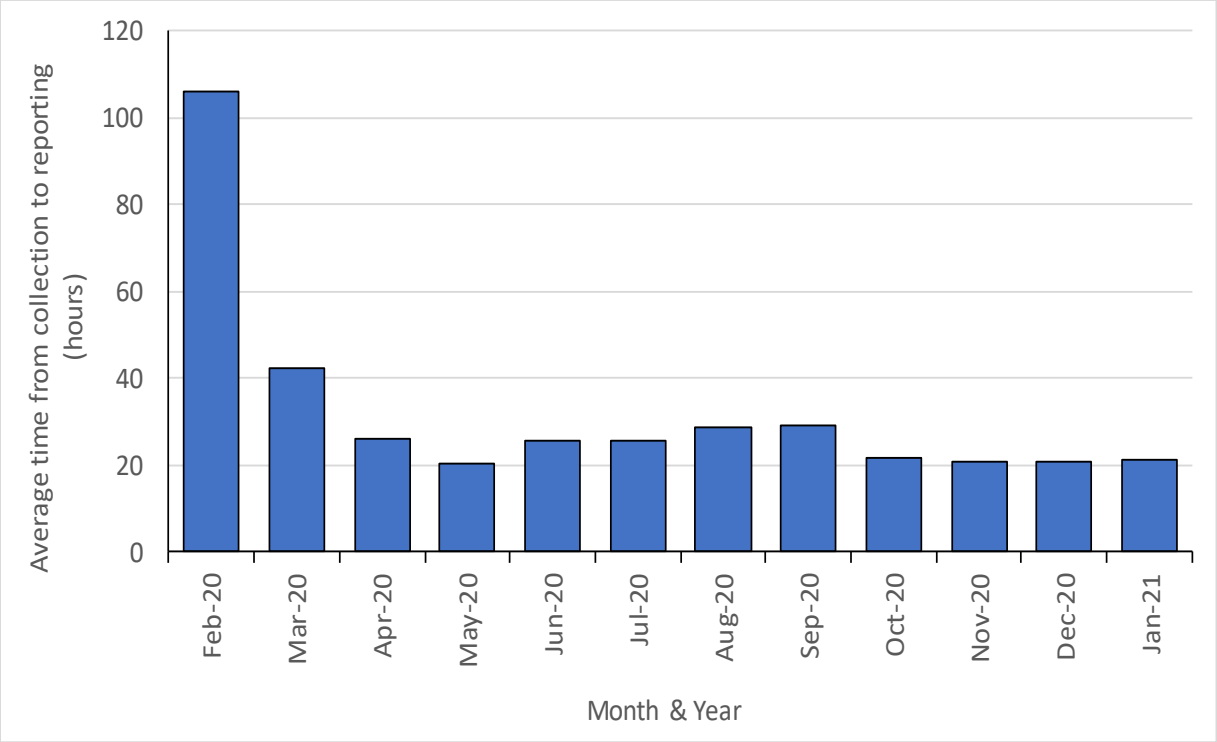

Figure 6: Epidemiological curve of PathWest COVID-19 average specimen collection time to result notification time to PHOps, February 2020 to January 2021, Western Australia

There was an aim to calculate the average time between receiving the laboratory result notification to the public health action being undertaken, however, the data available did not make this calculation possible. For example, data collected on cases in REDCap before 8 April 2020 all had the same entity/record creation date when data was mapped into PHOCUS. The REDCap server that this information, specifically the timestamps, was stored on has since been decommissioned and therefore unable to be accessed. For the cases since the 8 April 2020, there is no specific fields for the date and/or time that the case interview took place. An analysis of laboratory result notification to when the PHOCUS entity/record was first created was attempted, however no meaningful conclusions from this analysis was able to be drawn, due to changing and differing operational use of entity and record creations.

The timeliness of the date of notification to date of isolation of cases was analysed previously in Chapter 2: First 600 COVID-19 cases in Western Australia: Public Health Response Effectiveness of contact tracing and restrictions in WA. Data was available for 477 cases and resulted in an average of 0.38 days (median 0, IQR 0-1) between notification and isolation date.

The time involved in the public follow-up of different types of cases can vary dramatically. Stakeholders noted that initially the follow-up can depend on when the laboratory notifies PHOps of a positive result. For instance after hours the on-call public health physician may undertake

minimal follow-up, like briefly speaking with the case to collect demographic information, a brief history and to ensure they are isolated appropriately. The full interview and public health action will then be undertaken the following day by PHOps staff.

Cases notified who are already isolated in hotel quarantine (for example those who are returned travellers from overseas) are generally quick to complete the initial public health action, ranging from half to one working day. However, it was noted by stakeholders that the ongoing management of these cases can be quite complex and time consuming. The ongoing daily monitoring (judged to be approximately 15-30 minutes daily) and complexities when cases are in the same hotel room as their family members. There have been numerous instances where case teleconferences with The Health and Wellbeing service (HWB) within the State Welfare Incident Control Centre (SWICC), PHOps staff and the family members are needed to discuss the implications of choosing not to, or being unable to separate, due to family members being minors. This situation can mean extended stays in hotel quarantine, given close contacts requiring to isolate, or they become cases themselves.

Cases who have acquired COVID-19 in the community or have been out in the community while infectious (for example case 903, a hotel quarantine worker who acquired their infection from a case in hotel quarantine and then while infectious, was out in the community) can be far more complicated in terms of the timeliness of public health action. The initial interview is completed immediately, however if they have been in the community, obtaining all of their exact movements, times, dates and who they were in contact with can take time. Most recently, the case infectious out in the community was highly sensitive politically and there were high expectations of contact tracing, which utilized the SafeWA App, CCTV footage and there was WAPOL involvement. Stakeholders recognised that this response was far more intensive than any other they had experienced. This therefore meant completing all public health action and follow-up was no longer timely, due to all avenues being explored and rigorous contact tracing and testing of both close and casual contacts.

Release from isolation also plays a part in the timeliness of the COVID-19 system. The COVID-19 SoNG sets our criteria which has to be met before a case is released from isolation, with recently the WGS for VOC's playing a major role in the extension of cases' isolation periods in hotels.

The timeliness of data collection and entry into PHOCUS was also raised with stakeholders. They agreed that on occasions case interviews are not directly entered into PHOCUS, they are hand-written, or notes taken in a Word document and then transferred into PHOCUS. This can affect

the time it takes for all known case information to be visible and available to all staff in PHOCUS, which is required for reporting purposes or handover documents. It was also highlighted that there needs to be better documentation of the cases entire history including contextual information regarding all of their movements during their infectious and incubation period.

Currently, owing to the use of pre-existing statistical codes in R and STATA, pivot tables and templates, data for reporting and monitoring can be completed promptly. Daily and weekly reporting undertaken by PHIC, as well as daily handovers by the public health physicians, are generally quick to produce and disseminate.

FLEXIBILITY

The WA surveillance system showed from the beginning how adaptable, flexible and prompt it can be with PHEOC being activated on 23 January 2020, and by rapidly making "Human coronavirus with pandemic potential" declared an urgently notifiable disease in WA on 29 January 2020.

The entire system in WA has evolved constantly from the start of the pandemic, as described previously. It was known at the start of the pandemic response that WANIDD was not going to be a flexible enough system to be able to cope with the operational demand of the COVID-19 response, specifically in terms of the case/contact tracing management aspect. This then prompted the use of REDCap, with the first case notified on 21 February 2020, before the development and use of the PHOCUS database beginning on 8 April 2020.

Given COVID-19 is an emerging disease, there were no clear protocols for surveillance and response in Australia or worldwide, and therefore these needed to be developed and implemented. COVID-19 surveillance has adapted to rapidly advancing knowledge and learnings about the disease as the pandemic has progressed, which has seen a multitude of changes and versions of the SoNG, case definition, as well as the NNDSS data specifications and requirements.

Both case and contact definitions have been revised numerous times during the pandemic response, as they are based on knowledge about the clinical and epidemiological profile of COVID-19 cases presenting in Australia and worldwide. All stakeholders agreed that the current surveillance system and both WANIDD and PHOCUS, have shown to be able to be capable, flexible and able to accommodate, both operationally and in terms of surveillance, these continuous revisions to the case and contact definitions, and can continue to do so.

The changes in data requirements from NNDSS but also operationally in WA, can also be easily added to PHOCUS when required. Some modifications can be made to the database by PHIC, for example the addition of VOCs to the database was prompt, however some changes, including major upgrades, require the involvement of Health Support Services (HSS), which has been associated with significant delays. One stakeholder indicated that PHOCUS is currently not as flexible as it could be and consistent updates to the system are required. WANIDD is also flexible enough to accommodate the collection of disease-specific enhanced data, however, there can also be a slight delay in this process.

Flexibility to adapt to changes in reporting requirements, both nationally and locally is also able to be accommodated by the system. WANIDD transmitting COVID-19 core and enhanced data to NNDSS is able to be adapted if additional fields are required. Stakeholders noted that PHOCUS is also able to adapt to changes in reporting requirements, however similar to the process of making modifications and upgrades, it can take time and extra effort for this to occur.
This current surveillance system has not yet experienced a substantial increase in the number of COVID-19 cases or contacts. The previous iteration of the system which experienced high case and contact numbers in March/April 2020 has evolved considerably since. Case 903, notified at the end of January 2021, highlighted some strengths and also gaps in the system, specifically processes and data entry into PHOCUS. This case acquired their infection after working in a quarantine hotel facility and was infectious while out in the community. The public health response was substantial, with a 5-day lockdown implemented and hundreds of close and casual contacts identified, quarantined and regularly tested.

Stakeholders were therefore asked if the current system could adapt and be flexible to accommodate a substantial increase in the number of COVID-19 cases notified and therefore contacts. It is believed that the databases would be able to adapt to an increase, with it being compared to WANIDD managing an Influenza season of 22,000 cases and up to 100 notifications a day. However, there were concerns raised with the current method of notification from the laboratories to PHOps, PHOCUS and WANIDD. Likewise, in regard to the public health follow-up of cases and contacts, as well as what data is collected (core and enhanced data), transmitted and reported, may need to be altered.

ACCEPTABILITY

Acceptability is demonstrated through willingness to participate in the system (24). From the stakeholder interviews, all who are directly involved in operating the system, it is evident that the COVID-19 surveillance system is highly acceptable. There was a clear recognition of the public health significance of COVID-19 surveillance in WA, as well as how this pandemic has highlighted the overall importance of public health. Therefore, the willingness of stakeholders to be involved in the system was explored by asking what they thought the strengths and challenges were of participating in and interacting with the COVID-19 system in WA.

All interviewed stakeholders noted that from the beginning a challenge was knowing that WANIDD was an old system with no contact tracing capacity or outbreak management module. This knowledge translated into REDCap being utilised and then the PHOCUS database. However, given WANIDD is still currently being used to transmit the core and enhanced fields to NNDSS, all stakeholders did agree that operating between two systems is not ideal and adds a level of complexity and inefficiencies, as well as further workload on staff to manage both systems.

A new database (PHOCUS) to navigate a few months into the pandemic response was also noted as a challenge. However, the progression from before PHOCUS to now has been significant and has been seen to be a huge benefit to the public health response to COVID-19 in WA. PHOCUS was seen as illogical, clunky and to have numerous limitations at first, however improvements have progressively been made. The workflow and automation component (automation of text messages and emails, workflow tasks and management) of PHOCUS are seen as invaluable and a huge strength to WA's COVID-19 surveillance system and response.

Manual processes, including those of un-encrypting and downloading laboratory results, data entry of case data stored in PHOCUS across to WANIDD and reporting to stakeholders were all noted as challenges ultimately creating inefficiencies, that have continued throughout the pandemic response. In an attempt to decrease manual data entry and automate processes, a direct feed from PHOCUS to WANIDD by mapping the NNDSS required data fields across has been attempted, however the data dictionary for PHOCUS hasn't yet been adequate to be able to complete this task.

Stakeholders all agreed that the PHOps surge workforce and the ability to rapidly increase the number of contact tracers if required is a huge strength. However, within this strength, there also were noted challenges involved, including the ability to maintain the number of surge staff, as well as the need for ongoing education and training of these staff. Training surge staff in the use of PHOCUS has proven to be challenging as PHOCUS isn't the most user friendly or intuitive system. However, the PHOCUS SOP, as well as scripts for cases and contact interviews was mentioned to be a valuable and informative document for not only surge staff, but also baseline staff using PHOCUS. It was also mentioned that the links between teams within PHOps and the working relationships between all staff involved in the surveillance system is an asset, but also one which could be further strengthened.

The laboratory capacity is also able to be increased when required. An increase in the number of pathology collectors and COVID-19 clinics in desired suburbs has been witnessed recently when there was a surge in testing due to a case in the community, which was also indicated as a strength of the system.

Representativeness

How well COVID-19 cases are represented in the surveillance system is dependent on many factors: patient presentation for testing, specimen collection, testing practices and criteria, case and contact case definitions and laboratory notifications to PHOCUS/WANIDD. All laboratories in WA test for COVID-19, and report to PHOps via email and/or PHOCUS laboratory feed and to WANIDD. WGS is undertaken by PathWest.

At the beginning of the COVID-19 response the testing criteria for SARS-CoV-2 was narrow, as was the definition of close contacts. This under-represented the cases that were in the community at the time, which has been shown by known contacts of cases being subsequently tested and classified as historical cases.

As at the time of writing, COVID-19 is entering the state via returned travellers from overseas who are quarantined in state-run hotels and under a Centre Quarantine Direction, must be tested at the hotel on days 2 and 12. Alongside this, and the fact that there is currently no community transmission occurring in WA, there are also the testing regimes for high risk occupations, as discussed previously, including the DETECT Borders initiative and the Presentation for Testing (Quarantine Centre Workers) Directions (No 6). Therefore COVID-19 case ascertainment in WA

could be considered close to perfect in its current state, and likely that cases are well-represented.

There was concern, however, that if community transmission was to occur again and of a larger scale, there are certain pockets of Perth and wider WA who are currently under-tested and therefore would pose a risk in that situation, due to lack of understanding and access to testing. This coincides with those who are generally under-represented, for example people of low socio-economic status (SES), rural and remote, culturally and linguistically diverse (CALD) and those who are marginalised and non-mainstream groups.

STABILITY

The surveillance system was perceived to be relatively stable and reliable. Stakeholders from PHOps reported incidents where in the internet browser used for PHOCUS required to be updated. This update was not automatic through all user accounts within the Health Department and therefore when PHOps staff tried to access PHOCUS, it was no longer compatible and was found to have several glitches. Another incident noted was when the Health Departments internet went down, therefore not allowing the use of PHOCUS.

These incidents were identified promptly and reported to HSS to be resolved. As a solution to if these issues were to occur again, there have been designated laptops setup in PHOps with external internet access (via an internet dongle), to allow access to PHOCUS.

All interviewed stakeholders agreed that their roles and function in COVID-19 surveillance in WA could be maintained and managed during staff absences or changes. Staff are continually trained and supported in each role, with detailed handovers being provided in each instance. It was noted, however, that staff absences would affect the portion of the system related to laboratory feeds and WANIDD. Currently, there are only a few staff members within CDCD that are able to undertake those specific manual tasks of un-encrypting files from the laboratory. Similarly, the expertise in which the PHIC team has in the understanding of PHOCUS is crucial within the surveillance system. Interviewed stakeholders, specifically those within PHOps who work solely with PHOCUS, raised the absence of PHIC staff, especially during times of increased public health action, as a potential issue in the functioning and use of PHOCUS during the response.

It was believed by all interviewed stakeholders that these issues in stability were able to be managed easily during times of low case numbers and with those cases already being in hotel

quarantine and therefore isolated. They all stated that it these could be a major issue if case numbers were high, community transmission was occurring and there were inevitable also high numbers of contacts requiring follow-up.

USEFULNESS

The usefulness of the COVID-19 surveillance system in contributing to the identification, management and control of cases and contacts was largely considered with respect to how well the four main surveillance objectives, as defined in the COVID-19 SoNG, are being met. How well the surveillance system meets these objectives is affected by several attributes, predominantly acceptability, timeliness, data quality and representativeness of the system.
Stakeholders agreed that the overall surveillance system functioned well to enable the surveillance system objectives to be met, particularly while case and contact numbers are low and in hotel quarantine.

Cases, particularly in returned travellers from both overseas and interstate are able to be easily identified, isolated and managed. Likewise, with the identification, quarantine and provision of relevant information to contacts. Stakeholders all highlighted that even during previous iterations of the surveillance system and when case numbers were high, it was made clear that the staff using the system/s were able to effectively and efficiently identify cases and contacts, isolate, quarantine and manage each as appropriate and were successful in doing so. This was also apparent in the detection and management of outbreaks, when the majority were occurring in 2020.

Stakeholders agreed that currently, the objective of characterising the epidemiology of COVID-19 in WA is being met. At the time of writing, system data (coming from numerous sources including PHOCUS, the Excel spreadsheet and WANIDD) was still being used to report cases daily (as discussed previously) to both national and local stakeholders. These reporting processes were not simple and still required a lot of manual manipulation.

DISCUSSION

The public health importance of the COVID-19 pandemic response and WA's surveillance system was recognised by all interviewed stakeholders. The evaluation findings demonstrated that in the current climate of minimal COVID-19 cases in WA, overall, the current COVID-19 surveillance system performs well to meet its defined objectives (9). The system, throughout all of its changes, has been adequate for monitoring, detecting, reporting and informing public health response during the COVID-19 pandemic response in WA. The system is undoubtedly useful and is currently effective, however, all stakeholders have concerns if case numbers were to dramatically increase.

An identified strength of the system was its flexibility, adaptability and the staff's willingness to embrace changes. From the start of the pandemic in China, it was recognised this response required rigorous public health measures, including thorough case finding, isolation, immediate testing, exhaustive contact tracing and quarantining of close contacts(7) and therefore a database with both case and contact management capabilities. It was acknowledged from the beginning that WANIDD was not going to be able to adapt or be flexible enough to accommodate this type of response. Therefore, the REDCap system was introduced, which saw the peak of cases in WA, before the PHOCUS system was implemented on 8 April 2020. The ability of the automation of text messages and emails, workflow tasks and management through PHOCUS was noted as a strength, especially when compared to the initial response beginning in February 2020. There have been updates to this system throughout the response, however, all stakeholders agreed that there is a continual need for automation of data flow into and out of the system. Furthermore, system users require more control over adding additional data fields or changing the data collection flow as the public health response evolves.

Upon reflection, there were some limitations in the evaluation of this system as it stands, given low case numbers being recorded in WA (Figure 3). The majority of notifications have been cases who had travelled from overseas and placed into hotel quarantine, therefore, posing no risk to the community. Notably, WA's last case due to community transmission where the source could not be identified, was 11 April 2020.

In terms of evaluating the current system, data extraction proved to be difficult due to the changes in systems and data fields over time. Some calculations, specifically for timeliness of public health response, were unable to be made due to specific data fields not existing or the

findings having had numerous caveats. Additionally, the data has been continually cleaned since the beginning of the pandemic response. Therefore, an analysis of the completeness of data was not meaningful in terms of assessing the system.

Remarkably, during this chapter write-up there was one locally acquired case reported after a hotel quarantine breach. This case then produced 602 close and casual contacts, however, did not lead to further transmission in the community. Even though it was just one case, the hundreds of contacts that required public health follow-up tested the current surveillance system and highlighted some common themes and areas for improvement, all which stakeholders had indicated irrespective of this case.

The one case was easily managed by the system, even with manual processes between the laboratory notification to PHOCUS, the interview documented into PHOCUS, through to the data entry into the Excel spreadsheet and then manually into WANIDD. However, the follow-up undertaken for all of the close and casual contacts was sizeable. The contacts were tested numerous times throughout the follow-up, which highlighted the manual processes of un-encrypting and downloading laboratory results, both positive and negative, as an issue. The political and public health importance of this case in WA also meant that reporting was required over weekends and early every working day, which also meant a CDCD staff member, who had the ability and access to complete this task, had to physically come into the WA Health building. The need for automation of both laboratory results and reporting, as well as staff in PHIC having the knowledge and access to un-encrypting the laboratory files, was highlighted from this public health follow-up.

The PHOps surge workforce was able to be implemented and saw the number of contact tracers rapidly increase to assist with the public health response for case 903. It did, however, show that training and education in contact tracing, interviewing, data collection and the use of PHOCUS needs to be continual and possibly more in depth. It also highlighted that some PHOCUS data fields required updating or the addition of other options within a drop-down box, as well as education about how PHOps contact tracing staff should be completing them, as it directly linked to certain reporting which was requested by the WA Health Minister.

Another limitation in this evaluation was not interviewing stakeholders from the public or private laboratories and being able to gain insight into their systems and opinions on the role that they play in the overall surveillance system. Notably, during the response for case 903, a strength shown by the laboratories was being able to increase laboratory capacity, in terms of collection

and testing when required. An increase in the number of pathology collectors and COVID-19 clinic in the desired suburbs was seen and assisted tremendously in the response, specifically the testing regimes of the 602 contacts. This response also highlighted another area for improvement, in an operational aspect. The lack of community engagement, specifically in terms of Case 903 and the community in which they were involved. The engagement of community groups to discuss the situation and provide education about the follow-up and testing of contacts may have assisted the cases wellbeing but also their contacts and community.

Importantly, the COVID-19 pandemic response and its surveillance has highlighted aspects of the WA system that required change and innovation. This surveillance system and its evaluation has highlighted areas in which WA can improve not only the surveillance of COVID-19, but also the surveillance of all other notifiable conditions in WA going forward. This includes the use of a single database which can undertake both case and contact management and surveillance, electronic notification systems (both laboratory and doctor notifications) and automated reporting.

RECOMMENDATIONS

Based on the findings and assessment against core surveillance system characteristics and the stakeholder engagement process, to improve key aspects of the COVID-19 surveillance system in WA, the following recommendations have been made:

MINOR/SHORT-TERM RECOMMENDATIONS

DATA FIELDS & QUALITY ASSURANCE

- Given the current situation of COVID-19 in WA, the addition of an occupation option into PHOCUS and WANIDD, which is specific to being a "quarantine worker", should be created. This field could also be further broken down into the type of quarantine worker. This would then allow for easy data extraction and less risk than is involved with having this as a free text option.
- To be able to properly assess the timeliness of public health action between result notification and the public health response (in regard to the case interview), a data field for the date and time of case interview should be added to PHOCUS. The use of the PHOCUS entity or record creation date or time does not definitively mean this was when the public health action via interview begun.
- Alteration to the notification date and time field in PHOCUS – this needs to be made clear that it is when the laboratory first notifies PHOps. Currently this is via email and therefore the date and time should correspond to that email date and time stamp, not when the case was allocated to the PHOps staff for example.
- Each case and/or contact in PHOCUS to have a check-list linked to their record, to ensure all of the appropriate public health action has been correctly completed. This list should be able to be easily extracted and used for PHOps handover purposes.
- For data quality in PHOCUS, field explanations should be updated to provide more clarity for data entry.
- Where these are not already in place, the implementation of flags within the system to prevent entering non-logical data and to conduct post-entry logic checks.
- A formal process within PHOps for quality assurance of PHOCUS data. Detailed guidelines for data cleaning and specific times when each QA process should occur.

EDUCATION, TRAINING AND WORKFORCE

- The PHIC team to constantly communicate and work closely with the Contact Tracing team in PHOps in regard to the addition or updates occurring to data fields in PHOCUS. Continuous communication and the provision of training should be considered, as well as an accessible PHOCUS data dictionary.
- In regard to the laboratory data received by CDCD, the number of staff members able to access this data and undertake the task of un-encrypting and downloading these files should be increased. This should occur in training staff members in both CDCD and also PHIC.
- An increase in scenario testing, to test and also educate the surge workforce, as well as the surveillance system.

OPERATIONAL ASPECTS

- Stronger engagement with community groups, for example CALD groups during case and contact follow-up and management, if required. This engagement can increase the communities understanding about COVID-19, the follow-up and in-turn their engagement with the requirements public health may request

MAJOR/LONG-TERM RECOMMENDATIONS

- Continue to investigate the use of a single database for both case and contact management, but also the ability to map and transmit the required data fields (core and enhanced) to NNDSS.
- Continue to advocate for the implementation of exclusively electronic laboratory notification systems, ensuring that these systems collect data consistent with the NNDSS data fields. Ideally, the laboratory feeds would be able to feed straight into PHOCUS.
- Continue to work towards the automation of all reporting and the use of the LDR.
- Investigate how the COVID-19 surveillance system and its attributes can be applied to all notifiable conditions in WA and improve their surveillance. For instance as discussed previously, the use of a single database that can accommodate both case and contact management and surveillance, electronic notification systems (both laboratory and doctor notifications) and automated reporting.

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APPENDIX

APPENDIX 1:

Stakeholder semi-structed interview questions: COVID-19 surveillance system in WA

Scope: If there was a breach in hotel quarantine, would the current system identify this? Would the current system have the capacity to scale up and deal with potential local transmission?

Section 1: Your role	
1	Please describe your role/s in the COVID-19 surveillance system in WA.
Section 2: Surveillance system objectives and usefulness *How well the surveillance system meets its defined objectives, and the usefulness of the system*	
2	In your opinion and experience, do you think the following objectives of the COVID-19 surveillance system being met? Why/why not? i. Identify, isolate and manage cases ii. Identify, quarantine and provide relevant information to contacts iii. Detect and manage clusters and outbreaks iv. Characterise the epidemiology of COVID-19 in WA
Section 3: Simplicity *Ease and operation of the surveillance system*	
3	In your opinion and experience, in terms of simplicity: i. Is the notification process of COVID cases simple? ii. Is the public health management of cases simple? iii. Is the public health management of contacts simple? iv. Is it easy to identify clusters/outbreaks?
Section 4: Flexibility *Ability of the surveillance system to adapt to relevant changes*	
4	Do you think the current system is able to adapt to: i. A change in case definition ii. Updates to and/or additional data fields added to the surveillance database iii. A change in reporting requirements, locally and by the Commonwealth iv. A large increase the in number of notified cases on COVID-19; and therefore, an increase in contacts requiring follow-up
Section 5: Acceptability *Willingness of stakeholders to participate in the surveillance system*	
5	In your opinion (as relevant to your role), what are some strengths of COVID-19 surveillance?
6	In your opinion (as relevant to your role), what are some challenges with COVID-19 surveillance, and what could be done to address these?
7	In your opinion, is data collected/recorded/produced in a timely manner to allow for prompt case/contact follow-up and management?
Section 6: Data quality *Completeness and validity of surveillance system data*	
8	In your opinion and experience (as relevant to your role), what are some potential barriers to: i. Data collection ii. Data completeness
Section 7: Representativeness *How well the cases detected by the surveillance system represents the distribution of COVID-19 in WA*	
9	How well do you think the surveillance system captures COVID-19 cases in WA?
10	In your opinion, are they any groups of people likely to be underrepresented in the surveillance system?
Section 8: Timeliness *Timeliness of steps in the surveillance system*	
11	Starting from lab notification of a positive COVID-19 case, how much time is involved in the public health follow up of a COVID-19 case and their contacts, until a case has been closed for: i. An overseas acquired case who is in hotel quarantine i. A Locally-acquired case who has not been/is not in hotel quarantine
Section 9: Stability	
12	How have you found the disruptions to the database aspect of the surveillance system being used?
13	Can the surveillance system be managed during staff changes or absences?

CHAPTER 4: MEASLES OUTBREAK INVESTIGATION & RESPONSE, PERTH, WESTERN AUSTRALIA

LIST OF ABBREVIATIONS

ACIR	Australian Childhood Immunisation Register
AHPPC	Australian Health Protection Principal Committee
AIR	Australian Immunisation Register
CDCD	Communicable Disease Control Directorate
CDNA	Communicable Diseases Control Network
COVID-19	Coronavirus Disease 2019
ED	Emergency Department
GP	General practitioner
HSP	Health Service Providers
MCDC	Metropolitan Communicable Disease Control
MMR	measles-mumps-rubella
MMRV	measles-mumps-rubella-varicella
NIP	National Immunisation Program Schedule
NIR	National Incident Room
NHIG	normal human immunoglobulin
NOK	next of kin
NZ	New Zealand
PEP	Post-exposure Prophylaxis
PHEOC	Public Health Emergency Operations Centre
PHU	public health unit
RT-PCR	real-time polymerase chain reaction
SoNG	Series of National Guidelines
WA	Western Australia
WACHS	Western Australia Country Health Service
WANIDD	Western Australia Notifiable Infectious Diseases Database

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PROLOGUE

MY ROLE

I was part of the outbreak operations team in Metropolitan Communicable Disease Control (MCDC). My primary role was to support the coordination of the measles outbreak response, under the leadership of Dr Suzanne McEvoy and Dr Benjamin Scalley, MCDC.

I was involved from the start to the end of the outbreak, collecting and analysing all epidemiological data in relation to the measles cases and contacts. As part of my role, I proposed the use of an excel template which I helped formulate in my previous role at the South Australian Health Department (SA Health). The template collected epidemiological information on all measles cases linked to the outbreak including demographic information, case number, vaccination status, laboratory result, nature of their link, case timeline – which includes exposure date, calculated incubation period, onset date and calculated infectious period. The spreadsheet also contained a tab to record community exposures by date and case identifier (Appendix 1). I would update the spreadsheet with every new case and continually undertake quality assurance on the data, which I could then report on to the outbreak response team verbally during team meetings, as well as providing the spreadsheet daily to the on-call team. This spreadsheet and data collection/reporting received extremely positive feedback from the outbreak response team, specifically the MCDC nurses and physicians, as well as the Communicable Disease Control Directorate (CDCD) on-call physicians.

I also undertook the following tasks:

- Within the measles epidemiology spreadsheet, I collected, updated and maintained data in relation to the following (Appendix 1):
    - confirmed measles cases (as discussed above)
    - all "suspected" cases called through by doctors, or those pending through laboratory requests
    - all cases that were deemed as "rejected"– these were classified as those who were tested for measles and were negative on PCR or if they only had a serology test, IgG positive and IgM negative

    - "High risk contacts" (those who had received normal human immunoglobulin (NHIG), those who were too late for any interventions, those who were told to remain at home)
    - contacts who required daily monitoring– those who were to be contacted daily to check if they had become symptomatic.
- Active participant in case follow up and outbreak investigation:
    - called contacts of cases who required a risk assessment as to whether they required post exposure prophylaxis or serology testing
    - assisted in updating individual case summaries
    - data entry of the outbreak cases into the Western Australian Notifiable Infectious Disease database (WANIDD)
    - continuous data quality checks and cleaning in both in WANIDD and measles outbreak spreadsheet.
- General communication tasks including:
    - preparing, managing and maintaining the measles outbreak situation report, which included "actions" for cases/contacts that were new/ongoing (Appendix 5)
    - provided detail on all exposure places (to assist those on phones/taking calls about new cases and their potential exposure to measles cases), and the case timeline (which included their infectious period)
    - ensured the on-call team were emailed the outbreak spreadsheet at 4pm daily (including weekends)
    - clarified media queries about community exposure locations (where an infectious measles case has been)
    - being an active participant at daily outbreak meetings, which included discussions between MCDC, CDCD, WACHS and PathWest laboratory
    - participated and assisted in the measles outbreak debrief workshop, took minutes and then produced the debrief workshop summary report.

LESSONS LEARNT

This wasn't my first involvement in a measles outbreak, however I still learnt (and was reminded of) many important aspects of outbreak investigation and response, including:

- the importance of clear and regular communication in an outbreak situation
- the importance of teamwork and the maintenance of strong relationships with key stakeholders (in particular MCDC, CDCD, PathWest, medical practitioners, hospitals) to ensure a cohesive outbreak response. This was further solidified through daily outbreak meetings and clearly defined roles and responsibilities
- the importance of close working relationships between the operations and epidemiology arm of the investigation
- the WA Health organisational structure and how it functions with a system manager and public health units (metropolitan and regional) undertaking the operational duties
- the importance of having staff highly skilled in case and contact follow up and management, data management and presentation, as well as data science and coding expertise
- reminded of the intensity of a measles outbreak, and the importance of in-depth case interviewing and contact tracing.

Prior to my MAE I had undertaken and led measles outbreaks in South Australia (SA), but was never able to solely focus on the epidemiology of a measles outbreak. As my MAE placement was split between both MCDC and CDCD, I requested to be in the MCDC office to experience the operational side of the outbreak and to see how they function, and also assist by providing epidemiological support. Being physically located in the office where all of the interviews took place was extremely beneficial as I had real-time access and a full understanding of all incoming data and information about cases and their contacts. I believe this was vital for updating the measles epidemiology outbreak spreadsheet, undertaking continual data quality checks and being able to provide epidemiological support to both MCDC and CDCD in the form of daily outbreak situation reports and summaries for those physicians on-call. I truly believe having that close working relationship between the operational activities and epidemiology is crucial to an outbreak investigation.

Public Health Impact

Firstly, it was great to be part of a team of highly skilled and passionate professionals that was able to successfully contain a measles outbreak, especially since they aren't common in Australia. During this outbreak, I was able to assist in an interview of a case of measles at their place of residence. This case was unvaccinated and acquired their infection in Thailand and was not linked to this outbreak. Contacting the case was proving difficult via telephone, thus it was decided that a public health physician (and my supervisor) Dr Ben Scalley and myself would attend the cases' residence to try and contact the case and if possible complete the interview. The case was at home as he was extremely unwell and still infectious. To be able to visit the case, I knew that I was immune to measles as I have been previously vaccinated twice. We were able to interview the case and obtain his social history, while also providing measles health information and informing him of his infectious period. While we were at his house, we also met his housemate who had been exposed to him while infectious – and were able to provide him with measles information and the explanation of the importance of knowing his immunisation status. His housemate had only received one dose of MMR and serology testing for immunity was negative, so he was then advised to isolate himself. Approximately 12 days after his first exposure to his housemate he also developed measles and was considered a secondary case. I thoroughly enjoyed being able to go out and assist with an interview and contact tracing of a measles case. This was not my first time seeing a case of measles or interviewing them, but it definitely reminded me how much I enjoy speaking to cases (especially face to face) and obtaining their social history, showing them empathy and educating them about measles. It feels like you are able to make a difference to that person (even if they are feeling extremely unwell) and their contacts.

I was also an active participant in the Measles outbreak debrief in November 2019, which involved numerous stakeholders that we involved in the outbreak – from the system manager (CDCD), operations lead (MCDC), the laboratory (PathWest), hospitals/GP practices. This debrief brought together all stakeholders to discuss what worked well, what were the issues and what could be done better during the next measles case and outbreak, with an action plan being formulated. It is envisaged that the action plan will be implemented by the stakeholders as an important preparedness measure. After this meeting, I wrote the minutes/report. The agenda of the outbreak debrief is in Appendix 2. At the time of chapter write up, the minutes had not yet been finalised and signed off.

The lessons learnt from this measles outbreak, were also applied during the early COVID-19 pandemic response in WA. Initially, MCDC were undertaking all COVID-19 case and contact follow up and management, with the support of public health physicians and the epidemiology team. The spreadsheet used in the measles outbreak was altered to accommodate COVID-19 case information and was utilised for data collection, task management and reporting to the WA Health Minister, Chief Executives and PHEOC on-call physicians. I was again managing this spreadsheet while being physically located in the same office as the contact tracers and therefore I again had real-time access and a full understanding of all incoming data and case/contact information. This reiterated the benefit of close working relationships between the operational and epidemiological team during an outbreak, but especially during a pandemic response.

ACKNOWLEDGMENTS

First of all, I would like to thank all of the staff at MCDC. These incredible nurses, doctors and public health intelligence staff worked tirelessly to interview cases, contact trace and ultimately contain this outbreak, by working overtime and during weekends, while providing amazing support. This outbreak was truly was a bonding experience and one we have referred to numerous times since! I would also like to thank Dr Suzanne McEvoy and Dr Ben Scalley for their leadership, guidance, support and encouragement throughout the outbreak. I would also like to thank the staff at the CDCD.

ABSTRACT

BACKGROUND

Measles is an acute, highly infectious and vaccine-preventable viral illness. Transmission of the virus is airborne, primarily person to person via respiratory droplets. Measles is a vaccine preventable disease. There is no treatment for measles apart from supportive, with the prevention being in the form of vaccination (1-4). On 20 September 2019 the Australian Government Department of Health, National Incident Room (NIR) notified Western Australia (WA) Health of a confirmed case of measles in a resident of New Zealand (NZ), who had been in metropolitan Perth, WA whilst infectious. We commenced public health follow up and describe here the subsequent investigation of an outbreak that began with this index case.

METHODS

Measles is a notifiable disease by laboratories and medical practitioners in WA. Cases were either laboratory confirmed, or epidemiologically linked to a confirmed case. Laboratory diagnosis was by real-time polymerase chain reaction (RT-PCR) and/or serology. Case information was extracted from the WA notifiable infectious diseases database (WANIDD) and the measles outbreak cases epidemiological spreadsheet, with date of notification between 10 September 2019 and 16 October 2019, which demographic characteristics, the links between cases, laboratory aspects and outbreak control activities were described.

RESULTS

The NZ resident who was notified in September 2019 through the NIR was considered the index case. From this index case, a further 22 cases resulted, of which sixteen were classified as secondary cases and the remaining six were tertiary cases. Between 10 September 2019 and 16 October 2019, 29 cases of measles were notified in WA. Twenty-three of these cases were part of the outbreak (including the NZ resident who was the index case). During the outbreak, there were a further 4 cases that were import-related, with a subsequent two secondary cases linked.

Within the outbreak cases (n=23), there were eight males and 15 females, with a median age of 21 years (age range: 6 months to 43 years). No cases were identified as being of Aboriginal or Torres Strait Islander origin. All outbreak cases (n=23) were symptomatic, with varying degrees of severity and duration of illness. All cases reported a rash, followed by coryza (19/23, 82.6%), a fever (17/23, 73.9%) and cough (16/23, 69.5%). Seven cases (30%) were admitted to hospital and nine cases (39%) presented to a hospital Emergency Department (ED) but were not admitted. Three cases were under 12 months of age and therefore not eligible for vaccination, five cases were conscientious objectors to the measles vaccine and five cases in the 40-44 year age group had an unknown vaccination status. Of those cases who were laboratory confirmed, only five cases were genotyped. All five were genotyped as the D8 strain.

CONCLUSION

This outbreak response exhibited the vigilant surveillance system in WA, particularly the tireless work and dedication by all staff involved to effectively and efficiently control and prevent further measles transmission. There was a large impact on public health resources, as well as frontline clinical services. The improvement of these systems and processes must continue to be refined and modernised going forward.

BACKGROUND

MEASLES ILLNESS

Measles is an acute, highly infectious and vaccine-preventable viral illness. The measles virus is a member of the genus Morbillivirus. Transmission is airborne, primarily person to person via respiratory droplets. There is no treatment for measles, only prevention with vaccination, or in some circumstances, post-exposure prophylaxis using normal human immunoglobulin (NHIG) (1-4). Prodromal (initial) symptoms of measles can include tiredness, cough, sore throat, runny nose, conjunctivitis and Koplik spots, usually lasting 2 to 4 days. A characteristic non-itchy maculopapular rash then appears around 2 to 7 days after the prodrome onset, beginning on the face and spreading to the rest of the body. A fever is also generally present at the time of rash onset (3-5).

As defined by the Measles Communicable Diseases Network Australia (CDNA) National Guidelines for Public Health Units, the incubation period (time between becoming infected and developing symptoms) of measles averages approximately 10 days (range 7 to 18 days) to the onset of fever and about 14 days to the onset of rash (3). Measles cases are considered to be infectious from 24 hours prior to onset of the prodromal symptoms, until 4 days after the onset of rash.

As per the Measles CDNA Series of National Guidelines for Public Health Units (SoNG), if the prodrome is not defined, the onset of the infectious period is to be considered 4 days before the onset of the rash, until 4 days after (3). The basic reproduction number (R_0) is defined as "the average number of secondary cases of an infectious disease arising from a typical case in a totally susceptible population and can be estimated in populations if pre-existing immunity can be accounted for in the calculation". As previously stated, measles is one of the most highly communicable infectious diseases(3, 5) and is therefore often cited have an R_0 of 12-18, which means each person with measles would on average infect 12-18 other people in a totally susceptible population(6).

Severe complications can arise from measles, including otitis media, croup, pneumonia, diarrhoea, febrile seizures and encephalitis. It is estimated that the case fatality rate is less than 1% in developed countries but can still be anywhere from 3-5% in developing countries (5).

Setting And Population

Western Australia is Australia's largest state, covering one-third of the landmass of the country. There are 2.65 million residents in WA, with 2.1-2.2 million who reside in the capital, Perth (7), in which MCDC public health unit oversee. Outside of Perth, the state is divided into seven regional areas for the provision of medical and public health services – these areas make up the WA Country Health Service (WACHS). These regions include the Kimberley, Pilbara, Midwest, Goldfields, Wheatbelt, South West and Great Southern.

Measles in Australia & WA

The live, attenuated measles vaccine was first registered for use in Australia in 1968 and recommended for children aged 12-23 months in 1969. This then transitioned to a combined measles-mumps vaccine in 1982 for those of 12 months of age. In 1989, the measles-mumps dose at 12 months of age was replaced with measles-mumps-rubella (MMR) vaccine and then in 1992, a two-dose MMR schedule was recommended and funded for all children (8).

Catch-up programs for measles have also occurred, including a funded National Measles Control Campaign in 1998, involving one-off school-based catch-up MMR vaccination for children aged 5-12 years. In 2019, WA introduced a funded MMR catch-up vaccine program for adults. The funded vaccine was made available for adults born during or after 1966 and aged ≥20 years, who have not already received two-doses of a measles-containing vaccine (8).

Since widespread vaccination for measles began in Australia, there has been a noticeable decrease from an average of 2714 cases per year between 1991-1995, to an average of 139 cases per year between 2014-2018(9). Measles data in WANIDD dates back to 1990, with national measles surveillance through NNDSS beginning in 1991 (10). From 1 January 1990 to 31 October 2019, there were 832 measles notifications on WANIDD (Figure 1). More recently from 2014 to 2018, the 5-year historical average was 23 measles cases per year. In 2019 (1st January to the 31st October 2019), there were 54 cases notified, of which 23 of those cases were part of this outbreak.

There have been numerous outbreaks of measles in WA throughout the years, with most cases occurring in metropolitan Perth, ranging in the number of cases linked. Through to the 1990s, measles continued to circulate through the community. As immunisation rates increased in the

1990s, cases became rare. The largest outbreak this century was a multi-jurisdictional outbreak in 2006, of which 82 cases were linked Australia-wide, and, of those, 26 cases were in WA. This outbreak was associated with an Indian spiritual group that toured Australia from March to May 2006 (10).

Between 2014 and 2018, an average of 23 cases of measles was notified annually in WA. This largely reflected import related cases of measles and resulting limited local transmission. In 2019, there were 54 cases notified (2 times higher than the 5-year historical average), of which 23 were linked to this outbreak. Prior to this, the largest measles outbreak experienced in WA was in 2006.

Measles Disease Control Guidelines in WA

Measles is one of the 82 notifiable infectious diseases under the WA *Public Health Act 2016* and the *Public Health Regulations 2017*(11). Case confirmation is based on the case definition published in the Surveillance Case Definitions for Notifiable Infectious Diseases and Related Conditions in Western Australia (12) and, equally, the CDNA Australian national notifiable diseases case definitions (13).

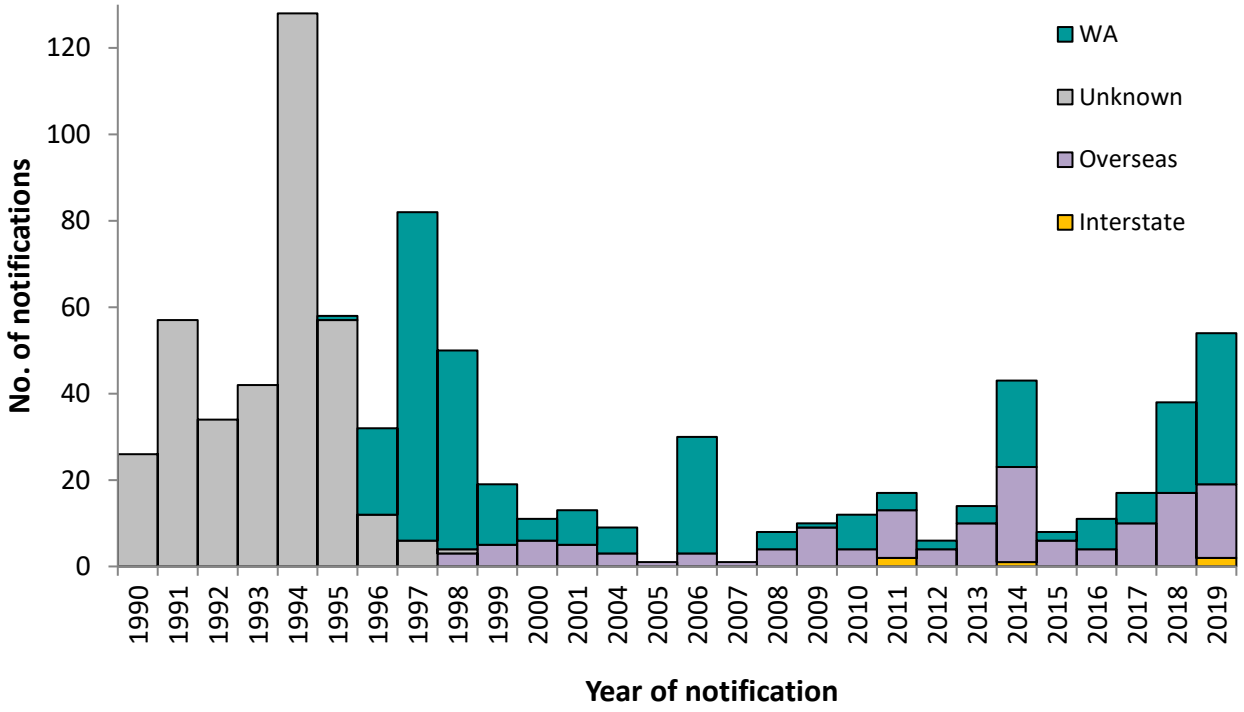

Figure 1: Epidemiological curve of all measles cases notified in Western Australia, by place of acquisition and by year of notification, from 1990 to 2019.

When a suspected or confirmed case of measles is identified by a doctor or the laboratory, this should, pursuant to the *Public Health Act 2016*, be urgently notified, by telephone within 2x hours of first suspicion of a measles diagnosis (12). Outside of business hours, telephone calls for telephone notifiable diseases are triaged through an on-call after hours system, which is staffed by the CDCD public health physicians.

The guidelines WA Health follow are the Measles CDNA National Guidelines for Public Health Units (3). These Series of National Guidelines' were developed by CDNA and endorsed by the Australian Health Protection Principal Committee (AHPPC), with their purpose being to provide nationally consistent guidance to public health units in responding to a notifiable disease event. These guidelines capture the knowledge of experienced professionals and provide guidance on best practice, which is based upon the best available evidence at the time of their completion. The measles SoNG provides guidance on case and contact management, and the response procedure including the identification and management of contacts, such as post-exposure prophylaxis, isolation/restriction and education (3).

2019 MEASLES OUTBREAK

During the Queen's Birthday long weekend (28 to 30 September 2019), five cases of measles had been notified by PathWest to CDCD. Once these cases were interviewed and links were established (time and place) to the index case, it was apparent that this was an outbreak. The outbreak was declared on Tuesday 1 October 2019.

AIMS OF INVESTIGATION & CONTROL ACTIVITIES

The aims of the outbreak investigation was to:

- rapidly identify cases and conduct contact tracing
- rapidly follow up contacts to assess requirement of post exposure prophylaxis
- establish links between cases
- stop further spread in the community.

METHODS

Public health follow-up and management was conducted for all measles (suspected and confirmed) cases notified to CDCD, according to the Measles CDNA National Guidelines for Public Health Units, within The Series of National Guidelines (3).

OUTBREAK CASE DEFINITION

A suspected outbreak case required:

Clinical evidence and/or epidemiological evidence

A confirmed outbreak case required:

Cases of measles* (Box 1) notified between 10/09/2019 and 16/10/2019

AND

Had an epidemiological link* (Box 1) to an outbreak case (index or secondary), or was related geographically (an exposure location or is from the south-west of Perth and South of Fremantle)

CASE INFORMATION

All cases of suspected and confirmed measles were investigated in accordance with the SoNG. Through an interview, either face-to-face, over the phone or via their next of kin (NOK), the collection of information about the case and their contacts occurred.

Case information, including demographics, clinical and laboratory results, date of onset, vaccination status, infectious period, incubation period, exposure locations and epidemiological link/s were entered into the measles outbreak cases epidemiological Excel spreadsheet (created and managed specifically for this outbreak) and then into WANIDD.

Within the spreadsheet, exposure locations, including the date and time, were entered immediately after each case interview and constantly updated with any new information. Generations of transmission were also recorded. In instances where a secondary case was able to mention an exposure location in common to an infectious primary case, a link was confirmed.

Suspected links were identified if a secondary case had been in a similar geographic area at the same time as an infectious case.

Box 1: Australian national notifiable diseases measles case definition*

Confirmed Case

A confirmed case requires either
1. laboratory definitive evidence OR
2. clinical evidence AND epidemiological evidence.

Laboratory definitive evidence

At least one of the following:
1. Isolation of measles virus OR
2. Detection of measles virus by nucleic acid testing OR
3. Detection of measles virus antigen OR
4. IgG seroconversion or a significant increase in antibody level or a fourfold or greater rise in titre to measles virus EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing. (NOTE: paired sera must be tested in parallel). OR
5. Detection of measles virus-specific IgM antibody confirmed in an approved reference laboratory EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing.

Clinical evidence

An illness characterised by all of the following:
1. A generalised maculopapular rash lasting three or more days AND
2. Fever (at least 38°C if measured) at the time of rash onset AND
3. Cough OR coryza OR conjunctivitis OR Koplik spots.

Epidemiological evidence

An epidemiological link is established when there is:
1. Contact between two people involving a plausible mode of transmission at a time when: a. one of them is likely to be infectious (approximately five days before to four days after rash onset) AND b. the other has an illness that starts within seven to 18 (usually 10) days after this contact AND
2. At least one case in the chain of epidemiologically linked cases (which may involve many cases) is laboratory confirmed.

Probable Case

A probable case requires Laboratory suggestive evidence AND clinical evidence.

Laboratory suggestive evidence

Detection of measles specific IgM antibody other than by an approved reference laboratory EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing (13).

Confirmation of vaccination status was through the Australian Immunisation Register (AIR), a national register that records all vaccines given to all people in Australia, enrolled in Medicare. The AIR includes vaccines given under the National Immunisation Program (NIP), through school programs, and privately (14). Vaccination confirmation could also be have been in the form of verbal advice from a health provider, or sighting of a health record (15).

The index case was not entered into the WANIDD as this case was diagnosed only on return to NZ and was a resident in NZ. This case was, however, included in the total outbreak numbers and results section.

Control Measures

As per standard procedure for telephone notifiable diseases in WA, following a notification to the Department of Health by doctor or laboratory, the public health nurses or public health physicians in Public Health Units (PHU) or on-call CDCD physicians, begin the response procedure. During this outbreak, the case management and response procedure was undertaken by MCDC staff and CDCD on-call physicians, in collaboration with the treating doctor, laboratory and the case/NOK. The follow-up included:

- confirming the diagnosis (confirm relevant pathology tests/results or arrange appropriate testing)
- obtaining the cases vaccination status, the type of vaccination they received and the dates of vaccination
- confirming the onset date (especially rash onset) and symptoms of the illness
- calculating the incubation period and infectious period
- ascertaining the likely source/place of acquisition, whether it be travel or contact with a confirmed case of measles during their infectious period, obtaining a detailed history of the cases infectious period activities, their specific movements and the exposed contacts, including the places they visited, detailing their times of arrival, duration of stay and departure times
- providing education to the case about measles and advising them (verbally and in writing) to remain isolated until 4 days after the rash onset.

The contact management in this outbreak was also undertaken by MCDC and CDCD on-call physicians when required, with some assistance provided by WACHS PHUs and hospitals. Once contacts were identified from the case interview, the staff would assess each contact's susceptibility to measles, identifying those most susceptible to measles, including those who were unvaccinated, infants, immunocompromised, or pregnant. These types of contacts were then

provided measles advice and how to manage themselves if they do become symptomatic, and if it was deemed appropriate, staff would arrange post-exposure prophylaxis (PEP) through a hospital emergency department (ED) or general practitioner (GP). Susceptible contacts were also quarantined, with their compliance and potential onset of symptoms monitored daily by SMS.

If contacts were deemed to be immune to measles (those born before 1966 or born during or since 1966 and who have documentation of having received two doses of a measles-containing vaccination, documented evidence of immunity, or laboratory evidence of prior measles) they would be given measles information and no further follow up would be undertaken.

Contacts deemed as household and household-like contacts (other settings where people share communal facilities, for example, in a hospital), childcare centres and schools, waiting areas in healthcare facilities such as emergency departments and general practices and work settings were individually followed up during this outbreak. When individual follow-up was not feasible, group level communication via hosts of a party was used, as well as using media releases to alert the public to the venues which an infectious case of measles may have been and during what time period, for example, at a shopping centre, Perth airport and at cafes.

Laboratory Testing

Specimen collection for suspected measles cases included nasopharyngeal swab and/or aspirate, throat swab, first catch urine and/or blood. The majority of testing was undertaken at PathWest Laboratory Medicine in Perth, with some serological testing undertaken by private laboratories.

Detection of measles ribonucleic acid (RNA) by real-time polymerase chain reaction (RT-PCR) is a rapid and sensitive test and is the preferred testing method for acute measles cases(16-18). RT-PCR was completed on nasopharyngeal swabs, throat swabs and urine samples. Samples for RT-PCR testing from private laboratories were also referred to PathWest.

Detection of measles' specific Immunoglobulin (Ig), both IgM and IgG antibodies on blood samples was also undertaken during this outbreak. Specimens that were reactive on the measles IgM enzyme immunoassay (EIA) had supplementary testing performed by indirect fluorescent antibody test (IFA)(17, 18). This testing was undertaken on suspected cases samples, as well as being used to check immunity status of contacts.

All RT-PCR positive and IgM positive cases were urgently notified to the CDCD/MCDC. These results were then interpreted in the context of clinical symptoms, vaccination status and epidemiological findings (3). Domiciliary services by private laboratories were also used during this outbreak. Collection of specimens at home was arranged for contacts that were possibly symptomatic/infectious. Therefore by testing these suspected cases at home, it would decrease the risk of further measles transmission in the community. Genotyping of the measles virus was completed by PathWest scientists on selected cases within the outbreak.

Statistical Analysis

A descriptive analysis was conducted using Microsoft Excel. The statistical package R (19), in conjunction with the excel spreadsheet, was used to map the chains of transmission during the outbreak. R packages "*network* and *ggnetwork*" were used. A 23x23 adjacency matrix was manually created to outline links between each of the 23 cases involved in the measles outbreak. In the matrix, each row and column represented a case, with a '0' signifying that there was no link between two individuals and a '1' representing transmission between cases. Each of the node attributes (colour by vaccination status) and edge attributes (nature of disease acquisition) was specified manually in the R code(19).

Ethical considerations

Protocol 2017/909: Request for waiver of consent for use of data in research for Master of Applied Epidemiology students for 'Outbreak Investigation' and 'Surveillance in Public Health' projects was approved by the ANU Human Research Ethics Committee on 7 February 2018.

RESULTS

DESCRIPTIVE EPIDEMIOLOGY

On Friday 20 September 2019, the Australian Government Department of Health National Incident Room (NIR), notified WA Health of a confirmed case of measles in a 25-year-old resident of NZ, who had visited metropolitan Perth, WA, while infectious.

The NZ resident was considered the index case of this outbreak. The case travelled from NZ to Perth on 6 September 2019, becoming symptomatic with prodromal symptoms (a runny nose, headache and cough) on 11 September 2019, with a rash developing on 16 September 2019. As cases are considered to be infectious from 24 hours prior to onset of prodromal symptoms until 4 days after the onset of rash (3), their infectious period was therefore considered to be from the 10 September 2019, up to and including the 20 September 2019. The case departed Perth on Sunday 15 September and returned to Auckland, whilst still infectious.

The index case reported to be unvaccinated and, given the average incubation period of 10 days, with a range from 7 to 18 days (3), would have acquired their infection in NZ. The majority of their time in WA was spent south-west of the Perth city centre and south of Fremantle. This index case resulted in an outbreak of locally acquired measles cases in metropolitan Perth, which was investigated by MCDC. Between the 10 September 2019 and 16 October 2019 (36-day period), a further 22 cases were reported, of which sixteen were classified as secondary cases and the remaining six were tertiary cases.

Within the outbreak cases (n=23), there were eight males and 15 females, with a median age of 21 years (age range: 6 months to 43 years). No cases were identified as being of Aboriginal or Torres Strait Islander origin. During the outbreak, there were a further four cases of measles notified to MCDC, all of which were unrelated to the outbreak. All four cases were import-related, with their place of acquisition being from Indonesia, Thailand (n=2) and NZ, with a subsequent two secondary cases linked. Figure 2 shows all measles cases (outbreak and non-outbreak) notified between the 10 September to 19 October 2019, by their transmission classification and date of onset of prodromal symptoms.

Approximately 260 suspected cases of measles were also monitored throughout this period and found to be negative for measles PCR.

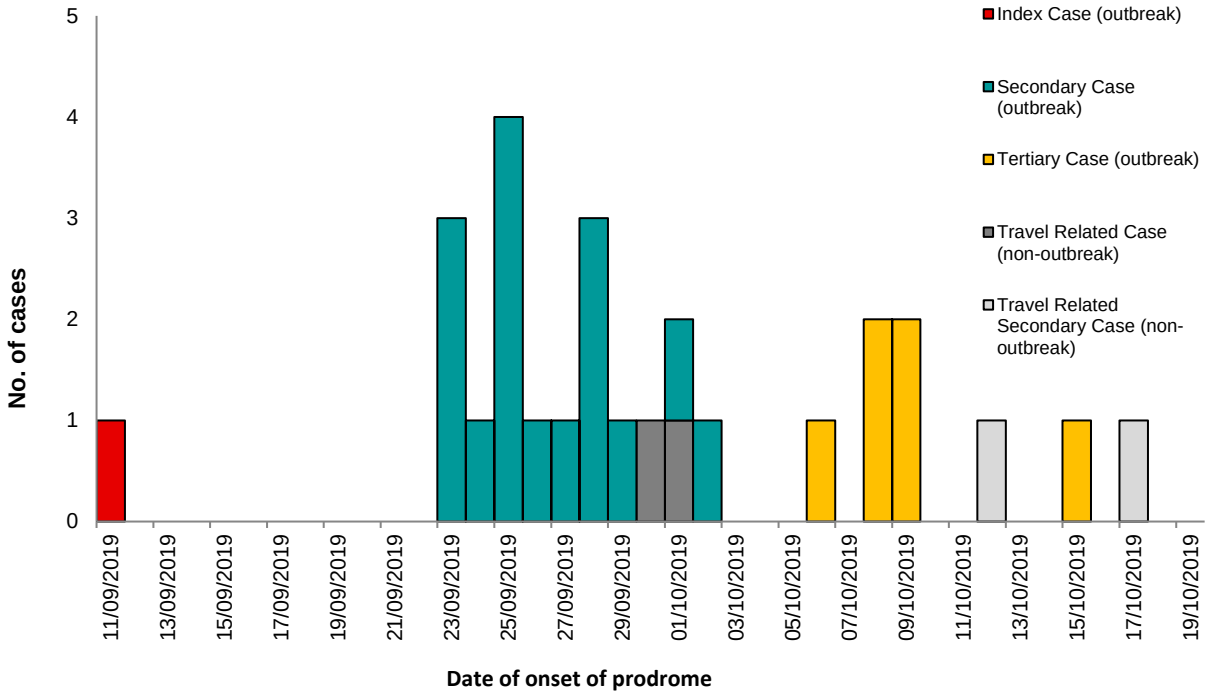

Figure 2: Epidemiological curve of all measles cases notified (outbreak and non-outbreak cases), by transmission classification and date of onset of prodrome (initial symptoms), Western Australia, 11th September to 19th October 2019

Symptoms & Hospitalisation

All outbreak cases (n=23) were symptomatic, with varying degrees of severity and duration of illness. Complete clinical information was not available for all cases. All cases reported a rash, followed by coryza (19/23, 82.6%), a fever (17/23, 73.9%) and cough (16/23, 69.5%).

Seven cases (30%) were admitted to hospital, nine cases (39%) presented to a hospital ED but were not admitted, three (13%) presented to their GP, three cases (13%) did not seek any medical care and one case was unknown (index case).

Vaccination Status

Three cases (in the 0-4 year age group) were under 12 months of age and were therefore not eligible for routine vaccination under the national schedule. Five cases who were “unvaccinated” were known conscientious objectors to the measles vaccine, while five cases in the 40-44 year

age group had an unknown vaccination status (Table 1). There were no cases in this outbreak that were fully vaccinated with two or more measles containing vaccinations.

Table 1. Vaccination status of measles outbreak cases by age group, Western Australia, September-October 2019

Age groups, years (n)	Vaccination status of cases		
	Partially vaccinated n (%)	Unvaccinated n (%)	Unknown n (%)
0-4 (4)	1 (25%)	3 (75%)	-
5-9 (3)	1 (33.3%)	2 (66.6%)	-
10-14 (1)	-	1 (100%)	-
15-19 (1)	-	1 (100%)	-
20-24 (5)	1 (20%)	3 (60%)	1 (20%)
25-29 (4)	1 (20%)	3 (60%)	1 (20%)
40-44 (5)	-	-	5 (100%)
TOTAL	**4 (17.4%)**	**13 (56.5%)**	**6 (26%)**

LABORATORY RESULTS

A total of 20/23 cases were laboratory confirmed. The remaining three cases had a clinically compatible illness and were epidemiologically linked to a laboratory confirmed case within the outbreak. From those cases that were laboratory confirmed, 15 had two or more specimens collected, all which returned a positive result. There were 17 PCR positive throat swabs, two PCR positive nasopharyngeal swabs, 16 PCR positive urine specimens and ten serology specimens had a detectable IgM. Genotyping was completed on five of the laboratory confirmed cases by PathWest, with all being genotype D8.

NATURE OF TRANSMISSION & TYPES OF CONTACT

Information on the nature of the links between the index and secondary cases, and that of the secondary and tertiary cases were collected during the interview of the case, where the case/NOK is asked as to whether they have had contact with a known case of measles, as well as going through the Community Exposure list of where infectious cases of measles had by location and

date. The exposure must fit within the incubation period (the period between exposure to an infection and the appearance of the first symptoms) of measles.

A social network analysis was undertaken during and post outbreak, Figure 3 shows the social network between all cases in the outbreak by their case number, outbreak generation, place of acquisition and each cases' vaccination status.

Within this outbreak, the largest number of secondary cases (n=7) resulted from exposure to the index case at a sporting event. Six secondary cases were unable to be directly linked to the index case via a specific place or time, but all were in the general area where the index case resided and was most active whilst infectious, with two cases specimens genotyped as D8, with the remaining secondary cases (n=3) being attributed to contact within the household (1), at the airport (1) and on an international flight (1).

There was also a total of 6 cases classed as tertiary cases. Three attributed to contact within a household and one linked to a social gathering. Of note, there were two tertiary cases linked to hospital exposure.

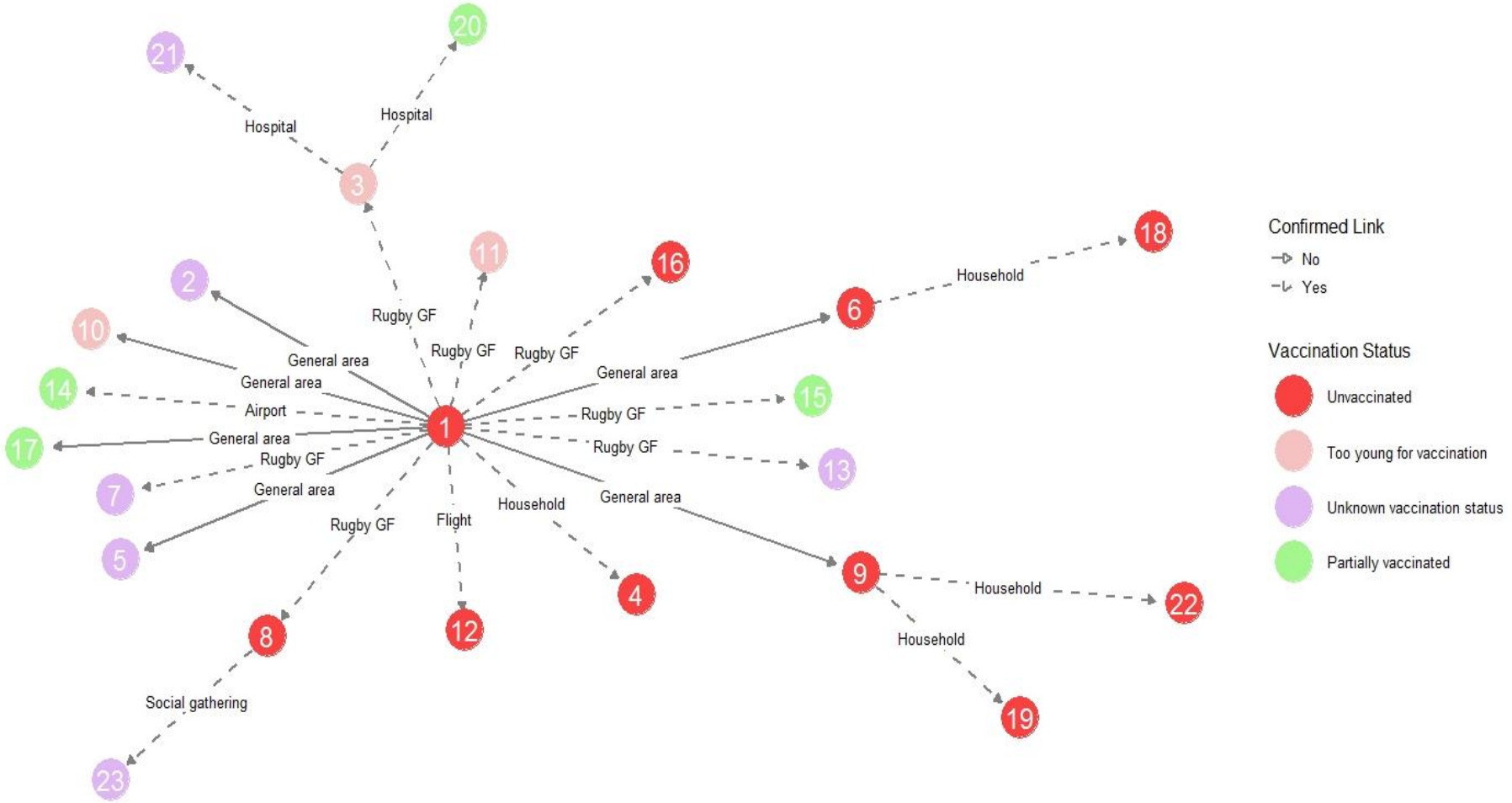

Figure 3: Outbreak social network, by case number, outbreak generation, place of acquisition and vaccination status, Western Australia, September-October 2019.

Control Measures: Contact Management

During this measles outbreak, over 2000 contacts were followed up individually by MCDC with some assistance from WACHS PHUs, from approximately 150 exposure locations. Multiple methods of communication were used, including direct contact via phone calls, text messages sent through Essendex (bulk SMS provider for businesses) or via email. Within those contacts that were followed up by the PHUs, 18 doses of NHIG were arranged by MCDC staff for susceptible contacts, while approximately 67 MMRs were recommended. The number of contacts and post-exposure prophylaxis recommended could be an underestimation, as during the outbreak some hospitals assisted with contact tracing and management and therefore specific numbers are unknown.

Included in the 150 exposure locations are settings that aren't possible to identify every individual person. As per the measles SoNG, group level communication or a media release is sufficient (3). All venues and businesses were individually contacted, with staff members being risk-assessed individually, but to also inform the owners that their business may be named in a media release, along with the date and time the infectious case was present (plus 30 minutes after the case had left the venue).

During the outbreak, the WA Department of Health Communications Directorate, in conjunction with MCDC and CDCD, compiled nine media releases. In these releases, the public were updated with new case details including the locations, dates and times that the infectious cases were present, the total case numbers, symptoms and advice about measles. Given this process, the total number of people who may have had contact with an infectious case of measles during this outbreak is unknown. Communication between WA Health and health practitioners also occurred via clinician alerts throughout the outbreak (Appendix 3).

Of the 150 exposure locations obtained through case interview, they included seven hospitals, 14 general practices, workplaces (which included a mine site and corrective services), schools and childcare centres, the airport, flights and multiple shopping centres, cafes, public transport and general public areas.

DISCUSSION

Here I describe the epidemiology of the second largest measles outbreak reported in WA, in which 23 cases met the outbreak case definition.

Given the highly infectious nature of measles, high vaccine coverage of 95% is needed to achieve herd immunity in order to maintain measles elimination (20). Australia obtained measles elimination status from the World Health Organisation (WHO) in 2014(2). This status was reached as a result of the NIP, which included high coverage with MMR, as well as rapid response to measles cases and outbreaks via effective surveillance systems as well as intensive case and control management by public health units (21, 22). However, measles cases that are acquired overseas, such as in this instance, and that which has been previously seen in New South Wales in 2012 with the index originating from Thailand and resulting in an outbreak of 168 cases (23) , are still being detected in Australia, which can then result in outbreak with ongoing transmission in an under-immunised population. A challenge found in this outbreak were cases with an unknown vaccination status. This is consistent with the lack of systematic documentation of vaccination in individuals of this age – as the Australian Childhood Immunisation Register (ACIR) was not consistently reporting until the late 1990s(24), as well as having grown up in the period when measles was not endemic in Australia, but due to their age, they may have missed the 1998 measles vaccination program(23).

In this outbreak, the index case resided in Auckland, NZ before travelling to Perth. At the time, NZ was experiencing a widespread outbreak, with 2161 confirmed cases of measles notified from 1st January 2019 to 11th December 2019, 1718 of these cases were from the Auckland region, with genotype D8 in circulation (25). Genotyping of the measles virus is important in outbreak settings. Genotyping reviewed in conjunction with epidemiological information gathered during the outbreak can play a valuable role in tracking and linking the transmission pathways between cases, distinguishing between wild-type measles or “vaccine-induced” measles, and can also help establish which foreign country it may have been imported from (however, each genotype can circulate in multiple countries and regions of the world)(26). The cases that were able to be genotyped within this outbreak were also the D8 strain, however, given the index case was tested in NZ it is not known if their specimen was the same. Notwithstanding, given the epidemiological

evidence, it is almost certain that the index case introduced this strain into Perth and further transmission occurred.

The outbreak social network analysis (Figure 3) was also an important tool used during and after this measles outbreak. The analysis used the epidemiological information collected during each case interview to generate a visual representation of the outbreak. This provided useful insight of the transmission pathways between each measles case. The analysis and its graphic representation played a vital role in the understanding of this outbreak and could be further harnessed as an important component in the control and management in future measles outbreaks (26).

This measles outbreak and its response once again highlighted those aspects previously noted - the need for a robust surveillance system, timely public health action, surge capacity and the impact on resources involving public health, frontline clinical services, laboratory, communications and media. It is well known and has been previously documented in a study undertaken after an outbreak occurred in Western Sydney in 2011, that considerable effort and resources are required to manage a measles outbreak with staff representing the largest cost component of the public health response(27).

The public health response to one case of measles can be labour-intensive in itself. During this outbreak, MCDC were notified of 15 cases in one week that required follow up, which meant doctors and nurses interviewing each case and obtaining complete social histories, including all contacts' details and then undertaking risk assessments for each contact. Coupled with this is the possibility for recall bias by the case and/or contact/s, in terms of being able to or knowingly withholding information such as names of contacts, contacts details or locations they had been while infectious.

Furthermore, following a case interview if required, PEP was arranged to try to provide protection or modify measles among those who are susceptible. This could have been in the form of MMR vaccine or NHIG depending on the time that had elapsed since their exposure to the infectious case (MMR if within 72 hours of first exposure, NHIG from 73 hours to 144 hours), the contacts age, previous MMR vaccination history and whether they are immunocompromised) (3). This also produced a large workload for staff which was extremely time sensitive, with 18 doses of NHIG having to be arranged through EDs and approximately 67 MMRs recommended.

The monitoring of infectious cases and susceptible contacts in isolation was also undertaken, as well as the distribution of general measles information. As noted previously numerous people in hospitals and GPS, workplaces, schools and childcare centres, Perth Airport and multiple shopping centres were exposed to an infectious case of measles, with MCDC liaising with each venue to undertake and assist with the public health follow up of those contacts.

Another element which can increase the workload during a measles outbreak is the need for enhanced surveillance, which is the collection of data above that collected for routine surveillance and in essence trying to find and isolate cases of measles in a timely fashion, therefore reducing the potential for further transmission. Suspected cases of measles should be notified. However, this was highlighted and reiterated to clinicians via WA Health Clinician alerts. Highly suspicious cases of measles can also warrant a full interview to obtain information, before having the test result available.

Enhanced surveillance during this outbreak also included requesting pending and negative test results from PathWest. The suspected cases and their testing were monitored by MCDC staff. A pending results list was constructed and, once a negative laboratory result or immunity via serology was notified to MCDC, the case moved to a rejected list. This list and the follow up of suspected cases and then at times having to communicate that result with a suspected case and/or their clinician took extensive amounts of time and resources. Similarly, to the 2011 NSW measles outbreak, as there was more public and clinical awareness of measles due to the outbreak, suspected cases and their notification/testing can also last beyond the final case and the conclusion of the outbreak (27).

All of the workload endured by MCDC early in this outbreak highlighted the need for more surge staff to be enlisted to assist in contact management, which included CDCD staff, WACHS public health nurses assisting from regional areas and also utilizing and training other nursing staff throughout the North Metropolitan Health Service. Also, of note, while this measles outbreak occurred, other notifiable infectious diseases continued to occur and required public health action from MCDC.

In conjunction with the operational response by MCDC, CDCD had the system manager role within this outbreak, which was also resource intensive as many tasks were undertaken. The CDCD public health physicians performed the after-hours on-call service (every night from 5pm to 9am) which involved interviewing cases of measles that were notified, contact follow-up and discussing with doctors suspected cases of measles. Another large role was played in regard to the preparation

and creation of communications for the public, businesses and healthcare professionals. Working closely with the Media and Communications Department within WA Health, measles posters were produced for clinicians use, as well as for healthcare settings and for the general public (see Appendix 4). Clinician Alerts, communiques for Health Service Providers (HSPs), communications to businesses and State-wide Outbreak Situation Reports were all produced. The WA Health Minister was also sent briefing notes in regard to the status of the outbreak. Daily morning meetings were also arranged between CDCD, MCDC, WACHS PHUs and PathWest to discuss operations, planning, communications and logistics of the outbreak.

Measles outbreaks not only affects public health staff but also heavily impacts on other sectors and stakeholders in the health system. During this outbreak both public and private laboratories in WA were utilized. During any measles outbreak there is increased media attention, and with that, education of measles symptoms, which therefore normally leads to an increased number of people being tested for measles by their GP or the hospital ED. In this outbreak, it was seen that the number of requests for measles testing rose markedly, with PathWest testing hundreds of specimens throughout this period and beyond, having to increase the number of measles PCR laboratory runs throughout the day/night. Urgent PCR testing was required on highly suspicious cases, while urgent serology testing was also requested for contacts in the need to assess as to whether NHIG was required for themselves or their child. Domiciliary testing was also made available by the private laboratories in WA, which meant suspected cases could remain isolated at home and have a specimen collected, therefore minimising any potential spread to the public if there were indeed a case. PathWest would also communicate to MCDC and CDCD daily via email correspondence, reporting on all results available from the measles PCR runs. This increase in workload during this outbreak period for the laboratories was noted during daily outbreak teleconferences with CDCD and MCDC.

The other health sectors also assisted in this outbreak with considerable resources and time being invested. There were seven instances where people in hospitals were exposed to infectious measles cases during this outbreak, some cases presenting to ED and some being admitted. Hospital settings are known to be ideal for the spread of measles, as seen in previous outbreaks due their susceptible contacts as well as the closed spaces and patient management (28, 29), with this outbreak notably producing two tertiary cases after exposure while at a hospital. Therefore, numerous staff from EDs, hospital wards and their infection control practitioners were involved in both case and inpatient contact management. Contacts in 14 general practices were also exposed. There were cases in which their illnesses resulted in repeated presentations to both healthcare settings, which then increased the number of potential contacts exposed and the need

for public health action. This highlights the need for continual education, training and communication (Appendix 3) to hospital EDs and GPs in regard to the presentation of measles cases and their management in terms of diagnosis, isolation and notification (23, 27).

Similar to any outbreak, there are many learnings to emerge. It highlighted the need for communication and collaboration and the need to solidify relationships within the health system. A debrief was held with all stakeholders involved in the outbreak response, identifying and discussing issues that arose, as well as what worked well. An action plan was then drafted, with some alterations to the follow up of cases and contacts being improved in terms of resources and specific duties being better defined and allocated.

The use of electronic solutions was explored during this outbreak, however, further work to make these standard practice, is to be finalised. Like in the outbreak in NSW in 2011, it was found that obtaining lists of contacts took considerable time, similar to what was experienced in this outbreak, which could directly impact the type of public health intervention which could be undertaken, potentially then putting susceptible people at risk(27). The debrief discussed the need for exploration into this issue, with it being suggested that statistical programs such as R could assist in generating lists in a timely fashion and in a format that would be easily manipulated for further use by public health units. This could therefore lead to faster public health action and interventions, with the automation of checking these lists against the AIR, performing risk assessments of contacts susceptibility based on information obtained and then sending tailored information to contacts via SMS using Essendex. These processes would ultimately decrease the workload for public health units and the frontline clinical staff involved, while increasing the efficiency of the public health response.

CONCLUSION

A large measles outbreak occurred in metropolitan Perth, the second largest reported in WA. The outbreak was caused by genotype D8 measles virus. Measles outbreaks are still occurring globally and in Australia. In this instance, it began with an imported case, however, the secondary and tertiary cases were in those in the population who were unvaccinated and/or partially vaccinated. This highlights the need to maintain high population immunity through routine childhood vaccination programs, as well as targeting susceptible age groups who may have only received one dose of MMR (23). This could then assist in preventing outbreaks even in the event of a case of measles which is imported (27).

This outbreak response exhibited the vigilant surveillance system in WA. The tireless and extensive work and dedication by all staff involved, in particular, effectively and efficiently controlled and prevented further measles transmission. This was done by using early and rapid diagnosis and notification, prompt management and isolation of infectious cases, the timely and effective identification and management of contacts, in conjunction with the ongoing epidemiological analysis of cases and contacts. The improvement of these systems and processes must continue to be refined and modernised going forward.

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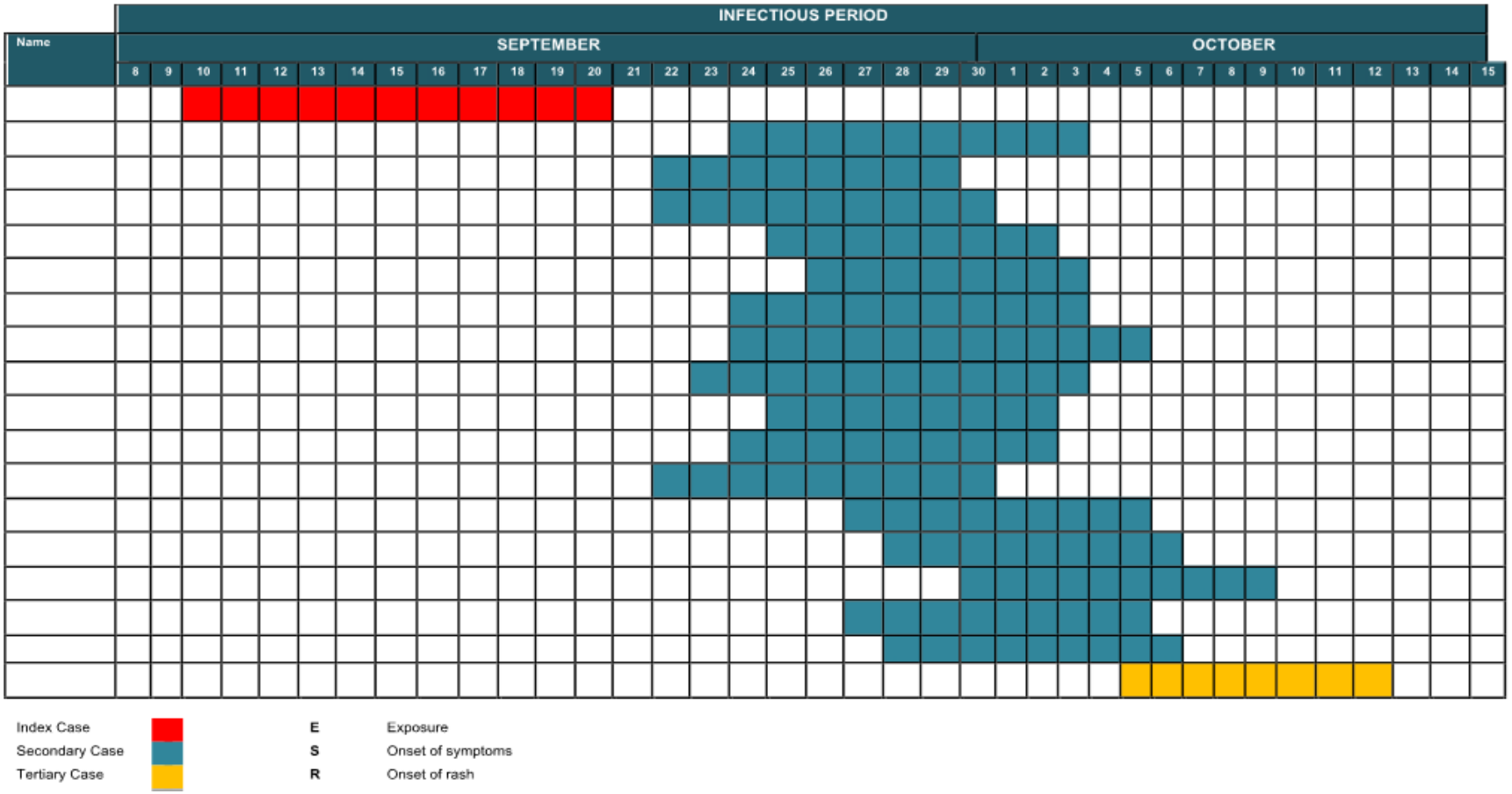
APPENDIX

APPENDIX 1: MEASLES OUTBREAK CASES EPIDEMIOLOGY SPREADSHEET – TRANSMISSION CHAINS; SHOWING EXPOSURE DATE, INFECTIOUS PERIOD, SYMPTOM AND RASH ONSET, WESTERN AUSTRALIA, SEPTEMBER-OCTOBER 2019



MEASLES SPREADSHEET TEMPLATE CONTINUED – CASE TIMELINE, COMMUNITY EXPOSURE LIST, HIGH RISK CONTACTS, DAILY MONITORING, PENDING CASES & REJECTED CASES (DATA FIELDS)

CASE TIMELINE:

Case number	WANIDD ID	Name	DOB	Age	Sex	ATSI	Address	Phone number	Conf status	Vaccination status

IgM	IgG	PCR			Genotype	Epi link to case	Nature of link
		Nasoph	Throat	Urine			

COMMUNITY EXPOSURE BY DATE

DATE	CASE CONTACT	EXPOSURE LOCATION	TIME	Case Lead:	Number of contacts	Notes:

HIGH RISK CONTACTS & DAILY MONITORING LISTS:

First name	Last Name	DOB	Phone Number	Place of Exposure	Index Case	Reason for being high risk	Treatment Authorised	Treatment Received?

PENDING AND REJECTED CASES LISTS:

Date entered	First name	Last name	DOB	Address	Phone	Conf status	IgM	IgG	PCR Nasoph	PCR Throat	PCR Urine	Notes

APPENDIX 2: 2019 MEASLES OUTBREAK DEBRIEF WORKSHOP AGENDA

Government of **Western Australia**
Department of **Health**

2019 Measles Outbreak Debrief Workshop Agenda

Date & Time	Monday 11 November 2019 11:30 AM – 2:00 PM

Agenda items

11:30-11:40	Welcome	Facilitator
11:40-12:10	***October 2019 Measles Outbreak Overview*** Outbreak overview Overview of outbreak control	 MCDC CDCD
12:10-13:40	Facilitated session *Issue identification, what worked well & identifying improvement opportunities* • Initial/early response • Incident command/control • Operations • Logistics (surge/staffing/ vaccine/NHIG) • Communications • Planning • Intelligence/Surveillance • Reporting	All / Facilitator
13:40-14:00	Building an Action Plan *Actions required*	All / Facilitator
End of workshop		

APPENDIX 3: CLINICIAN ALERT, 10 OCTOBER 2019

Government of **Western Australia**
Department of **Health**
Communicable Disease Control Directorate on

WA MEASLES OUTBREAK - UPDATE FOR CLINICIANS

10 October 2019 - 1 PM

KEY POINTS

- **19 measles infections have been reported in WA since 30 September 2019**
- **Three of the 19 infections were acquired overseas (NZ, Indonesia, Thailand).**
- **The remaining 16 were locally acquired - 14 of which were likely exposed to a NZ national who visited Perth and was diagnosed with measles upon return to NZ.**
- **At present, most locally acquired cases reside in the southern suburbs of Perth.**
- **The age range for cases is 6 months to 43 years**
- **More than 150 ill persons have ruled-out for measles by laboratory testing**

Over the last 10 days, measles infection has been confirmed in 19 individuals in WA. Ten of 19 patients were hospitalized. The majority of the recent infections appear to be linked to exposure to a visitor from New Zealand (NZ) who was infectious during his stay in the Rockingham area during 10-15 Sep 2019. Subsequent potential exposures to measles have occurred outside the Rockingham area.

International travel remains a significant risk for measles, as three of the recent infections were acquired during trips aboard. Of note, there is currently a large measles outbreak in NZ with more than 1,700 infections notified as of 7 October 2019.

Clinicians are requested to maintain a high index of suspicion for measles when assessing persons with a febrile rash illness and use their clinical discretion when deciding who to test for measles. Factors that increase the likelihood of an illness being measles include:

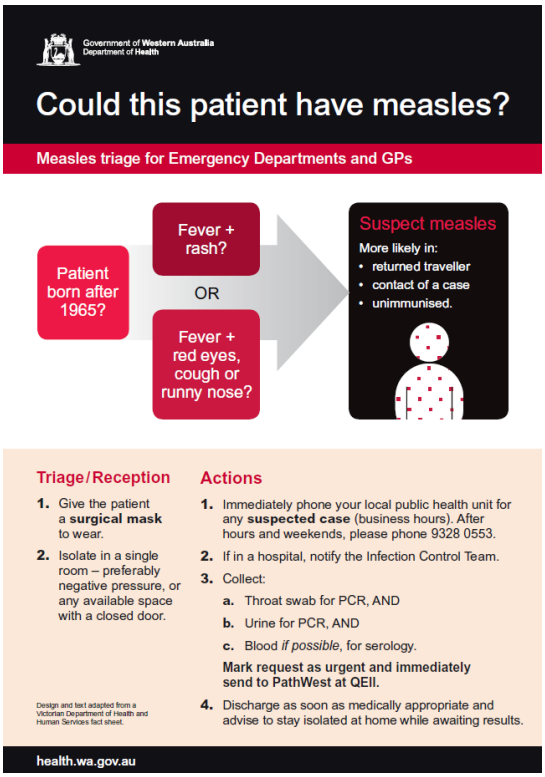
- Less than 2 prior measles vaccinations
- Patient born after 1965
- Recent travel overseas (within 18 days)
- Contact with recent measles case
- Prodromal illness with cough, runny nose, conjunctivitis and fever (often high)
- Fever present at the time of rash onset
- Rash commences on face/head then descends
- Rash is prominent, maculopapular becoming confluent

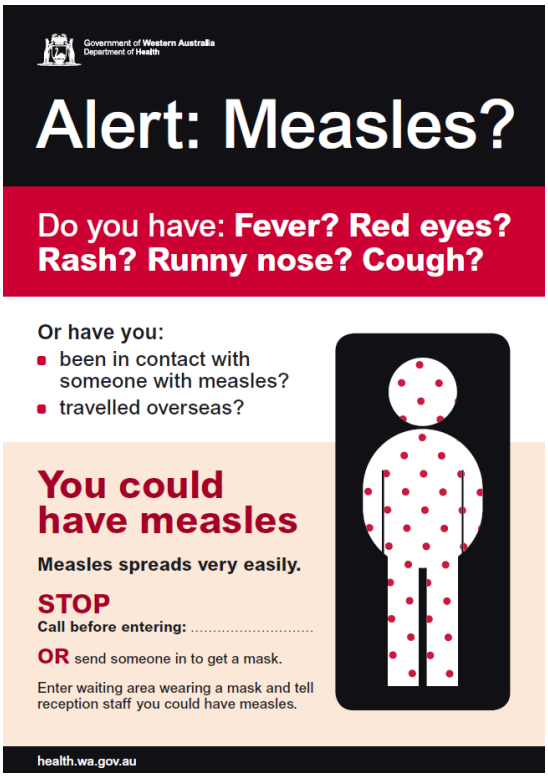
Persons being assessed for measles should have a respiratory AND urine specimen sent for ***urgent*** testing by PCR; during the current outbreak some patients have had a negative result on the respiratory specimen but were positive on the urine sample. Serum for measles IgM/IgG serology should also be collected, when possible.

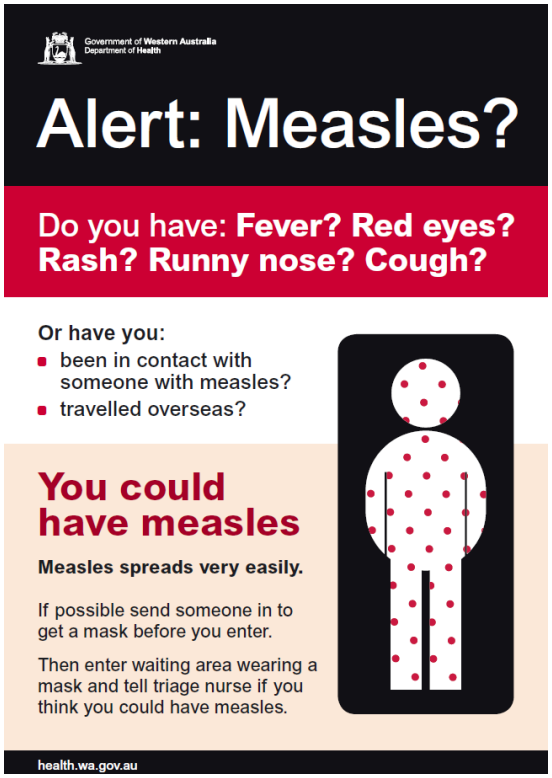
Increased measles activity overseas is likely to continue for the foreseeable future. **The most important thing you can do to help protect your patients is to offer MMR vaccine to any (non-pregnant, non-immunocompromised) person 1 through 53 years of age who does not have prior documentation of two prior doses of measles vaccine.**

Further measles information is available at https://ww2.health.wa.gov.au/Articles/J_M/Measles
Thank you for your assistance in protecting the health of our community.

APPENDIX 4: MEASLES POSTERS FOR CLINICIAN TESTING, AND FOR THE PUBLIC (FOR EDS/GPS)







Measles Situation Report Summary

Date:

Case count:	High risk pending:	Daily Monitoring:

EPI CURVE:

OUTSTANDING ACTION ITEMS:

Name: DOB: Last day of incubation:	
Action item:	**To be actioned by:**
Pending IgG/PCR:	
Name: DOB: Last day of incubation:	
Action item:	**To be actioned by:**
Pending IgG/PCR:	

SITES OF EXPOSURE:

DAY	DATE	CASE CONTACT	EXPOSURE LOCATION	TIME

CHAPTER 5: MEASLES CASES THAT HAVE PREVIOUSLY RECEIVED ANY MEASLES-CONTAINING IMMUNISATIONS: INFECTIVITY & REASONS FOR AN APPARENT RISE IN INCIDENCE

LIST OF ABBREVIATIONS

ACIR	Australian Childhood Immunisation Register
AIR	Australian Immunisation Register
CDC	Communicable Disease Control
CDCD	Communicable Disease Control Directorate
CDNA	Communicable Diseases Network Australia
CI	confidence intervals
GP	General practitioner
MCDC	Metropolitan Communicable Disease Control
MMR	Measles, mumps, rubella
NHIG	normal human immunoglobulin
NNDSS	National Notifiable Diseases Surveillance System
SoNG	Series of National Guidelines
SVF	Secondary vaccine failure (SVF)
WA	Western Australia
WACHS	Western Australia Country Health Service
WANIDD	Western Australia Notifiable Infectious Diseases Database
WHO	World Health Organisation

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PROLOGUE

MY ROLE

As the lead investigator of this project I was responsible for, while working closely with my field supervisor's Dr Ben Scalley and Dr Paul Armstrong, the project proposal, epidemiological study design and data analysis plan, ethics review applications, data applications, data cleaning and analysis (Appendix 1).

When beginning this study in 2019, the initial study design was to assess Western Australia (WA) and Australian-wide measles data. To obtain this data, I had to complete data request applications for the Western Australia Notifiable Infectious Diseases Database (WANIDD), the National Notifiable Diseases Surveillance System (NNDSS) and ACT Health (due to the NNDSS data request). To obtain data from other jurisdictions not captured by NNDSS, I then wrote, and with the assistance of Dr Paul Armstrong, and submitted an agenda paper to the Communicable Disease Network Australia (CDNA), requesting the endorsement by CNDA for me to form a working group of members from each State and Territory, to assist with sharing measles data not captured by NNDSS. This request was endorsed, and a working group was formed, consisting of a member from each jurisdiction. This group met once on 3 December 2019 with all members agreeing that the data I was requesting would be able to be provided. The next meeting was to be scheduled in early 2020. With the emergence of COVID-19 the focus of these staff then shifted to the global pandemic response (Appendix 2).

Pre-COVID, I was able to prepare a section of this project and present the findings for the Communicable Disease Control (CDC) conference in Canberra in November 2019 via a "Long Oral presentation", and at the Public Health Nurses State-wide Update (Appendix 3).

Due to the pandemic, this project therefore had to be re-adjusted multiple times. This also meant that all relevant research protocols submitted for ethics also had to be amended. After discussions about the methodological and statistical aspects of the project with my field supervisors, it was agreed that I would amend and adapt some of the research questions and only focus on the available and extractable WA data. The original research intention and written proposal can be found in the Appendices.

LESSONS LEARNT

This project provided a wealth of experience and lessons learnt. It expanded my capacity to be continually flexible and adapt to numerous challenges. This was my first experience with ethics applications, which I found particularly challenging and very time consuming. Initially requiring data from multiple sources, I had to prepare numerous data applications from WA and Australia-wide data, which then meant I had to have a thorough understanding of which specific data fields were required to answer the proposed research questions. This included obtaining the knowledge of which data fields are collected, entered into databases and the ability for those to be extracted and if paper-based records were needing to be accessed. From this, it was highlighted that a national working group should be formed to request and obtain the required missing data fields which were not currently collected by the NNDSS.

The formation of a working group was a great experience. I was the chair and the secretariat of this working group, which meant I undertook all preparation, organisation and communications for the group, along with facilitating and minuting the (one) meeting. Even though it was only one meeting, it was great to engage with all members and it was evident that they were enthusiastic about contributing and being a part of this project.

Another valuable lesson was writing a conference abstract, preparing the presentation slides and then finally presenting at the CDC Conference in Canberra (Appendix 3).

My experience in this project (and the entire MAE) demonstrated the need to be flexible and agile and know when to change or alter the project. Before the COVID-19 pandemic I was also involved in a meningococcal and measles outbreak, which saw this project be pushed back due to the urgent nature of the public health response and follow-up in both instances. And then the COVID-19 pandemic response commenced (and is still ongoing at the time of writing), meaning this project was again pushed back and required adjustments due to the timeliness of data availability.

Public Health Impact

Whilst we were unable to complete the initial proposed project, the modified project undertaken provides further evidence of the need to improve measles data capture, both in WA and nationally. An enhanced data collection system should be developed to capture all measles data prospectively. From this project, recommendations have been made in regard to the improvement of the surveillance system for measles in WA, specifically data collection, data entry and therefore easy data extraction and collation for analyses. The creation of an enhanced measles form with set data fields within measles case records in WANIDD (which has been implemented for COVID-19 cases during the pandemic response) would help significantly in terms of data entry and extraction, and the use of paper-based data collection can no longer be used. All symptoms of measles and further detail on secondary cases and their "types of contact" for example can be entered into WANIDD directly. These fields can then be transmitted to the NNDSS. The findings of this project also highlight the need for further retrospective data cleaning of WA data, either manually or via the use of AIR data matched to measles case records.

The findings of this project, using WA data only, highlights the need to continue with the initial project proposal, of analysing further WA data, and especially Australia-wide surveillance data. This may be of benefit to continue to seek to improve the understanding of the epidemiology of measles in WA and Australia, specifically regarding immunity and infectivity. This could then inform policy, changes to national guidelines and other public health interventions in WA and Australia-wide.

Acknowledgments

I would like to acknowledge and thank my supervisor's Dr Ben Scalley and Dr Paul Armstrong for their expertise and guidance in developing and refining this project, for answering all of my questions and listening to my ethics application grievances! I would also like to thank Mark Trungove (NNDSS) for his support, as well as all of the national working group members for supporting me and this project.

ABSTRACT

BACKGROUND

The proportion of measles cases who have previously been vaccinated has increased in Western Australia (WA) in recent years. Since the beginning of 2018 until January 2019, 13 cases of measles were notified in WA that had previously received two measles-containing immunisations. It was noted that many of these cases had an attenuated disease course. Some of these fully immunised cases also had close contact while infectious with people who were known to not be immune but did not develop measles, while one with extensive exposures did, suggesting they may have reduced infectivity. Current National guidelines do not specify a different response for cases that have received two measles-containing immunisations. The purpose of this study was to improve the understanding of the epidemiology of measles in WA, specifically, regarding immunity and infectivity. The research questions for this study comprised of:

1. Of all measles cases notified in Western Australia, is there an increase in cases of measles in people who have previously been vaccinated? If so, what are the likely reasons for this?
2. Of all measles cases notified in Western Australia who have previously received any documented measles containing immunisations, does measles immunity decline over time?
3. Of all measles cases notified in Western Australia, is there a difference in infectivity in those who have received any documented measles containing vaccine, as compared to those who have not?

METHODS

A retrospective case series analysis was undertaken, of all cases of measles notified in WA, from 1 January 2009 to 31 October 2019. All confirmed and probable cases were extracted from WANIDD. A descriptive analysis was conducted using Microsoft Excel, which was used to calculate proportions, "year of birth" age groups, means and medians. All cases were described by confirmation status, public health region in WA, age, year of birth (5-year time periods), sex, vaccination status of measles cases as reported to WANIDD at the time of notification. For some analyses, only those cases extracted from WANIDD who had "validated" vaccination records were analysed, as defined by the NNDSS core dataset field specifications (2016).

Results

From the analysis of WA surveillance data, there was an increase of the proportion of notified measles cases who had previously been vaccinated. Further analyses suggested that in the year of birth cohort of 1995-1999 during which circulating wild type measles was less common than in preceding years, there could be waning immunity in those who have received two measles-containing vaccinations. A trend was identified suggesting measles cases that had been notified in WA, who have received one or two measles-containing vaccines may have reduced infectivity and therefore are less likely to result in secondary cases. The analysis also suggests these cases have then resulted in secondary cases from the household or household-like, hospital/GP waiting rooms and the workplace "types of contact", with no secondary cases linked to school, day-care or public areas.

Conclusion

This study provides the first analysis and examination into the potential reasons for increase of the proportion of measles cases who had been previously been vaccinated in WA during 2018 and 2019. From the analysis of WA surveillance data, it was postulated that there may be waning immunity in those who have received two measles-containing vaccinations, in the year of birth cohort of 1995-1999, during which circulating wild type measles was less common than in preceding years, but the duration since their childhood immunisation would be the longest. In terms of infectivity, a trend was also identified suggesting that measles cases in WA who have received one or two measles-containing vaccines may have reduced infectivity and therefore are less likely to result in secondary cases. It is recommended that the continuation and expansion of the initial conceptualised study, specifically regarding the analysis of Australian-wide data should be undertaken.

BACKGROUND

Measles is a highly infectious viral illness. Measles is transmitted by airborne droplets and direct contact with discharges from respiratory mucous membranes of infected persons. No treatment exists for measles, only prevention with vaccination, or in some circumstances, post-exposure prophylaxis using normal human immunoglobulin (NHIG). Before the introduction of the measles vaccine in 1963, measles was the primary cause of morbidity and mortality worldwide in children below the age of five. There were 2.6 million deaths recorded annually and major epidemics were occurring every two to three years (1-3).

Since the introduction of widespread vaccination, which included first and second dose vaccinations, there have been large reductions in measles-related deaths globally, from around 550,000 in 2000 to 89,780 in 2016(1). However, despite a significant decline in global mortality caused by measles, re-emergence of the disease in developed countries with highly vaccinated populations, where vaccine access, health literacy and public health infrastructure aren't significant issues, is fast becoming a public health concern (4).

Australia obtained measles elimination status from the World Health Organisation (WHO) in 2014(2). This status was reached as a result of the Australian National Immunisation Program (NIP), which included high coverage of the two-dose immunisation schedule with MMR (mumps, measles and rubella). Also playing a large part in the elimination status was the rapid response to measles cases/outbreaks with intensive contact tracing by public health units and effective disease surveillance systems (5, 6). Given the highly infectious nature of measles, high vaccine coverage of 95% or more is needed to achieve herd immunity in order to maintain measles elimination (4).

The US Centres for Disease Control and Prevention claim that vaccine induced immunity is long-term and likely to be life-long (7). However, the duration of the protective effect afforded by the vaccine is not entirely understood. There have been serological studies undertaken which suggest that antibody titres within vaccinated individuals are subject to decline, some considerably, which suggests that there is potential for vaccine failure as a result of waning immunity (8-10). This is known as a secondary vaccine failure (SVF), where individuals who have successfully developed a protective immune response after a two-dose vaccination course, lose this immunity to measles

over time (11). Therefore, the implications of waning immunity are that individuals may become susceptible to measles some years post vaccination (4, 8, 9, 11, 12). WHO has considered the evidence regarding declining immunity, with their conclusion being that 'the protective immunity against clinical measles does not seem to be substantially decreased with increasing time following immunisation'. This, however, was noted to be based on a low level of scientific evidence (13).

There have also been some international outbreaks that have suggested waning immunity may occur in fully vaccinated cohorts, however, the evidence is of low quality. In 2014, after 20 years with no reported cases of measles, the Federated States of Micronesia experienced a measles outbreak, which consisted of 393 cases. Of those, two thirds of cases were over 20 and half had received two MMRs. Most cases were aged 20 to 40 with few cases in children or older adults. The extent of transmission among adults with documented vaccinations, many with 2 doses, is atypical. It was noted that the low rate in children was attributed to high vaccine coverage, and in older adults to exposure to wild virus. The high rate in younger adults who had reasonable vaccination coverage was ambiguous, however cold chain lapses couldn't be ruled out. Another possible cause noted, was waning immunity from historic vaccination without wild virus exposure (14).

Within Australia, there is currently little published evidence to suggest concerns regarding waning immunity. An assessment of measles vaccine effectiveness in Australia from 2006-2012 suggested that two doses of measles vaccine were 99.7% protective. This study suggested that the measles vaccine was protective at a population level, however, vaccination coverage gaps may have contributed to outbreaks (6).

As defined by the Measles CDNA Series of National Guidelines for Public Health Units (SoNG), measles cases are considered to be infectious from 24 hours prior to onset of the prodromal symptoms, until 4 days after the onset of rash. As per the SoNG, if the prodrome is not defined, the onset of the infectious period is to be considered 4 days before the onset of the rash, until 4 days after (3). The basic reproduction number (R_0) is defined as "the average number of secondary cases of an infectious disease arising from a typical case in a totally susceptible population and can be estimated in populations if pre-existing immunity can be accounted for in the calculation". As previously stated, measles is one of the most highly communicable infectious diseases and is therefore often cited have an R_0 of 12-18, which means each person with measles would, on average, infect 12-18 other people in a totally susceptible population (3, 15).

The infectiousness of cases who have received two documented measles' containing vaccinations is unclear. Reported secondary cases of measles from those who have received two documented doses of a measles containing vaccine are infrequent, with only a few having been documented globally – and this is despite the regular occurrence of those who have had two measles' containing vaccinations becoming cases. An outbreak occurred in 2009 in Virginia and Pennsylvania, which resulted in secondary infection in two physicians who had a documented history of receiving two (or more) doses of measles containing vaccinations. Both physicians continued to work and see patients, including unvaccinated contacts, and yet there were no additional cases identified (16).

Another example is that of a case in 2014 in the Netherlands, where it was reported that secondary measles infections occurred in four cases, all of whom had been vaccinated twice. Symptoms from those cases were reported to be mild to moderate in severity, with no reported hospitalisations. In addition, despite those secondary cases (with two vaccinations) having had contact with numerous people, there was no further transmission to be found to have occurred, with no tertiary cases reported (17). In New York in 2011, it was reported that there was transmission of measles from an index case with two measles' containing vaccinations and a documented secondary vaccine failure. Transmission occurred to four secondary cases, two of whom had documented MMR vaccines. Three of the secondary cases had contact with the index case in a healthcare facility, and the fourth was a workplace contact. In this instance, there was no further transmission and there were no tertiary cases reported (18).

PURPOSE OF STUDY

Locally, the proportion of measles cases who have previously been vaccinated has increased in Western Australia (WA) in recent years. Since the beginning of 2018 until January 2019, 13 cases of measles were notified in WA who had previously received two measles-containing immunisations. It was noted that many of these cases had an attenuated disease course. Some of these fully immunised cases also had close contact while infectious with people who were known to not be immune, but did not develop measles, while one with extensive exposures did suggesting, they may have reduced infectivity. This project seeks to improve the understanding of the epidemiology of measles in WA, specifically regarding duration of immunity and infectivity of fully vaccinated individuals.

Research questions

The research questions for this study comprise of:

1. Of all measles cases notified in Western Australia, is there an increase in cases of measles in people who have previously been vaccinated? If so, what are the likely reasons for this?
2. Of all measles cases notified in Western Australia who have previously received any documented measles containing immunisations, does measles immunity decline over time?
3. Of all measles cases notified in Western Australia, is there a difference in infectivity in those who have received any documented measles containing vaccine, as compared to those who have not?

Literature Review

A focussed review of the published literature was conducted using databases including the ANU SuperSearch, which provided access to the full ANU library collection, ProMed and PubMed. This search strategy included key words/search terms, as well as several terms to then broaden the search. Key words and search terms included: measles, vaccination, waning immunity, measles infectivity, measles in Australia, measles vaccine effectiveness, secondary vaccine failures, waning antibodies, measles transmission in immunised, re-emergence of measles, measles vaccine failure in adults, modified measles. Additionally, to identify articles potentially missed in database searches, grey literature searches to identify relevant published reports and the snowballing approach to identify literature cross-referenced in studies was also undertaken. No date boundaries were set. Endnote was used to maintain references.

METHODS

DATA SOURCE

Measles is a nationally notifiable condition (Box 1) and a notifiable infectious disease under the *Public Health Act 2016* and the *Public Health Regulations 2017.* Case confirmation is based on the case definition published in the Surveillance Case Definitions for *Notifiable Infectious Diseases and Related Conditions in Western Australia* (19) and, equally, the CDNA Australian national notifiable diseases case definitions (20). The data fields collected by WANIDD are defined by the NNDSS core dataset field specifications (2016).

Measles notification data in the WANIDD database dates back to 1990, with the earliest notification year for which the NNDSS contains measles data from WA is 1991(21). Due to data quality and completeness, all confirmed and probable cases of measles notified from 1 January 2009 to 31 October 2019 were extracted from WANIDD. Paper records which were still filed at Metropolitan Communicable Disease Control (MCDC) were also accessed to enable detailed analysis of type of contact and secondary cases.

Box 1: Australian national notifiable diseases measles case definition, version 1.1

Confirmed Case

A confirmed case requires either
1. laboratory definitive evidence OR
2. clinical evidence AND epidemiological evidence.

Laboratory definitive evidence
At least one of the following:
1. Isolation of measles virus OR
2. Detection of measles virus by nucleic acid testing OR
3. Detection of measles virus antigen OR
4. IgG seroconversion or a significant increase in antibody level or a fourfold or greater rise in titre to measles virus EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing. (NOTE: paired sera must be tested in parallel). OR
5. Detection of measles virus-specific IgM antibody confirmed in an approved reference laboratory EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing.

**Where measles vaccine has been given in the three weeks prior to illness onset and wild-type virus is not detected, or unable to be detected, a case may be considered "confirmed" only if the criteria for clinical and epidemiological evidence can also be met, suggesting wild-type infection. Vaccine-associated measles illness (genotype A) is not notifiable, but rather should be reported as an adverse event following immunisation.*

Clinical evidence
An illness characterised by all of the following:
1. A generalised maculopapular rash lasting three or more days AND
2. Fever (at least 38°C if measured) at the time of rash onset AND
3. Cough OR coryza OR conjunctivitis OR Koplik spots.

Epidemiological evidence
An epidemiological link is established when there is:
1. Contact between two people involving a plausible mode of transmission at a time when: a. one of them is likely to be infectious (approximately five days before to four days after rash onset) AND b. the other has an illness that starts within seven to 18 (usually 10) days after this contact AND
2. At least one case in the chain of epidemiologically linked cases (which may involve many cases) is laboratory confirmed.

Probable Case

A probable case requires Laboratory suggestive evidence AND clinical evidence.
Laboratory suggestive evidence
Detection of measles specific IgM antibody other than by an approved reference laboratory EXCEPT if the case has received a measles-containing vaccine eight days to eight weeks before testing (20).

VACCINATION STATUS

At the time of the public health follow-up of measles cases, vaccination status and all related vaccine fields are obtained and entered into WANIDD. Measles vaccination history was extracted from WANIDD. Table 1 includes the specific fields extracted, as defined by the NNDSS core dataset field specifications (2016).

For some analyses, only those cases extracted from WANIDD who had "validated" vaccination records were analysed, as defined by the NNDSS core dataset field specifications (2016). They included those cases who had:

- written documentation confirmed through an immunisation register, the Australian Childhood Immunisation Register (ACIR) established in 1996 and/or the Australian Immunisation Register (AIR) established in 2016
- or verbal advice from a health provider
- or sighting of a health record

Table 1: Measles data fields extracted from WANIDD

WANIDD Data field	Options
Vaccination status (VaccStatus)	• Fully vaccinated for age for this disease • Partially vaccinated for age for this disease • Not vaccinated for this disease • Not applicable • Unknown
Validation of vaccination (VaccSource)	• Validated (ACIR/AIR records, medical records including hospital, GP, other health care provider) • Not validated (self or parental recall only) • Information not collected, unknown or missing
Dose of vaccine (VaccDose)	• Number of doses • Not applicable • Unknown
Date of vaccination	• Date vaccination was administered
Vaccine codes (type of vaccine given)	• Priorix (MMR) • Priorix-Tetra • ProQuad • MMR-II • M-M-Vax • Measles vaccine given unknown

AGE GROUP

The date of birth, age and year of birth of all measles cases at notification were extracted. Cases were further categorised into "Year of Birth" groups. The "ceiling" formula in Microsoft Excel was used to round the year number up to the nearest multiple of significance. They were then grouped into 5-year time periods.

SECONDARY CASES & THEIR TYPE OF CONTACT

"Secondary cases" were defined as a person who acquired measles from the index case by being epidemiologically related in time, place or person. From cases with "validated" vaccination records, the analysis of any resulting secondary cases was undertaken. Outbreaks recorded in WANIDD were analysed, with the availability of paper records also assisting in understanding the outbreak and links between cases. The mean secondary cases per index case were calculated, per the index cases vaccination dose number (0, 1 and 2 or more measles containing vaccinations).

Following this analysis, the specific type of contact that these secondary cases was undertaken. As per the measles SoNG, a contact is defined as "anyone who has or may have shared the same air-space (enclosed area) for any length of time with an infectious case" (3). In general, contacts are prioritised in order of those contacts who are most susceptible to measles and therefore are requiring individual contact tracing, such as households, early childhood education, schools, shared a waiting room in a General Practice (GP) or hospital with the infectious case, as well as work settings. There are then settings that generally don't require individual contact tracing, with group level communication or media releases being sufficient, including public and general area where cases were known to be, for example, cinemas, shopping centres, airport transit lounges and sporting events. In this analysis, the "type of contact" was therefore classified as per the measles SoNG.

INCLUSION/EXCLUSION CRITERIA

All cases of measles notified from 1 January 2009 to 31 October 2019 were extracted from WANIDD and included in this study. However, due to data quality and completeness (missing vaccination dates for example), some cases were excluded, and the date range of data analysed was also altered (for instance from 1 January 2014 to 31 October 2019). Also, of note, cases who did not have "validated" vaccination records were excluded from further analyses.

Analysis

A retrospective case series analysis was undertaken, of all cases of measles notified in WA, from 1 January 2009 to 31 October 2019. A descriptive analysis was conducted using Microsoft Excel, which was used to calculate proportions, "year of birth" age groups, means and medians. All cases were described by confirmation status, public health region in WA, age, year of birth (5-year time periods), sex, vaccination status of measles cases as reported to WANIDD at the time of notification.

Ethical considerations

Ethics approval for this study was obtained from the Department of Health WA Human Research Ethics Committee (PRN: RGS0000003392, Protocol number: 05/08/2019) and the Australian National University Human Research Ethics Committee (Protocol number 2019/307). All data were de-identified.

RESULTS

From 1 January 2009 to 31 October 2019, there were 230 measles notifications on WANIDD (Figure 1). Two-hundred and twenty (95.7%) were classified as confirmed cases and the remaining ten (4.3%) met the probable case definition. There were 145 males (63%) and 85 females (37%), with a median age of 24 years (age range 0-56 years). One hundred and eighty-five cases were from metropolitan Perth, 31 from Western Australia Country Health Service (WACHS) areas and ten from overseas residents who tested positive in WA. One-hundred and fourteen cases (49.6%) acquired their infection from overseas, 111 (48.2%) from WA and five (2.2%) were acquired from interstate (Figure 1).

In 2014, 43 cases of measles were notified and there were six outbreaks, with the peak being largely due to a rise in the number of imported cases from the Philippines, where years of vaccination program complacency and disruption of the program in the wake of Cyclone Hai-an, lead to a large outbreak there. In 2018, 38 cases were notified, with 13 being import related and one large outbreak in a workplace occurred, which included 8 secondary cases. Then in 2019 (up until 31 October 2019), 54 cases of measles were notified, including nine outbreaks. Seventeen infections were acquired overseas two interstate and 36 infections were acquired locally in WA. A large outbreak occurred in September/October 2019 (see Chapter 4), which accounted for 22 secondary cases.

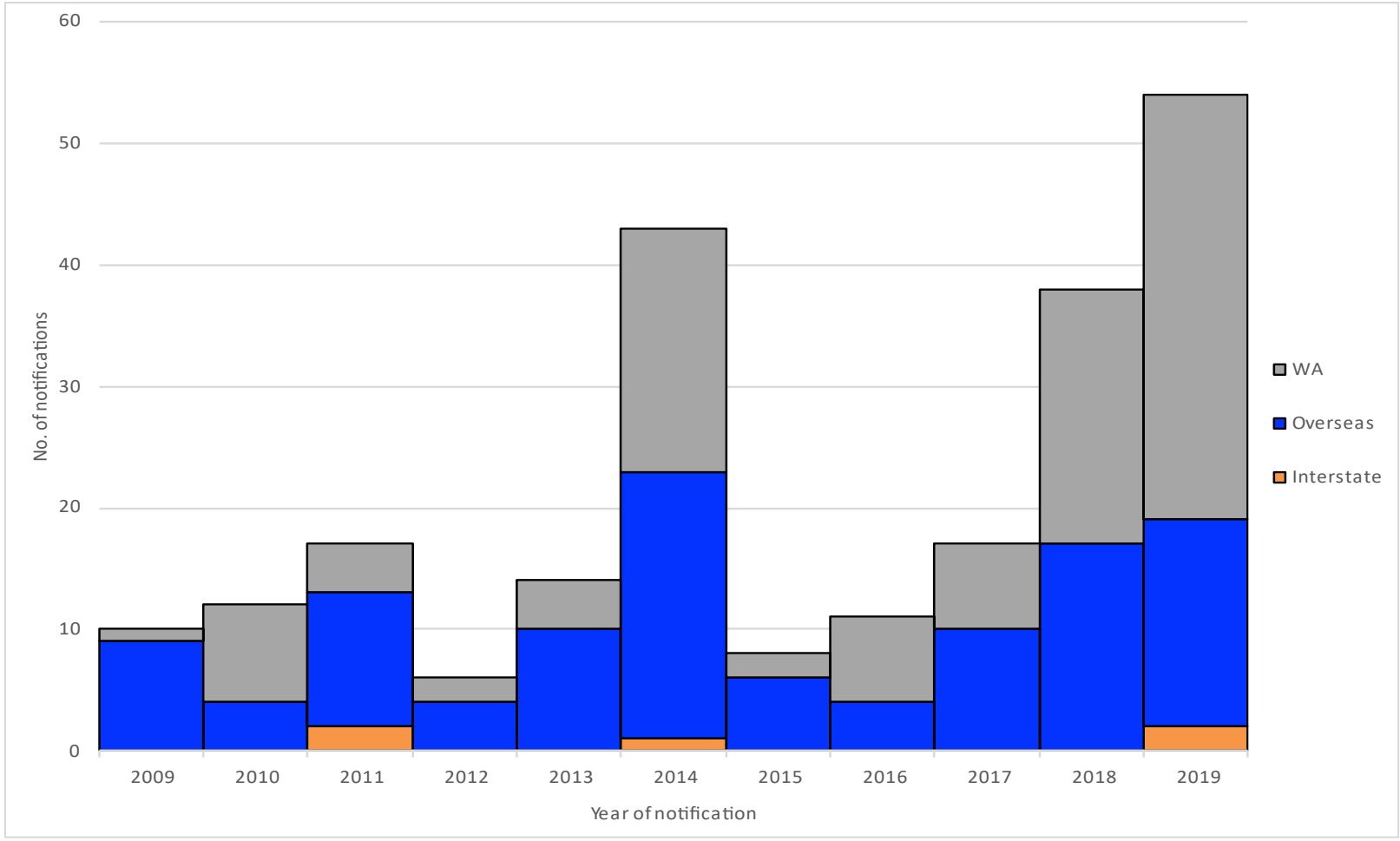

Figure 1: Epidemiological curve of all measles cases notified in Western Australia, by place of acquisition and year of notification, from 1 January 2009 to 31 October 2019

VACCINATION

Figure 2 shows all measles cases (n=230) notified in WA, by their recorded vaccination status on WANIDD, between 1 January 2009 and 31 October 2019. This epidemiological curve illustrates an increase in the number of cases "fully vaccinated", with a large rise in those not vaccinated in 2019. As discussed previously, 2019 saw a large outbreak of 22 cases, notably no cases in the outbreak were fully vaccinated with two or more measles containing vaccines, with five cases being conscientious objectors and a further five cases having unknown vaccination status (cases aged between 40-44 years).

Of the total 230 measles cases notified, 126 (55%) of those cases had a "validated" vaccination status, with the remaining 60 (26%) being "not validated" including self or parental recall only and 44 (19%) cases were entered as having had "information not collected, unknown or missing".

From the 126 cases with validated vaccination records, 31 (24.6%) were fully vaccinated for age, 12 (9.5%) partially vaccinated for age and 83 (65.9%) were not vaccinated (which also includes those who are classified as "not applicable". This 'validated vaccination record' category includes notified cases who are not vaccinated due to being too young for vaccination or identify as conscientious objectors at the time of notification).

Figure 3 shows the increase in the proportion of cases who are fully vaccinated, with both 2018 and 2019 with ten cases respectively (37% and 22.7%), as well as an increase in those not vaccinated particularly in 2019 (n=30, 68.2%) (Appendix 4). Of those cases, ten cases (37%) in 2018 and nine cases (20.5%) in 2019 had a record of having received two or more measles containing vaccinations, the highest of any year preceding (Appendix 5). In 2010 and 2015, the only cases notified in both years were fully vaccinated for age.

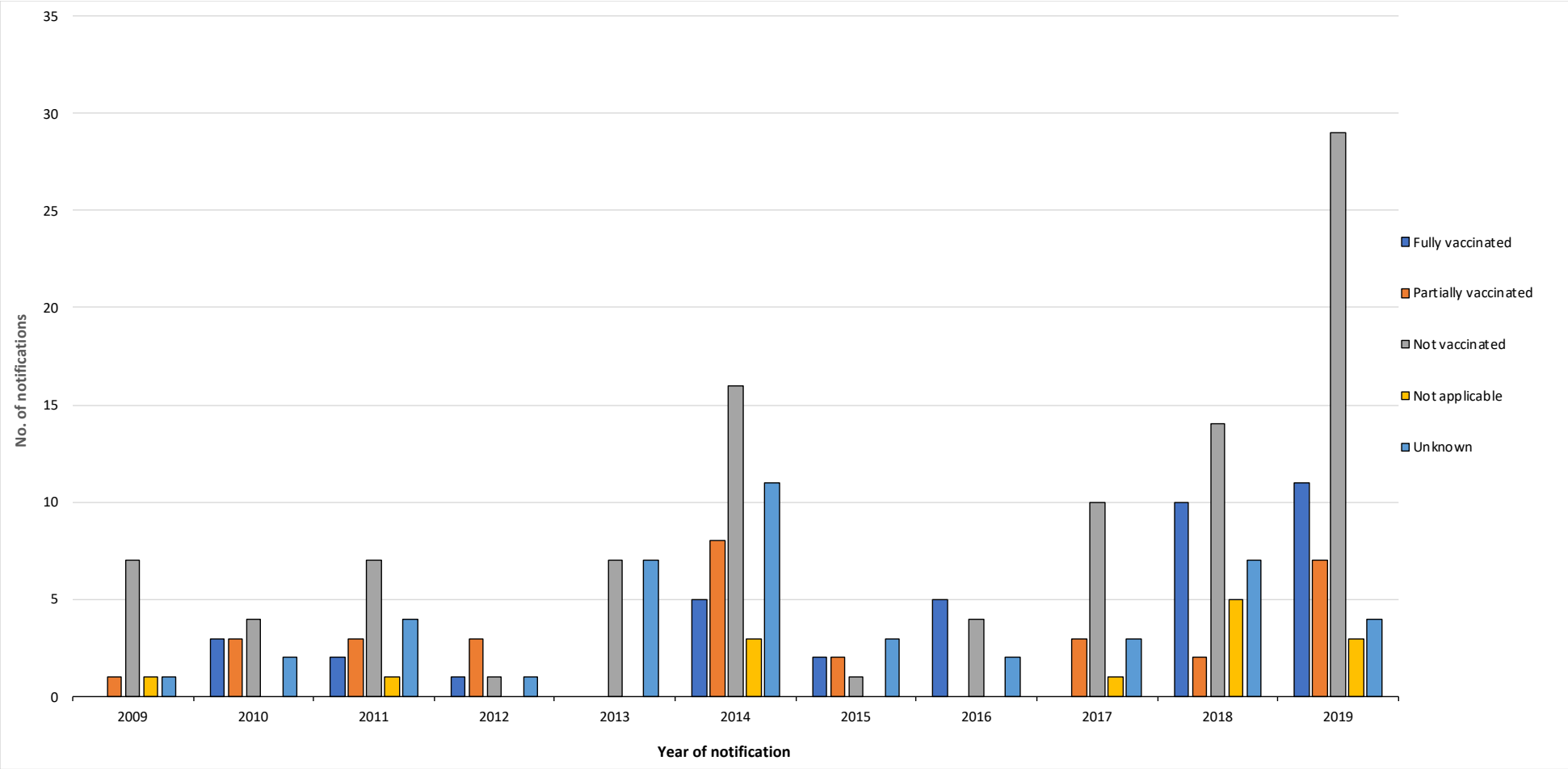

Figure 2: Epidemiological curve of all measles cases notified by vaccination status, including all validations of vaccination (validated, not validated, information not collected, unknown or missing), by year of onset, 1 January 2009 to 31 October 2019

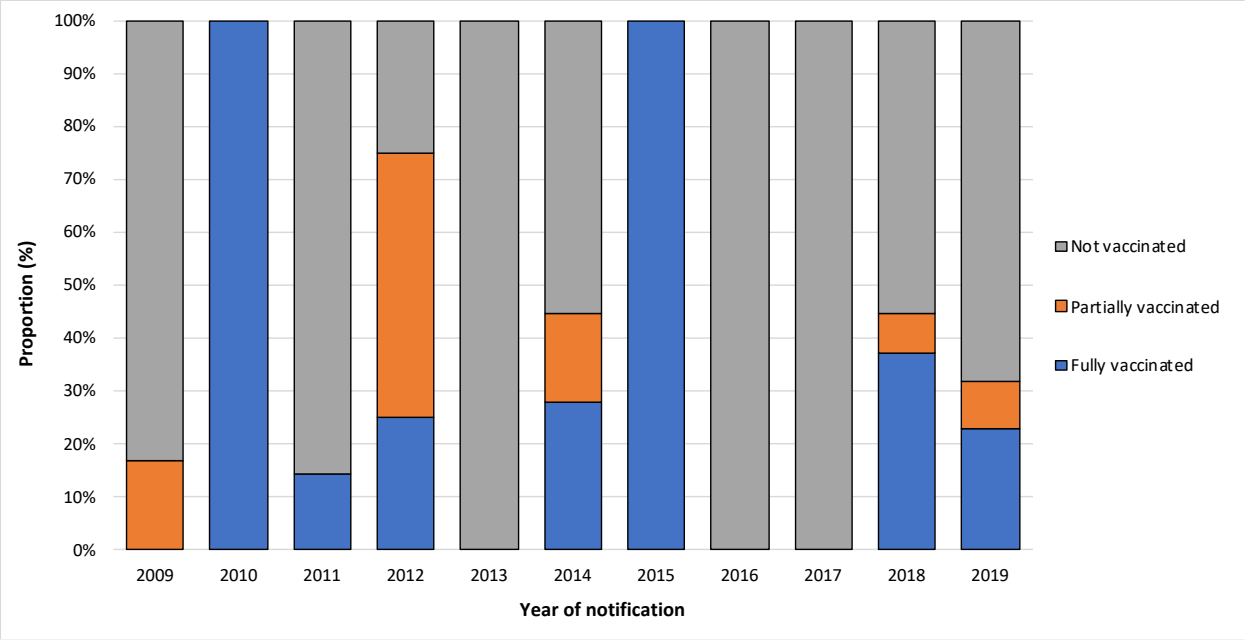

Figure 3: All measles cases notified by vaccination status, including only validated vaccination records, by proportion (%) and year of onset, 1 January 2009 to 31 October 2019*

*Not vaccinated also includes those who are classified as "not applicable". This category includes notified cases who are not vaccinated due to being too young for vaccination or identify as conscientious objectors at the time of notification

WANING IMMUNITY

Table 2 shows all measles cases notified and cases with validated vaccination records by their year of birth (5yr period). This table highlights high numbers of total notifications from year of birth periods of 1975-1979 (n=37, 16.1%), 1990-1994 (n=34, 14.8%), 1995-1999 (n=28, 12.2%) and 2000-2004 (n=25, 10.9%). By validated vaccination records, the highest number of notified cases in the year of birth period 1995-1999 was 23 (18.2%), followed by 18 (14.3%) validated cases in the next year of birth period of 2000-2004.

Table 2: All measles cases notified, cases with validated vaccination records, by year of birth (5yr periods), 1 January 2009 to 31 October 2019

Year of birth (5yr period)	Total number of notifications	Cases with validated vaccination records
1950-1954	2 (0.8%)	1 (0.8%)
1955-1959	-	-
1960-1964	1 (0.4%)	0 (0%)
1965-1969	4 (1.7%)	1 (0.8%)
1970-1974	13 (5.7%)	3 (2.4%)

Year of birth (5yr period)	Total number of notifications	Cases with validated vaccination records
1975-1979	37 (16.1%)	12 (9.5%)
1980-1984	20 (8.7%)	4 (3.2%)
1985-1989	24 (10.4%)	7 (5.6%)
1990-1994	34 (14.8%)	15 (11.9%)
1995-1999	28 (12.2%)	23 (18.2%)
2000-2004	25 (10.9%)	18 (14.3%)
2005-2009	11 (4.8%)	11 (8.7%)
2010-2014	17 (7.4%)	17 (13.5%)
2015-2019	14 (6.1%)	14 (11.1%)
Total	**230**	**126**

All measles cases with validated vaccination records were considered, by the year of their onset date and year of birth (5yr periods). Those in the 1995-1999 cohort saw an increase in the number of notifications in 2018 (n=8) and then again in 2019 (n=11). Similarly, increases were also seen in 2019 across the age cohorts of 1900-1994 (n=8), 2015-2019 (n=6) and 1975-1979 (n=5) (Appendix 6).

Analysis of the year of birth (5yr period) by validated vaccination records and the cases' vaccination status was undertaken and of the 126 measles cases with validated vaccination records, those born in the age cohort of 1995-1999, saw 14 cases recorded as "fully vaccinated" for their age. This was 45.2% of those who were fully vaccinated (Appendix 7).

Further analysis into how many doses of measles-containing vaccines cases had received, showed that again, the 1995-1999 birth cohort had 14 cases who had received 2 or more doses of a measles containing vaccine (Figure 4).

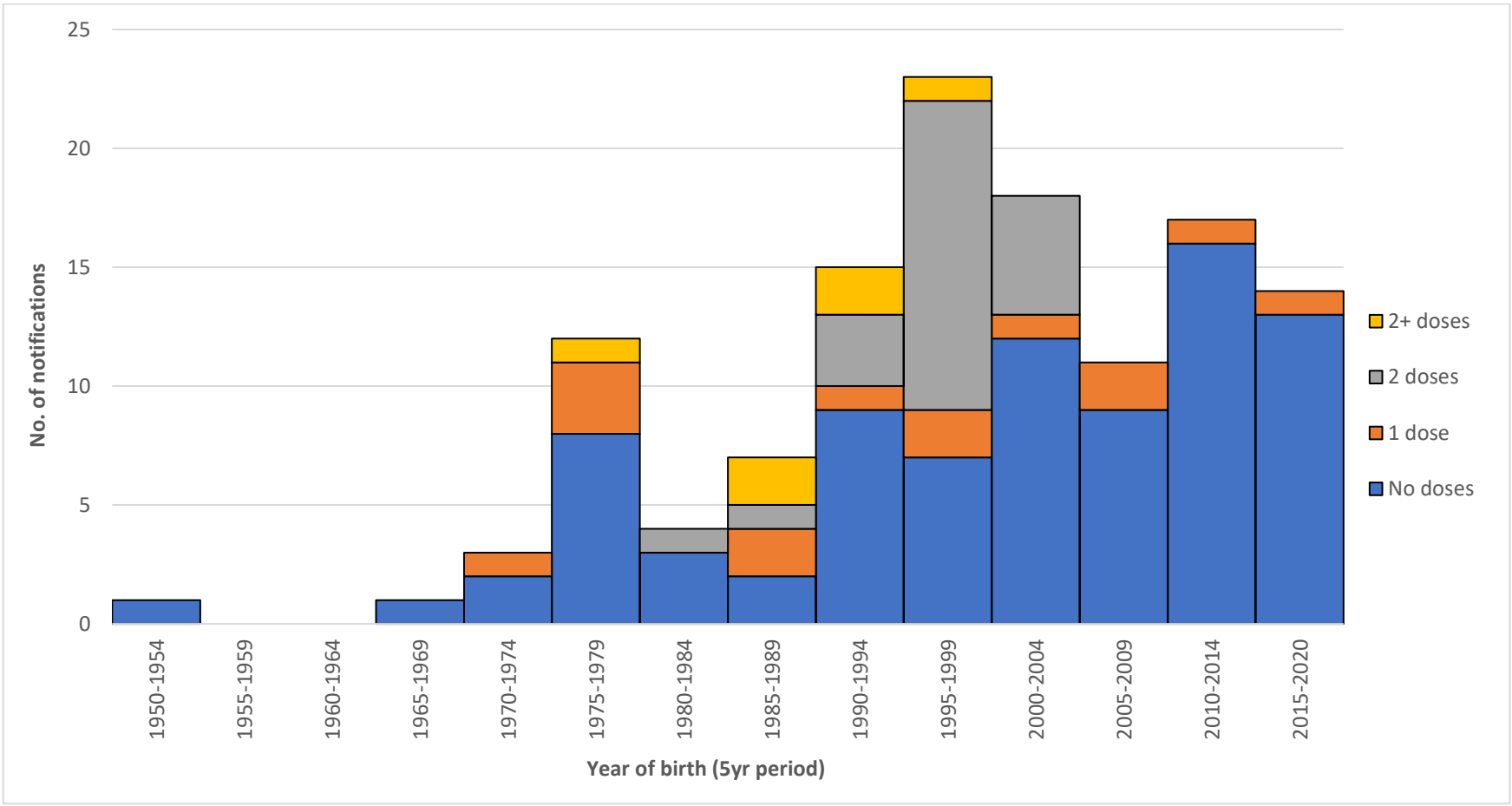

Figure 4: Epidemiological curve of all measles cases notified, including only validated vaccination records, by number of vaccine doses, by year of birth (5yr periods), 1 January 2009 to 31 October 2019

Of all cases of measles extracted from 1 January 2009 to 31 October 2019, 36 had extractable dates linked their measles-containing vaccination. Analysis occurred on those who had received two measles-containing vaccinations. Twenty cases were therefore analysed by their year of birth (5yr period), by the mean and median years between dose 1 and dose 2 (Table 3). The largest mean and median of 7.8 years was seen in the 1985-1989 age cohort (n=1), with the smallest in 2000-2004 age cohort (n=3) with a mean of 3.2 years (range 3.0 to 3.6 years) between the administration of dose 1 and dose 2.

Additionally, the mean and median years between dose 1 and onset date, and dose 2 and onset date was analysed (Table 4). Years between dose 1 and the cases onset date is largest in 1985-1989 age cohort (n=1, mean=27.8 years) and the least in the 2000-2004 cohort (mean=15.9 years). Years between dose 2 and onset show the longest period between being in the 1990-1994 cohort (n=3, mean=20.3 years), while the shortest period was in the 2000-2004 cohort (n=3, mean= 12.7 years).

Table 3: Notified cases of measles, by the mean and median years between dose 1 and dose 2 of a measles containing vaccine, by year of birth (5yr period), 1 January 2014 to 31 October 2019, WA

Year of birth (5yr periods) (n=20)	Mean (years)	Median (years)
1985-1989 (n=1)	7.8 (range N/A*)	7.8
1990-1994 (n=3)	5.2 (range 0.5 to 9.2 years)	5.9
1995-1999 (n=13)	4.7 (range 2.6 to 21.3 years)	3.1
2000-2004 (n=3)	3.2 (range 3.0 to 3.6 years)	3.1

Note: Validated vaccination records only analysed, those records which included an extractable date from WANIDD, and only included those cases with 2 measles-containing vaccinations.
*Range not applicable as n=1.

Table 4 Notified cases of measles, by the mean and median years between dose 1 and dose 2 of a measles containing vaccine and the cases date of onset of illness, by year of birth (5yr period), 1 January 2014 to 31 October 2019, WA

Year of birth (5yr periods) (n=20)	Years between Dose 1 to date of onset of illness		Years between Dose 2 to date of onset of illness	
1985-1989 (n=1)	Mean: 27.8	Median:27.8	Mean: 19.9	Median: 19.9
1990-1994 (n=3)	Mean: 25.5	Median: 25	Mean: 20.3	Median: 18.5
1995-1999 (n=13)	Mean: 19.6	Median: 19.7	Mean: 14.9	Median: 16.5
2000-2004 (n=3)	Mean: 15.9	Median: 16.5	Mean: 12.7	Median: 12.9

Note: Validated vaccination records only analysed, those records which included an extractable date from WANIDD, and only included those cases with 2 measles-containing vaccinations

INFECTIVITY

Of the cases (both confirmed and probable) of measles notified in WA from 1 January 2014 to 31 October 2019, a total of 171 cases were notified, with 104 (61%) cases having "validated" vaccination records (Table 5). Of the 66 cases (63.5%) who were recorded as having no measles-containing vaccines, 59 secondary cases resulted, with a mean of 0.89 secondary cases per index case. There were 13 cases (12.5%) who had 1 dose of a measles-containing vaccine recorded, with one secondary case resulting and a mean of 0.08 secondary cases per index case. Twenty-five cases (24%) of the 104 validated cases, received two or more measles-containing vaccinations, resulting in four secondary cases, with a mean of 0.16 secondary cases per index case. Given the small sample size, confidence intervals (CI) were not calculated.

Table 5: Measles cases by vaccination dose, number of validated vaccination records and resulting secondary cases, 1 January 2014 to 21 October 2019, WA

Dose/s of MMR	No. of cases with validated vaccination records	No. of secondary cases resulting	Mean secondary cases per index case
0	66 (63.5%)	59 (92.2%)	0.89
1	13 (12.5%)	1 (1.6%)	0.08
2 or more	25 (24%)	4 (6.3%)	0.16

For each index case, the resulting secondary cases were analysed by their "type of contact" in relation to the index case (Table 6). This data denotes that the most common type of contact, of where secondary cases that resulted from index cases who have had no measles-containing vaccinations, are those who are household/household-like and household visitors, with 37.3% (n=22). Whilst three out of the four (75%) secondary cases resulting from index cases with 2 vaccinations, was attributed to household/household-like contact.

Hospital/GP waiting rooms "type of contact" accounted for 23.7% (n=14) of secondary cases from index cases who had received no measles-containing vaccinations, with one secondary case resulting from an index who had received one measles-containing vaccination. School/day-care only accounted for 3.4% (n=2) from index cases who have had no measles-containing vaccinations, with one (25%) workplace contact becoming infected from an index who had received two measles-containing vaccinations. This however was after attending the same work function. There were 21 secondary cases (35.6%) resulting from being exposed to an index case who had no measles-containing vaccinations. These were all linked back to contact in public areas, including exposures on flights, at airports, social gatherings and sporting events.

Table 6: Secondary measles cases type of contact, by the index cases' validated measles-containing vaccination dose, 1 January 2014 to 21 October 2019, WA

Type of contact	0 MMR index case	1 MMR index case	2 MMR index case
Household, household-like & household visitors	22 (37.3%)	0	3 (75%)

Type of contact	0 MMR index case	1 MMR index case	2 MMR index case
Hospital/GP waiting rooms	14 (23.7%)	1 (100%)	0
School/day-care	2 (3.4%)	0	0
Work	0 (0%)	0	1 (25%)
Public areas	21 (35.6%)	0	0
Total	**59**	**1**	**4**

DISCUSSION

Although measles was declared to be eliminated in Australia in 2014, and with circulating wild virus being low since the mid-1990s, measles cases in Australia continue to occur – with cases being imported from other countries or linked to imported cases from endemic countries (22). As Australia and many other countries continues to have high levels of immunisation coverage and no sustained local transmission of wild type measles, it would be expected that the proportion of measles cases that have had two measles-containing immunisations would increase. This was found to be the case in this study. WA saw numbers of notified measles increase in 2018 and 2019, with the proportion of cases who had previously been vaccinated also rise. In 2018 and 2019, 20 cases with validated vaccination records were fully vaccinated for age, with 17 of those having received two measles-containing immunisations.

This study found that of the cases with "validated" vaccination records, they tend to cluster in age cohort and year of notification. Those cases born in the 1995-1999 cohort saw an increase in case numbers during 2018 (n=8) and in 2019 (n=11). Fourteen cases within that 1995-1999 cohort were fully vaccinated and 14 of those having received two measles-containing vaccinations, with one case receiving three doses. Most of these cases where born around the same time in which measles activity declined around Australia, with notification rates being generally low since 1998 (23). This age cohort, who would have been notified with measles while they were approximately 20-25 years of age, would therefore be the oldest cohort who would have been less likely to be exposed to circulating measles, and having had two measles-containing vaccinations as a child (24). This was also seen in an outbreak in the Federated States of Micronesia in 2014, which saw 393 measles cases reported, with two thirds of cases being over 20 and half had received two MMRs. Most of the cases were aged 20 to 40 years, with few in children attributed to high vaccine coverage, and older adults attributed exposure to wild virus. Cold chain lapses in those younger adults who were vaccinated could not be ruled out. However, waning immunity without wild virus exposure was also noted (14). This could also be postulated for the rise seen in WA, of the same age group who have been vaccinated.

The mean number of years between vaccination doses, and mean years between dose 1 and dose 2 to the cases onset was analysed, to see if there were any similarities or large differences between year of birth cohorts. With literature suggesting waning immunity indicates individuals may become susceptible to measles some years post vaccination (4, 8, 9, 11, 12). These results, however, were difficult to interpret given the poor level of completeness of vaccination record data, which therefore directly impact the sample size. Likewise, many other factors can affect timeliness of people being vaccinated, such as the individuals or parents' choice to be vaccinated, and the vaccination schedule recommendations (24).

The infectiousness of cases who have received one or two documented measles-containing vaccinations is not well described in the literature. Reports and literature of index cases who received two-measles containing vaccinations are scarce and findings differ. There have been documented occurrences of such index cases producing no additional cases. Conversely, there is documentation in the literature of one case (with an additional documented secondary vaccine failure) producing four secondary cases, three of which had contact with the index in a healthcare facility, and the fourth was a workplace contact(16, 18).

In this study, WA data suggests that measles cases who have received one or two measles' containing vaccines may have reduced infectivity and therefore are less likely to result in secondary cases of measles. The WA data also showed that cases who had received two documented measles-containing vaccinations resulted in secondary cases being from their household or having household-like contact, at a hospital/GP waiting room and a work "type of contact". Interestingly, there were no secondary cases linked to these index cases, with contact in public areas, schools or day-care.

The Australian National guidelines for public health units for measles state that all measles cases must be reported to state and public health units on suspicion. Once notified and a risk assessment is undertaken following those guidelines, the public health unit then conducts an intensive response to assess all possible contacts of that infected measles case. This can be extremely resource intensive. Currently the measles SoNG does not specify different responses to cases who have received two measles-containing vaccinations (3). With further investigation into the infectivity of these cases nationally, the findings if appropriate, may then inform whether the measles SoNG could be refined in terms of the public health follow-up of these cases and their contacts, for instance, if the risk outside the household for these vaccinated cases is sufficient to warrant a public health response or not. For the time being, regardless of vaccination

status, there is a continued need for thorough laboratory and epidemiological investigation and public health follow-up of suspected and confirmed cases of measles (18).

STUDY LIMITATIONS

Potential limitations for the study undertaken were known before commencement. For example, only analysing WA notification was already known to be of a small sample size, hence the request all measles data nationally via the NNDSS, as well as the establishment of the national working group. This also included the existing data able to be extracted from both WANIDD and NNDSS being sub-optimal or specific data fields not captured, requiring the working group to either extract data from their jurisdictions databases or access paper records, to obtain the data fields requested.

Likewise, the use of surveillance data can be imperfect, for instance it was noted that the cases who had received two doses of measles-containing vaccines had attenuated illnesses and therefore similar cases may not present to a doctor, be tested and therefore be left undiagnosed. Consequently, these cases would not be picked up by the surveillance system.

Another consideration in this study is the analysis of only "validated" vaccination status records in WANIDD. This could have excluded those who were actually vaccinated, however no longer had their records and/or were vaccinated before the establishment of the ACIR in 1996, which recorded details of vaccinations given to children under seven years of age who lived in Australia and were enrolled in Medicare. These cases with no records would then have to be classified as "not validated" and were excluded from this study. Therefore, the completeness of vaccination record data is an important consideration in interpreting these data. Data going forward should be more complete, since the ACIR expanded to the Australian Immunisation Register from 30 September 2016, which will record vaccinations given to people of all ages in Australia.

FUTURE IMPLICATIONS

A recommendation from this study, given the difficulties of obtaining data fields, warrants a national enhanced data collection system be developed for measles, to capture all data fields which were initially requested for this study. The data manager of the NNDSS did note the implementation of new enhanced data fields was being investigated, with the collection of data to be trialled. Data fields which can be easily extracted from surveillance databases to allow for

analyses is preferred. This could also be recommended for WANIDD, with the creation of an "enhanced form" within the measles case record (as has been built for COVID-19 cases during the pandemic response), to capture all symptoms of measles and further detail on secondary cases and their "types of contact" for example. Currently the "enhanced form" is paper based, with some data collected not having fields to enter into on WANIDD and are hence entered into a "free text" case notes section, which is able to be extracted, however does not lead itself to easy analysis, as shown in this study. Data cleaning on the extracted dataset was also undertaken throughout this study in regard to vaccination. This will be communicated with the WANIDD data manager and arrangements will be made to update those WANIDD records. Consideration should also be taken to update previous cases vaccination dates. This could occur through the use of AIR data to match those cases, or by accessing dates within case notes and updating specific date fields.

The findings from the WA data highlights the need to continue with the initial project proposal (see Appendix 1), including WA cases clinical characteristics and laboratory results in relation to vaccination status and infectivity. Further analysis of Australia-wide measles data, as proposed, to increase the sample size and possibly further support WA's findings, is particularly important to continue to seek to improve the understanding of the epidemiology of measles in WA and Australia, specifically regarding immunity and infectivity. Serological studies, looking at waning antibody levels and avidity, in conjunction with measles surveillance data, could also be investigated and undertaken. This could then lead to informing policy, a change to national guidelines, prevention strategies and other public health interventions in WA and Australia-wide.

CONCLUSION

This study provides the first analysis and examination into the potential reasons for increase of the proportion of measles cases notified in WA in 2018 and 2019 who had been previously been vaccinated. Waning immunity was investigated using notification data and it was postulated that there may be waning immunity in those who have received two measles-containing vaccinations, in the year of birth cohort of 1995-1999, during which circulating wild type measles was less common than in preceding years. A trend was also identified suggesting that measles cases in WA who have received one or two measles-containing vaccines may have reduced infectivity and therefore are less likely to result in secondary cases. What is more, the data also suggests that they have resulted in secondary cases from household or household-like, hospital/GP waiting rooms and the workplace "types of contact", with no secondary cases linked to school, day-care or public areas.

Considerations must be made about the continuation and expansion of the initial conceptualised study, which was proposed, specifically in regard to the analysis of Australian-wide data. Future findings could then inform the refinement of national guidelines for contact tracing.

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APPENDIX

APPENDIX 1: ORIGINAL STUDY RESEARCH QUESTIONS/AIMS, PROPOSED METHODS & REQUIRED DATA

The proposed research questions:

1. Of all measles cases notified in Australia, is there an increase in cases of measles in people who have previously been vaccinated? If so, what are the likely reasons for this?
2. Of all measles cases notified in Australia who have previously received any documented measles containing immunisations, does measles immunity decline over time?
3. Of all measles cases notified in Australia, are there differences in the clinical characteristics (signs and symptoms) and laboratory results in those who have documentation of having received any measles containing immunisations as compared to those who have not received any measles containing immunisations?
4. Of all measles cases notified in Australia, is there a difference in infectivity in those who have received any documented measles containing vaccine, as compared to those who have not?

Changed to:

1. Of all measles cases notified in Western Australia, is there an increase in cases of measles in people who have previously been vaccinated? If so, what are the likely reasons for this?

Of all measles cases notified in Western Australia who have previously received any documented measles containing immunisations, does measles immunity decline over time?

2. Of all measles cases notified in Western Australia, are there differences in the clinical characteristics (signs and symptoms) and laboratory results in those who have documentation of having received any measles containing immunisations as compared to those who have not received any measles containing immunisations?
3. Of all measles cases notified in Western Australia, is there a difference in infectivity in those who have received any documented measles containing vaccine, as compared to those who have not?

Initial key aims of this project were:

- To examine the possible reasons for the apparent increase in cases of measles in people who have been previously vaccinated.
- To ascertain if there is any evidence for waning immunity against measles vaccination.
- To compare those vaccinated and those not vaccinated for measles, in terms of clinical (signs and symptoms) and laboratory aspects and well as their infectivity – and what proportion result in secondary and tertiary cases.
- To assess if an enhanced data collection system needs to be developed to capture data prospectively, should the existing data be sub-optimal.

Planned study research questions, proposed methods and data required from where (AUS or WA only)

	Study research question & proposed methods	Data required and from where; AUS or WA only section
1.	*Study research question: In residents of Australia who have previously received two measles containing immunisations, does measles immunity decline over time?*	
	Proposed methods: A review of the literature on waning immunity after measles vaccination, and infectivity of measles cases in previously vaccinated individuals, will be conducted.	Lit review on infectivity and waning immunity
	Proposed methods: An initial analysis of measles cases in WA will be undertaken. This will consider the number of cases that have occurred by age groups and year of onset. This may suggest if certain cohorts, such as those born in the late 1990s and received two MMRs, may be experiencing an increase in measles cases as compared to other cohorts.	WA and AUS data ***NNDSS/WANIDD:*** Date of birth Age at onset Vaccine type Vaccine date/s Vaccine validation
	Proposed methods: For contacts of measles cases within WA, their degree of contact, immunisation status, age, and whether they developed measles will be recorded. The rate of secondary or tertiary cases will be examined by age group and where possible by immunisation status. Although the number of secondary cases may be small, this analysis may aid consideration of waning immunity in certain age groups.	WA data only ***WA paper files:*** Level of contact (need to define e.g. HH like, school/CCC, shopping centre etc.) ***NNDSS/WANIDD:*** Date of birth Age at onset Vaccine type Vaccine date Vaccine validation
2.	*Study research question: In the Australian population, are there differences in their clinical characteristics and laboratory results in those who have received any measles containing immunisations as compared to those who have not.*	
	Proposed methods: For each case of measles notified within Australia their immunisation status, clinical characteristics to determine their clinical course and the severity of disease will be recorded. Laboratory results will also be collated. This will be used to determine what, if any, difference occur between immunised and non-immunised cases.	WA and AUS data ***NNDSS/WANIDD:*** Laboratory diagnosis method Hospitalised Vaccine type Vaccine date Vaccine validation ***CDNA Working Group:*** Symptom profile
3.	*Study research question: In the Australian population, is there a difference in infectivity in those who have received any measles containing vaccine as compared to those who have not.*	
	Proposed methods: For each index case of measles notified within Australia, their immunisation status (1, 2 or more immunisations), date of birth, and the number of secondary cases that resulted from the case will be recorded. The number of secondary cases for each category will be compared statistically to consider potential differences in infectivity by immunisation status.	WA and AUS data ***NNDSS/WANIDD:*** Vaccine type Vaccine date Vaccine validation ***CDNA Working Group:*** Secondary cases from index cases
Ultimately: In the Australian population, why is there an apparent increase in cases of measles in people who have previously been vaccinated?		

WA enhanced measles investigation form (paper-based), symptoms collected

Symptomatic	Y/N
Onset date	**/**/****
Rash	Y/N
Rash onset	**/**/****
Rash duration (days)	
No. order of rash appearance	Head/trunk/extremities/other
Fever	Y/N
Fever at rash onset	Y/N
Max temp	
Cough	Y/N
Coryza	Y/N
Conjunctivitis	Y/N
Koplik spots	Y/N
Epi link to case	Y/N
Linked case NDD no.	
On medicine	Y/N
Notes	

Short-lived measles data sharing working group
Meeting Agenda

Security	In confidence
Date	Tuesday 3rd December
Time	12-1pm (AWST)
Venue	Teleconference
Distribution	Limited distribution – short-lived measles data sharing working group members

Agenda

Item no.	Description	Responsibility	Papers
1.0	Introduction		
1.1	▪ Objectives of the study ▪ Objectives of working group ▪ Data required for study	HV	Y
2.0	Roundtable discussion		
	Each jurisdiction to discuss: ▪ Is this data collected? o rash o rash onset o rash duration o fever o cough o conjunctivitis o coryza o koplik spots o number of secondary cases from index o "type" of contact of those secondaries ▪ Is this data able to be extracted o If so, are there any barriers in providing this data		
3.0	Timeframe		
	▪ Timeframe for data extraction		
5.0	Next meeting: Date and time to be confirmed		

Dummy Data requested from the Working Group:

UID	State	Confirmation status	Sex	Diagnosis date	Birth date (month/year)	Onset age	Symptom profile	rash	rash onset	rash duration	fever	cough	conjunctivitis	coryza	koplik spots	CASE_CLASSIFICATION	Outbreak reference field **	If secondary; measles source case ID
123	NSW	1	Female	1/01/2018	12/2017	0					Free text	1				1		

***Get from NNDSS and supply to states | ***Request this from states

Dummy Data requested from the Working Group, secondary cases:

ID of index case	Validated vacc doses (0,1 or 2+)	Number of secondary cases from index case	Notif. ID of secondary case	Vaccination status of secondary case	Type of contact
5201900001			5201900001		
5201900003			5201900004		

Data fields requested from NNDSS, from all states & territories

Requested data fields		
State	Date of birth	Vaccine type
Notification ID number	Age at onset	Vaccination date
Laboratory diagnosis method	Sex	Vaccination validation (AIR, self-report etc)
Specimen date	Place of acquisition	Outbreak reference (knowing that each state/territory may be different)
True onset date	Hospitalised	

APPENDIX 3 : COMMUNICABLE DISEASE CONTROL CONFERENCE 2019, 20 NOVEMBER 2019, LONG ORAL, POWERPOINT PRESENTATION

Government of Western Australia Department of Health

Government of Western Australia North Metropolitan Health Service

Australian National University

Are vaccinated measles cases less likely to result in secondary cases?

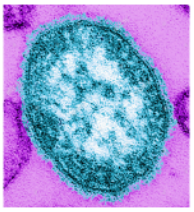
Hannah Vogt
Master of Philosophy in Applied Epidemiology (MAE) Scholar

health.wa.gov.au

Measles

Pathogen: Measles virus; a member of the genus *Morbillivirus*

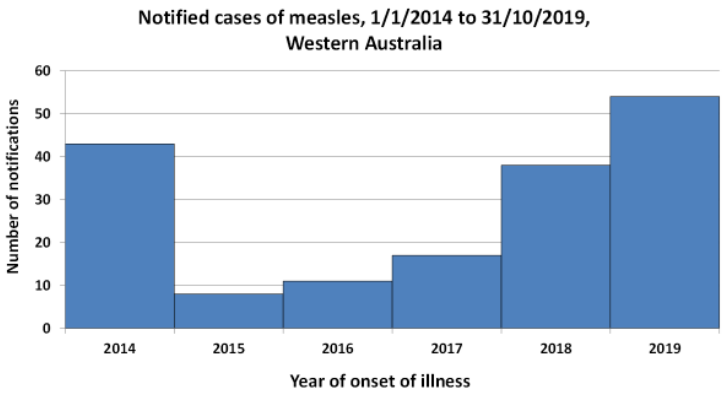
Transmission: Airborne by droplet spread, direct contact with nasal or throat secretions of infected persons.



Complications: Otitis media, pneumonia, croup, diarrhoea, febrile seizures, encephalitis

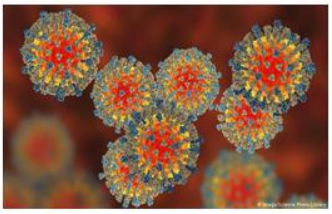
Global figures: There were over 324,000 cases of measles worldwide in 2018

Background

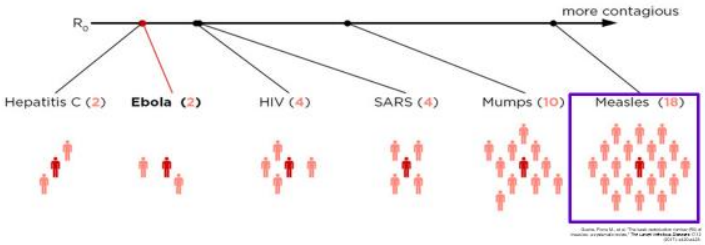


Background

- The proportion of measles cases who have previously been vaccinated has increased in Western Australia
- From November 2018 to February 2019; 11 cases who had received 2 doses of MMR were notified



The number of people that **one sick person** will infect (on average) is called R_0.
Here are the maximum R_0 values for a few viruses.



Aim: Is there a difference in infectivity in those who have received any measles containing vaccine as compared to those who have not?

Methodology

Measles notified in WA

Measles notifications extracted: 1/1/14 to 31/10/19

Analysis of vaccination status of each index case

Analysis of the number of secondary cases
- Mean secondary cases per index

Analysis of the secondary cases "type of contact"

Results

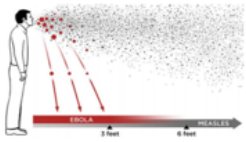
- Total of 171 cases were notified in WA
- 104 cases had “validated” vaccination records

Dose/s of MMR	No. of cases with validated records	No. of secondary cases resulting	Mean secondary cases per index case
0	66	59	0.89
1	13	1	0.08
2 or more	25	4	0.16

Results

- For each index case, the resulting secondary cases were analysed by their “type of contact”

Type of contact	0 MMR index case	1 MMR index case	2 MMR index case
Household, household-like & household visitors	22		3
Hospital/GP waiting rooms	14	1	
School/daycare	2		
Work			1
Public areas	21		



Limitations

- Small sample size
- Analysing by “validated” vaccination status
- Notification data can be imperfect

Key findings

WA data suggests that measles cases who have received one or two measles-containing vaccines:

- may have reduced infectivity & therefore are less likely to result in secondary cases
- have resulted in secondary cases being household/household-like, hospital/GP waiting rooms & work “type of contacts”

Implications of the findings

A trend has been identified using WA notification data, however:

- Analysis of Australia-wide measles notification data would provide more certainty
- If appropriate, future findings could inform the refinement of national guidelines for contact tracing, for this specific situation

Acknowledgments

- Dr Ben Scalley, Dr Erica Parker & Thilini Perera; Metropolitan Communicable Disease Control, North Metropolitan Health Service, Department of Health WA
- Dr Paul Armstrong; Communicable Disease Control Directorate, Department of Health WA
- Dr Aparna Lal; Australian National University

APPENDIX 4 : ALL MEASLES CASES NOTIFIED BY VACCINATION STATUS, INCLUDING ONLY VALIDATED VACCINATION RECORDS, BY YEAR OF ONSET, 1 JANUARY 2009 TO 31 OCTOBER 2019

Vaccination status	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	**Total**
Fully vaccinated	-	2	1	1	-	5	2	-	-	10	10	**31 (24.6%)**
Partially vaccinated	1	-	-	2	-	3	-	-	-	2	4	**12 (9.5%)**
Not vaccinated	5	-	6	1	4	10	-	3	9	15	30	**83 (65.9%)**
Total	**6**	**2**	**7**	**4**	**4**	**18**	**2**	**3**	**9**	**27**	**44**	**126**

*Not vaccinated also includes those who are classified as "not applicable". This category includes notified cases who are not vaccinated due to being too young for vaccination or identify as conscientious objectors at the time of notification.

APPENDIX 5: ALL MEASLES CASES NOTIFIED BY VACCINATION DOSE NUMBER, INCLUDING ONLY VALIDATED VACCINATION RECORDS, BY YEAR OF ONSET, 1 JANUARY 2009 TO 31 OCTOBER 2019

Number of doses	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
0 doses	5	-	6	1	4	10	-	3	9	15	30	**83 (65.9%)**
1 dose	1	-	1	2	-	4	-	-	-	2	5	**15 (11.9%)**
2 doses	-	1	-	1	-	1	2	-	-	9	8	**22 (17.4%)**
3 doses	-	1	-	-	-	2	-	-	-	1	1	**5 (4%)**
5 doses	-	-	-	-	-	1	-	-	-	-	-	**1 (0.8%)**
Total	**6**	**2**	**7**	**4**	**4**	**18**	**2**	**3**	**9**	**27**	**44**	**126**

*0 doses include notified cases who are not vaccinated due to being too young for vaccination at the time of notification or identify as being conscientious objectors

APPENDIX 6: ALL MEASLES CASES NOTIFIED WITH VALIDATED VACCINATION RECORDS, BY YEAR OF ONSET AND YEAR OF BIRTH (5YR PERIOD)

Year of onset	1950-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	Total
2009	1	-	-	-	-	1	-	1	-	-	1	2	-	-	**6**
2010	-	-	-	-	-	-	1	1	-	-	-	-	-	-	**2**
2011	-	-	-	-	1	1	-	-	-	-	2	2	1	-	**7**
2012	-	-	-	-	-	2	-	-	-	-	2	-	-	-	**4**
2013	-	-	-	-	-	-	-	-	-	1	1	-	2	-	**4**
2014	-	-	-	-	-	2	-	2	2	1	2	3	6	-	**18**
2015	-	-	-	-	-	-	-	-	-	1	1	-	-	-	**2**
2016	-	-	-	-	-	-	-	-	-	-	-	2	1	-	**3**
2017	-	-	-	-	-	-	-	-	-	1	3	1	1	3	**9**
2018	-	-	-	-	-	1	2	2	5	8	3		1	5	**27**
2019	-	-	-	1	2	5	1	1	8	11	3	1	5	6	**44**
Total	**1**	**0**	**0**	**1**	**3**	**12**	**4**	**7**	**15**	**23**	**18**	**11**	**17**	**14**	**126**

APPENDIX 7: NOTIFIED CASES OF MEASLES, WITH VALIDATED VACCINATION RECORDS, BY VACCINATION STATUS AND YEAR OF BIRTH (5YR PERIOD)

Year of birth (5yr period)	Fully vaccinated	Partially vaccinated	Not vaccinated*	Total
1950-1954	-	-	1	1
1955-1959	-	-	-	-
1960-1964	-	-	-	-
1965-1969	-	-	1	1
1970-1974	-	1	2	3
1975-1979	2	2	8	12
1980-1984	1	0	3	4
1985-1989	3	2	2	7
1990-1994	5	1	9	15
1995-1999	14	2	7	23
2000-2004	4	2	12	18
2005-2009	1	1	9	11
2010-2014	-	1	16	17
2015-2019	1	-	13	14
Total	**31**	**12**	**83**	**126**

*Not vaccinated also includes those who are classified as “not applicable”. This category includes notified cases who are not vaccinated due to being too young for vaccination or identify as conscientious objectors at the time of notification.

CHAPTER 6: OTHER PUBLIC HEALTH ACTIVITIES AND EXPERIENCES

INVASIVE MENINGOCOCCAL DISEASE SEROGROUP C OUTBREAK & SUBSEQUENT VACCINATION PROGRAM, PILBARA WA

LIST OF ABBREVIATIONS

ABS	Australian Bureau Statistics
AIR	Australian Immunisation Register
FAQ	Frequently asked questions
IMD	Invasive meningococcal disease
CDCD	Communicable Disease Control Directorate
CDNA	Communicable Diseases Network Australia
PPHU	Pilbara Population Health Unit
SoNG	Series of National Guidelines

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OUTBREAK RESPONSE & THE VACCINATION CAMPAIGN

An outbreak of invasive meningococcal disease (IMD) in regional WA was identified in May 2019. From January 2019 to May 2019, four cases of invasive meningococcal serogroup C (IMD C) were notified in the Pilbara region (Appendix 2), with all cases being of Aboriginal origin, with an age range of <1 year to 34 years, and all were geographically clustered. All cases were followed up according to the Communicable Diseases Network Australia (CDNA) Series of National Guidelines (SoNG) for invasive meningococcal disease (IMD SoNG) (1).

Prior to 2019, the average incidence of IMD C in WA was one case per year. This higher than expected number, therefore, constituted a community outbreak as defined by the IMD SoNG. Therefore, in this scenario, a vaccination campaign for the population at risk was considered, by the cluster response team, which was established, led by Communicable Disease Control Directorate (CDCD), in conjunction with Western Australia Country Health Service (WACHS) Pilbara Population Health Unit (PPHU). The Incident Command System structure was put into place, to organise and coordinate response activities. There were leads and supports for the cells of Communication, Logistics, Operations and Planning.

After some deliberation, research and data analysis of data from the Australian Immunisation Register (AIR) and the Australian Bureau of Statistics (ABS), it was decided that the WACHS Pilbara Expanded Men ACWY Vaccination Program (Men ACWY program) would be a 'once off' vaccination program against meningococcal disease, that would be offered to Aboriginal people living in Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland, using an age-group prioritization approach. The age-group priority approach would target Aboriginal people as follows:

- Priority 1: 6weeks to <5years AND 15years to <20years
- Priority 2: 5years to <15years
- Priority 3: 20years to 35years
- Priority 4: >35years

This campaign aimed to accomplish 80% vaccination coverage in specifically priority one and two age groups (6 weeks to <5yrs, 15-19yrs and then 5-15yrs).

VACCINATION CAMPAIGN OUTCOMES

The activities of the Men ACWY program were carried out over a 3-month period, commencing on 18 June 2019, with the final date of targeted activity being 29 September 2019. A total of 2,726 people were vaccinated during this campaign. Routine community health clinics and community-based vaccination clinics were used throughout the program, including the Pilbara Population Health clinics, Child and Parent Centre/Health Hubs, hospital wards, schools, community/home visits and community pop-up events. It was found that community-based clinics (65%) were the more effective way to vaccination the community, than onsite clinics (35%).

Figure 1 and Table 1 show the results of the campaign by coverage (%) and priority age group.

Within the Priority One cohort, comprising children 6 weeks to <5 years, the coverage reached 98%, with a 20% coverage increase from before the start of the vaccination campaign. In addition, Priority One also included those aged 15 years to 19 years, reaching 77% coverage at the time of completion, signifying a 15% improvement in coverage. This cohort was 23 vaccinations shy of reaching the target of 80% coverage.

Priority Two (those age 5 to <15 years) reached 76% coverage (with 54% coverage improvement), Priority Three (20 to 35 years) attained 36% (with 21% coverage improvement) and finally Priority Four (<35 years) reached 41% and saw a 30% coverage improvement.

Of note, certain age groups were already eligible for the ACWY vaccination at commencement, with the vaccine being funded by WA in 2018 for children aged 12 months to 4 years and then in 2019 by WA for Aboriginal and Torres Strait Islander children aged 6 weeks to <12 months.

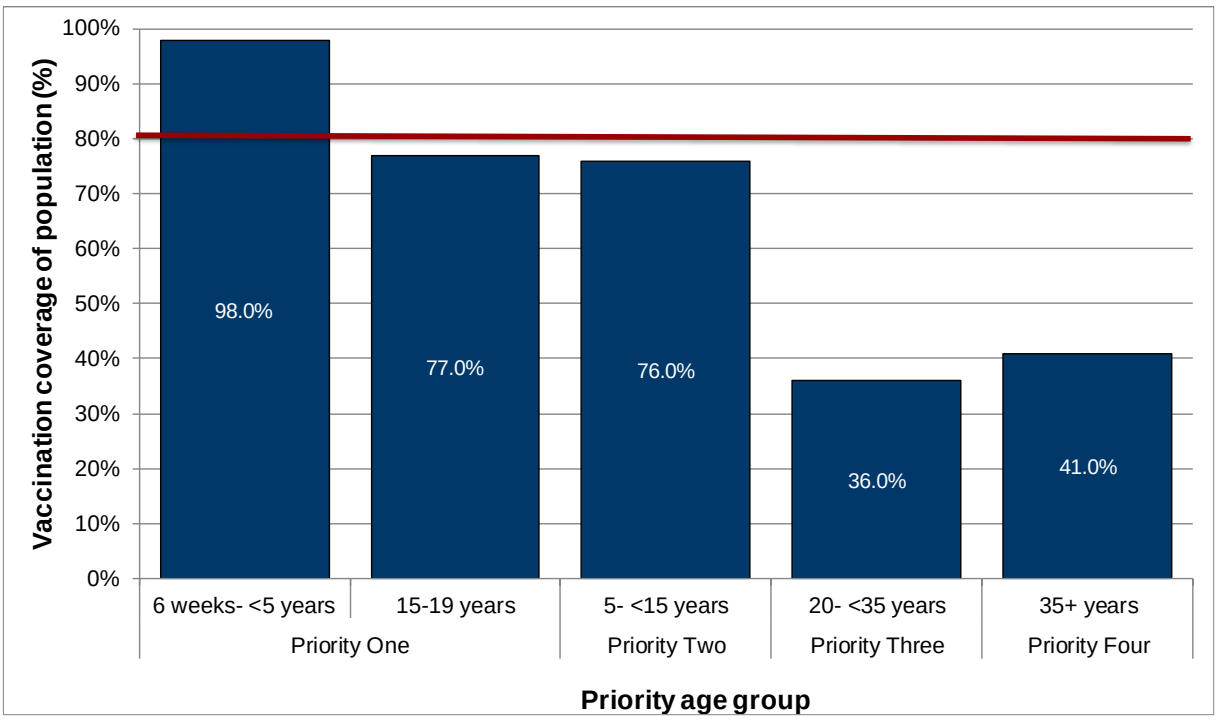

Figure 1. Number of vaccinations administered by WACHS Pilbara Population Health, by date of vaccination administration, 18 June 2019 to 29 September 2019

Table 1. Number of vaccinations administered by WACHS Pilbara Population Health, by priority group and vaccination coverage (%), 18 June 2019 to 29 September 2019

Priority group	Coverage % at commencement	Coverage % at completion	Coverage improvement (%
6 weeks to <5 years	78%	98%	20%
15yrs to 19 years	52%	77%	15%
5 years to <15 years	22%	76%	54%
20 years to 35 years	10%	36%	21%
>35 years	11%	41%	30%

The level of coverage this program achieved was outstanding. Even though only the Priority One age group of 6 weeks to <5 years met and exceeded the 80% coverage goal, all other Priority groups coverage improved immensely. The MenACWY vaccination continued to be available to all Aboriginal people in the identified target groups until 31 December 2019, through the usual primary health care vaccination providers. In terms of further cases of IMD in the Pilbara region in 2019, one case was notified in November, in a 37yo Aboriginal male who was unvaccinated.

My Role

This project was intended to be used for my outbreak project/chapter; however, it was superseded by the measles outbreak that occurred in metropolitan Perth, and shortly after COVID-19 commenced. While I was not part of the follow-up of specific cases of invasive meningococcal disease serogroup C (IMD C) in this outbreak, I did provide epidemiological and operational support during the outbreak investigation, especially during the subsequent targeted vaccination campaign. In July 2019, I had the amazing opportunity to fly to Port Hedland and work in the Pilbara Population Health Unit for 9 days.

During this project I completed the following activities:

- wrote the WACHS Pilbara Meningococcal C Cluster Response Communications Strategy (modelled from a pre-existing document written for the 2016 Kalgoorlie Targeted MenW Outbreak Response)
- compiled the WACHS Pilbara Targeted Meningococcal ACWY Vaccination Program FAQs (Appendix 1)
- created consent forms and log sheets for the vaccination campaign
- assisted with data entry during the vaccination campaign in the PPHU, using Excel spreadsheet to collate the numbers of people vaccinated, per location and vaccination strategy type
- assisted with data entry of vaccinations into AIR
- created a template Situation Report document that was used weekly
- Wrote the weekly Situation Report for the weeks I was in PPHU. The Situation Report included updates on the current situation: the vaccination campaign in terms of communications, operations, logistics, planning and the results of the campaign at that point in time
- completed situation report analysis and ad-hoc analysis as required to report on vaccination program outcomes.

Lessons Learnt

This was an extremely rich learning experience, especially given my favourite communicable disease is meningococcal. Therefore, when this outbreak occurred, I instantly asked if I could be involved. Being able to fly to Port Hedland and provide assistance to the PPHU during the commencement of the vaccination campaign was an amazing experience and one that I am very

thankful for. I was also lucky enough to be part of a vaccination clinic held in the town square in South Hedland. With the local knowledge of the PPHU nurses and given it was school holidays, a pop-up vaccination clinic was set up there as they knew a lot of the priority groups would be in the vicinity. It was a great experience and opportunity to speak to people in the local community about IMD and getting the vaccine, even some teenagers chose to wait 40 minutes with us, until their mum arrived to sign the consent form!

My key learnings include:

- how the Incident Command System structure could be adapted for a public health response. Learning this structure then helped when it was also implemented for the COVID-19 pandemic response in WA
- organising a vaccination campaign in a remote area of WA, including gaining an understanding of the complexity and challenges involved in the decision that one is required, to who is to be vaccinated, the logistics of acquiring the vaccine and the delivery and storage, to operationally how they will be administered to the priority groups
- the importance of communication and collaboration with those who are on the ground and working in the communities. The local knowledge the nurses had in the Pilbara was invaluable. Their understanding of the community and families, including their movements within the region and their healthcare seeking behaviours was instrumental in this vaccination campaign
- the importance of data analysis during the vaccination campaign. It was seen that initially vaccination clinics were being used by the community, however numbers then started to decline. Verbal reports from nurses and evidence from data analysis then prompted a change to the vaccination campaign strategy, which saw an increase in community-based vaccination clinics (for example in the town square, which was outside of the main shopping centre in South Hedland) and targeted follow-up, such as home visits
- the requirement for an outbreak response tailored to the WACHS regions, with chains of command identified, document templates, suggestions about what had worked well previously (for example the use of community pop-up clinics).

ACKNOWLEDGMENTS

I would like to acknowledge all who were involved in this vaccination campaign. Your dedication, adaptability and hard work showed through in the vaccination coverage results that were achieved. A special thank you to Dr Clare Huppatz for her leadership, guidance, and for pushing me to gain hands-on experience by travelling to the Pilbara to assist. Thank you for sharing your

experiences and expertise in IMD outbreaks and vaccination responses/campaigns – it was truly inspiring watching you lead this response, and I can only hope that I can be like you when I grow up! I would like to sincerely thank Jodie Bennett, Deanna Exeter and Philippa Jones from the Pilbara Population Health Unit. You all worked exceptionally hard during this response and I feel very privileged to have been involved. Thank you for instantly making me feel so welcome, for all your support, patience and for the local tour, laughs, cat pictures and coffees. Your knowledge of the local area and your enthusiasm for all things public health was evident and inspiring. And thank you for not making me dress up as "Immy the Immunisation echidna" in 30+ degree heat in Port Hedland (Figure 2).

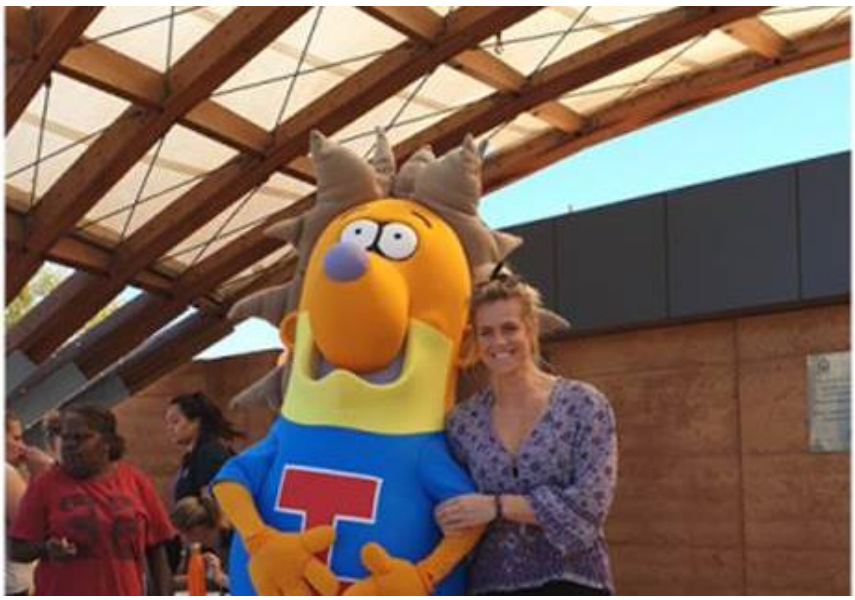

Figure 2: Working at a community vaccination clinic in South Hedland with Immy the Immunisation echidna

REFERENCES

1. Communicable Disease Control Network Australia. Invasive Meningococcal Disease CDNA National Guidelines for Public Health Units. In: Government A, editor. 2017.

APPENDIX

APPENDIX 1: WACHS PILBARA TARGETED MENINGOCOCCAL ACWY VACCINATION PROGRAM FREQUENTLY ASKED QUESTIONS (REPORT TO A NON-SCIENTIFIC AUDIENCE)

**FAQS to be provided to the public and also be uploaded on any website (Healthy WA, Pilbara Facebook page) for public viewing*

Government of **Western Australia**
WA Country Health Service

WACHS PILBARA TARGETED MENINGOCOCCAL ACWY VACCINATION PROGRAM

FREQUENTLY ASKED QUESTIONS (June 2019)

- **What is the targeted vaccination program?**
  The WACHS Pilbara Targeted Meningococcal ACWY Vaccination Program is a 'once off' vaccination program against meningococcal disease that will be offered to all Aboriginal people, using an age-group prioritisation approach, living in Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland.

  The program is in response to an increase in recent months of meningococcal 'serogroup C' infections, in the Pilbara region.
  The existing childhood and school-based meningococcal vaccination programs targeting serogroups A, C, Y and W will continue.

- **Why is the targeted vaccination program necessary?**
  There has been a significant increase in the number of cases of invasive meningococcal disease (IMD) recorded in the Pilbara region of Western Australia (WA).
  Prior to 2019, the average incidence of meningococcal serogroup C (MenC) in WA was one per year. Since January 2019, there have been four cases of MenC in the Pilbara region, with all cases being Aboriginal and geographically clustered around the South Hedland and Roebourne areas. In response, several public health measures are being implemented, including a targeted vaccination program.

- **Which vaccine will be used?**
  A meningococcal ACWY vaccine will be used and will protect against the four groups of meningococcal bacteria: A, C, W and Y. The brand that will be used in this response is Nimenrix® (Pfizer). This vaccine is also used for the routine childhood and adolescent meningococcal ACWY vaccination program.

- **What age groups will be targeted?**
  This vaccination program will be offered to all Aboriginal people, using an age-group prioritisation approach. The age-group priority approach will target:
    - Priority 1: 6weeks to <5years AND 15years to <20years
    - Priority 2: 5years to <15years
    - Priority 3: 20years to 35years
    - Priority 4: >35years

- **Can the meningococcal ACWY vaccine be given to children aged less than 2 months of age?**
  Yes, babies can have the meningococcal ACWY vaccine from 6 weeks of age. Refer to the Australian Immunisation Handbook for dose schedule: *https://immunisationhandbook.health.gov.au/vaccine-preventable-diseases/meningococcal-disease*. All Aboriginal children who commence meningococcal ACWY vaccines through this response will be able to receive further doses according to the WA schedule.

- **Which areas in the Pilbara will be included in the program?**
  Areas included will be: Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Onslow, Marable Bar, Warralong, Port Hedland and South Hedland.

- **Why are Newman, Tom Price and other areas in the Pilbara not included?**
  Newman and Tom Price have not experienced an increase in meningococcal cases over the expected rate and have had no MenC cases in 2019. Therefore, they will not be included in the WACHS Pilbara Meningococcal C Cluster Response. Meningococcal ACWY vaccines are still available for all children aged 12 months to under 5 years and 15-19 years including Year 10 through the School Based Immunisation Program (SBIP).

- **Will you be rolling out the program to other parts of the State, if not, why not?**
  There is no plan to roll out the program to other parts of WA. The WACHS Pilbara Meningococcal ACWY Vaccination Program is being implemented in response to an observed increase in cases in one particular geographical area. Any additional programs will be based on disease trends across the State.

- **Has this type of targeted meningococcal vaccination program intervention been done before?**
  Similar vaccination programs have been carried out in response to unexpected increases in meningococcal cases in several regions of WA, including regions of the Kimberley, Goldfields, remote Pilbara and most recently in the Midwest.

- **What is the aim of the targeted vaccination program?**
  The aim is to provide direct protection to those who are vaccinated and to prevent people who carry the meningococcal bacteria in the back of their throat, but who don't display symptoms, from passing the bacteria onto other people.

- **Who is most at risk from meningococcal disease?**
  Meningococcal disease can affect any age group. However, those most at risk of meningococcal disease are children aged 4 years and under, particularly Aboriginal children, and adolescents aged 15-19 years. Of the 52 meningococcal C cases diagnosed in WA since 2000, 23% of cases were children aged 4 years and under, and 12% were adolescents aged 15-19 years.

- **I am a non-Aboriginal resident of Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland or South Hedland, can I get a free vaccination?**
  Since January 2019, there have been four cases of MenC in the Pilbara region, and all cases were Aboriginal people residing in South Hedland and Roebourne areas. Therefore the WACHS Pilbara Meningococcal ACWY Vaccination Program is offered to all Aboriginal people only.
  Vaccines are still available for all children aged 12 months to under 5 years and 15-19 years including Year 10 through the SBIP.

- **I am a visitor (traveller) to Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland or South Hedland, can I receive the vaccination?**
  The program is targeted at Aboriginal people who are residents of Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland only.

- **If people are residents of Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland but are away when this vaccination campaign starts, can they have the vaccination elsewhere in Western Australia?**
  No, this program is only available in these areas; the program will run for three months.

- **What are other hot spots for meningococcal cases in WA**?
  Up to June 2019, there have been ten cases of meningococcal disease notified in WA. Of these, five cases were serogroup C (four of which are in the Pilbara region), three were serogroup W and one was serogroup B. Besides the hot spot identified in the Pilbara region, there is currently no other unexpected increases in meningococcal disease in WA.

- **How at risk are the Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland communities?**
  Meningococcal disease remains a very uncommon disease in the Pilbara region. The rise in cases that has been observed in 2019 means that the community needs to be aware of early signs and symptoms of the disease and seek medical attention immediately if they are concerned. Those most at risk of developing meningococcal disease in living in Karratha, Wickham, Roebourne, Nullagine, Onslow, Yandeyarra, Marble Bar, Warralong, Port Hedland and South Hedland, will have access to the WACHS Pilbara Targeted Meningococcal ACWY Vaccination Program.

- **How effective is the meningococcal ACWY vaccine?**
  The vaccine is safe and effective. Studies have shown that the effectiveness of the meningococcal ACWY vaccines is between 80 to 85% in adolescents and greater than 90% in infants. Meningococcal ACWY vaccination programs have been implemented in adolescents aged 13-15 years in the United Kingdom since 2015, and adolescents aged 11-12 years in the United States since 2005, and have been found to be safe and effective.
  The protection provided is estimated to last approximately 3 to 5 years.

  The community still needs to be mindful of the early signs and symptoms of meningococcal disease and seek medical attention immediately if they are concerned.

- **How long does it take for immunity to develop after having the vaccine?**
  It takes approximately 2 to 4 weeks for immunity to develop after Men ACWY vaccination.

- **What serogroups will the vaccine cover?**
  The vaccine protects against the meningococcal serogroups A, C, W and Y. Serogroup C is the one that has been responsible for the recent cases in the Pilbara region.

- **If my child has recently received another vaccination, can they have the Meningococcal ACWY vaccine now?**
  Yes, Nimenrix®, which is the vaccine being used in this program, can be administered even if it is being given shortly after another vaccine.

- **My child already received a MenC (Menitorix) or Neisvac vaccine at 12 months of age, is this vaccine different?**
  Yes, the vaccines used in this program protects against four types of meningococcal bacteria (A, C, W, Y). Menitorix® and Neisvac only protect against meningococcal type C.

- **If a person has received a meningococcal A, C, W, Y, do they get vaccinated again in this program?**
  No, you do not need to receive another Meningococcal ACWY vaccination, except for infants who commence their vaccinations when they are aged less than one, and need additional vaccinations.

- **Can a pregnant woman have meningococcal ACWY vaccine?**
  Meningococcal ACWY vaccines are not routinely recommended for pregnant women, but can be given where there is a strong clinical indication, such as increased risk of meningococcal disease.

- **Can a woman who is breastfeeding receive a meningococcal ACWY vaccine?**
  Yes

- **What about people in the target groups, who have a disability?**
  People with a disability should contact Pilbara Public Health on 91741358 to enquire about clinic access.

- **Can the vaccine cause meningococcal disease?**
  No. Only the bacteria, *Neisseria meningitidis*, can cause meningococcal disease. The vaccine does not contain any live bacteria.

- **What are the symptoms of meningococcal disease?**
  The symptoms of meningococcal disease can include: fever, headache, neck stiffness, muscle or joint pains, drowsiness, confusion, nausea, discomfort when looking at light, vomiting and a rash of red-purple spots or bruises.
  Common symptoms of meningococcal disease in babies include: fever, rapid breathing, rash, vomiting, irritability, drowsiness, and pale skin.

If you or someone you know develops symptoms or signs consistent with meningococcal disease consult your family doctor or the Emergency Department of the closest hospital immediately.

- **Where can people access their vaccine?**
  Contact **Pilbara Public Health on 91741660** for your local clinic information. It is free from Community Health Clinics and Aboriginal Health Services.

- **When will the targeted vaccination program start?**
  To be advised.

- **For how long will the campaign run?**
  This campaign will run for 3 months.

- **Who do I ring to find out about clinic times and locations?**
  Pilbara Public Health **(08) 9174 1660**

- **Can my child receive the vaccine at the local GP?**
  To be advised.

- **What is the cost of immunisations by GPs?**
  To be advised.

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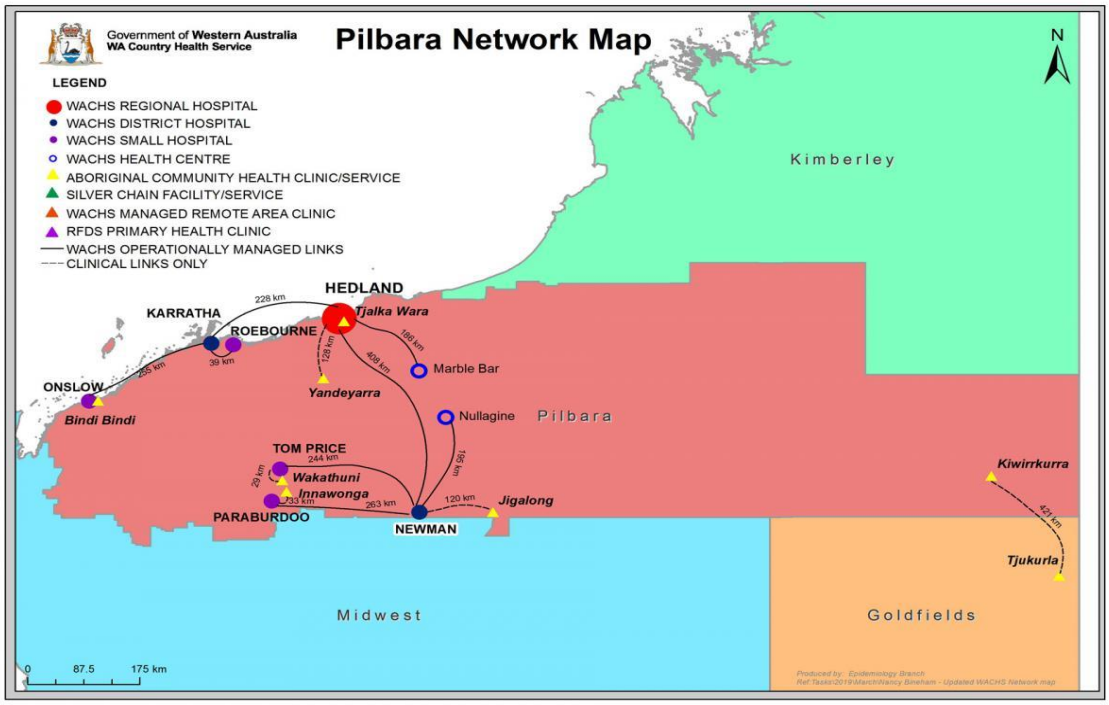
APPENDIX 2: PILBARA NETWORK MAP



Source: http://www.wacountry.health.wa.gov.au/index.php?id=436

CHAPTER 7: TEACHING ACTIVITIES

MAE TEACHING ACTIVITIES

The MAE program has two teaching-related core requirements: developing, delivering and participating in "Lessons from the Field" to our own MAE cohort, and preparing and delivering a teaching session to first year MAE students. My roles varied for each of the teaching requirements, however both included lesson planning, creating teaching material and session facilitation, coordination and participation.

ACKNOWLEDGEMENTS

I wish to thank and acknowledge my LFF group – Elenor Kerr, Laura Goddard and Srean Chhim, as well as my ANU supervisor Aparna Lal, who contributed useful suggestions to my LFF presentation. I would also like to thank my group for teaching the first year MAE students - Elenor Kerr and Laura Goddard (again!), as well as the MAE 2020 cohort, thanks for being great students during our teaching presentation.

TEACHING ACTIVITY LESSON FROM THE FIELD

BACKGROUND

The Lessons from the Field (LFF) component of the MAE teaching requirement is an opportunity for MAE students to share and teach some key lessons that we have learnt through our projects and placements, to a small group of our MAE cohort.

Given that the COVID-19 global pandemic was occurring at the time our LFF group decided to meet and present, I chose to focus my LFF on my current involvement in the COVID-19 pandemic response in Western Australia's (WA) Public Health Operations (PHOps), specifically about how the WA COVID-19 case and contact management system progressed during the first six months of the pandemic. The LFF contained a brief overview of the initial COVID-19 systems that had been used at the start of the pandemic, and the new system that was implemented during the pandemic in WA. The intention of the LFF was to introduce the group to the PHOps team structure, the data collected, reporting mechanisms and the advantages, challenges and lessons learnt (Appendix 1). The LFF was circulated to students in the group one week ahead of a scheduled hour-long Zoom teleconference, during which I presented the slides, and responses to

all questions were answered and discussed in more detail. The slides presented also yielded more questions from the group, in regard to the specifics of the WA COVID-19 systems and case/contact follow-up and management.

LESSONS LEARNT

The timing of the LFF teaching activity made it difficult to participate in and prepare for, given the COVID-19 global pandemic occurring and my involvement in the PHOps Epidemiology Team. However, I found that conducting the exercise was rewarding, mostly as it meant reconnecting with fellow MAE students (especially after our course block had been cancelled due to the COVID-19 pandemic). Overall, students enjoyed the LFF topic and the discussions which took place, particularly about how, during a highly intense pandemic situation, a new system specifically for COVID-19 case and contact follow-up/management can be designed and deployed.

TEACHING ACTIVITY: PEER TO PEER TEACHING SESSION

BACKGROUND

The teaching session to the first year MAE students occurred in August 2020 via Zoom (due to travel restrictions caused by the COVID-19 pandemic) during their 2nd course block (and our 3rd course block). Our MAE cohort worked within self-allocated groups of 3 students to prepare a teaching session on a topic that we felt would be beneficial and interesting to first year students. Following Zoom discussions, our group chose to present on Neglected Tropical Diseases (NTDs). We felt this was an interesting topic that was not necessarily addressed in formal course block teachings – and we also wished to discuss/teach something other than COVID-19!

The teaching session outline, including the learning objectives can be found in Appendix 2.

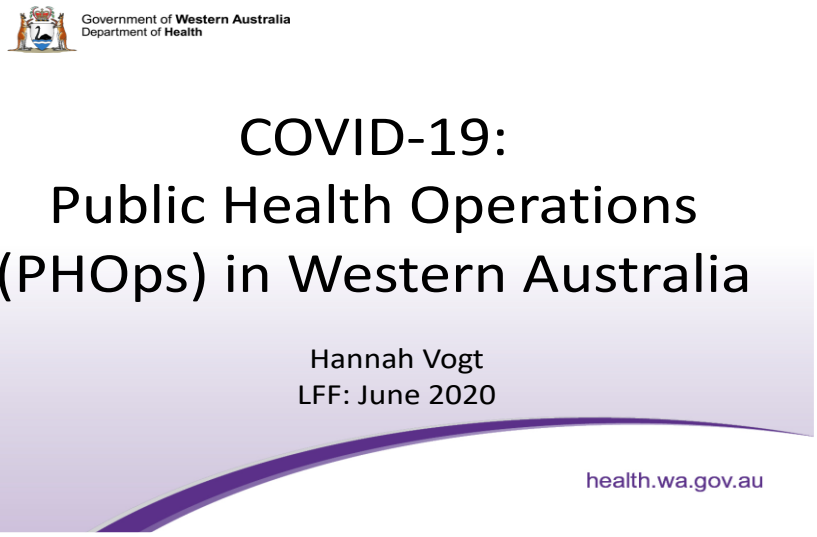
LESSONS LEARNT

Given that we were unable to all be in Canberra for course block we had to use and refine our technological skills, by holding Zoom meetings during course block to create/discuss our lesson plan, prepare our content and practice our presentation. We also used Google Docs to work on our PowerPoint slide presentation and lesson plan collaboratively and concurrently.

The intention of the teaching session was to give the first year MAE students a stimulating, non-COVID-19 related topic, in which 92% of students agreed that the presentation was interesting. As the presentation and group work session was via Zoom and in “break-out rooms”, it did make keeping to the allocated time (due to the need for different Zoom links between the 2019 MAE cohort), engagement and facilitation (both with the large group and smaller groups) slightly more difficult compared to if it was in person. However, 92% of students fed back that the material on NTDs was presented clearly, and 75% agreed that the presentation enabled them to meet the stated objectives (Appendix 3).

APPENDIX

APPENDIX 1: LESSON FROM THE FIELD



Background & Objectives

- Content based on my involvement in the COVID-19 pandemic response in PHOps (Public Health Operations), in Western Australia
- By the end of the LFF, the other members will understand:
  - The old & new system for case & contact management used in WA
  - Data management & reporting in WA
  - Challenges & lessons learned in contact tracing/implementing a new case & contact management system during a global pandemic

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Epidemiology of COVID-19 in WA

- First case detected on 21st March 2020 from a returned traveler from the Diamond Princess Cruise
- Up until 15th June 2020, 602 cases have been notified in WA
- Place of acquisition:
  - At sea: 42%
  - Overseas acquired: 43%
  - Locally acquired - contact of confirmed case: 11%
  - Locally acquired - contact not identified: 3%
  - Locally acquired - interstate travel: 1%
  - Under investigation: 0%

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Public Health Operations (PHOps)

Responsible for the case interviewing, contact tracing, ongoing management and outbreak monitoring of COVID-19 within WA

Contact Centre

Receive Enquiries

Contact Tracing

Contact & Interview

On-Going Maintenance

Daily Monitoring

Follow the CDNA Series of National Guidelines (SoNG) for Coronavirus Disease 2019 (COVID-19)

COVID-19 case & contact tracing team

- Identify cases
  - Following the ever-changing national case definition (suspect, confirmed, probable)

Step 1 – Contact, Inform & Reassure Case

Step 2 – Assess Disease Onset & Symptoms

Step 3 – Trace Contracts

Step 4 – Isolation

Step 5 – Contact 'Close Contacts'

Step 6 – Documentation & Closing loop?

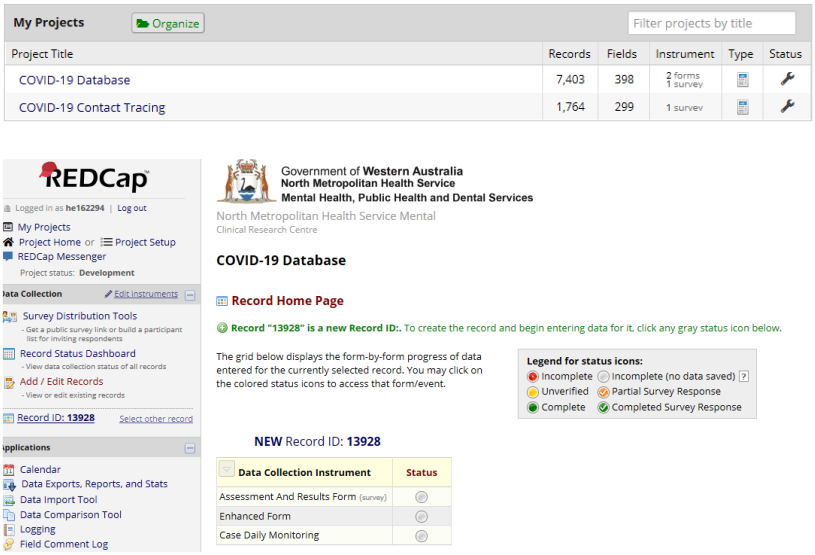
Ongoing case management team

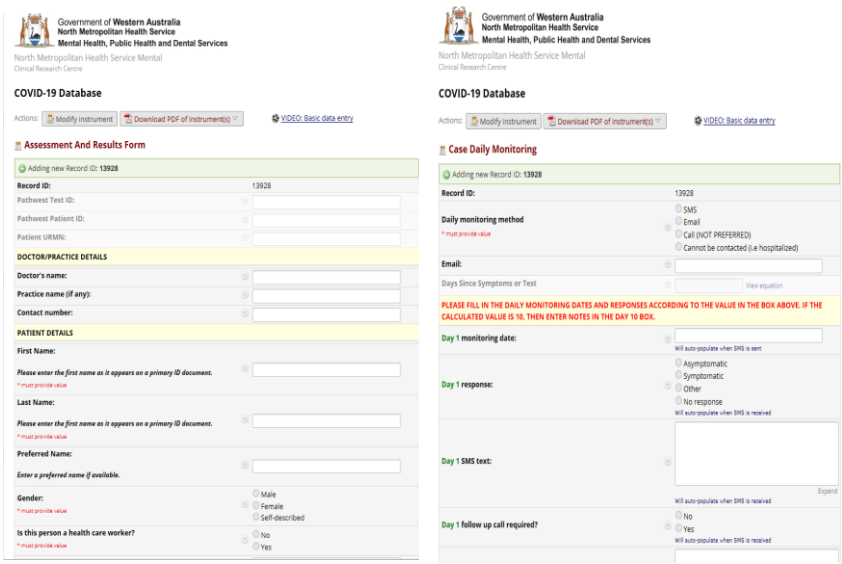
Examples of their key daily tasks:

- As required, ring cases
- Ring close contacts who have not replied to their daily text
- Ring close contacts who are symptomatic
- Ring negative results that we ordered
- Ring lists of airplane contacts

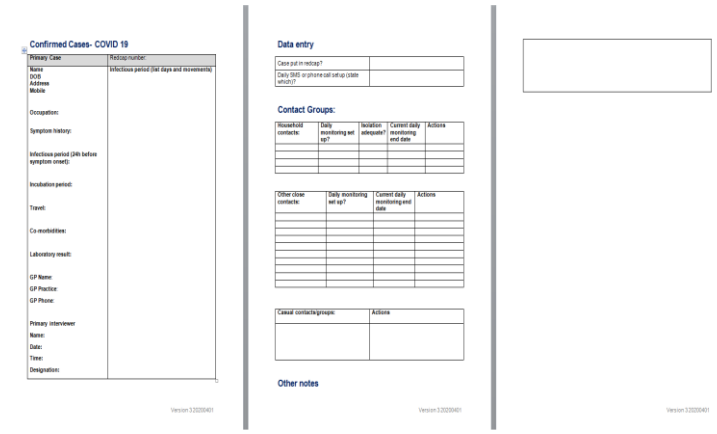
Way back in January 2020….

- RedCap forms were produced for suspected cases and also confirmed cases
- A “case summary” template was completed for each case
- Daily monitoring set up for cases & contacts
  - SMS, emails, phone calls
    - Information into RedCap
    - SMS’ and emails sent in bulk everyday





Case summary template



PHOps initial reporting

- Spreadsheet for all confirmed cases created
  - Evolved over time
  - Used for daily reporting to the on-call public health physicians, health service executives & ultimately the WA Health Minister/Premier
  - Time consuming & manual process
  - Checking REDCap entries & case summaries to get appropriate information
  - Updating fields constantly

Data fields on the COVID-19 spreadsheet

Case no
Metro/WACHS
Notification date
Time of notification (24hr clock)
WANIDD ID
GIVEN NAME
SURNAME
DOB
Age
Sex
ATSI
Address
Postcode
Region
Phone number
HCW
HCW detail
Other sensitive occupation

Symptom onset date
Admitted to hospital
Hospital name
Admitted to ICU
Discharged from hospital
Deceased/deceased date
Comorbidities
Flight manifest requested
Daily monitoring
Earliest date for clearance (DOO + 10 days)
Case cleared
Clearance Date
Epi link to case
Place of acquisition
Country/place of acquisition
Link
POA by region
Outstanding actions

Example of a report

As of 1500, 24/05/2020:

- New cases in last 24 hours:
- Cases cleared last 24 hours:
- Total number of cases: (metro vs regional)
- Deaths:
- Cleared:
- Active Cases: (community vs hotel)
- Currently using hospital facility for recovery (but cleared):
- Number of active HCW cases:
- Number of cases from cruise ships:
- Total number of cases who were in hotel quarantine:
- Contacts on daily monitoring:
- Cases on daily monitoring:
- Total number of cases ever been admitted to hospital:

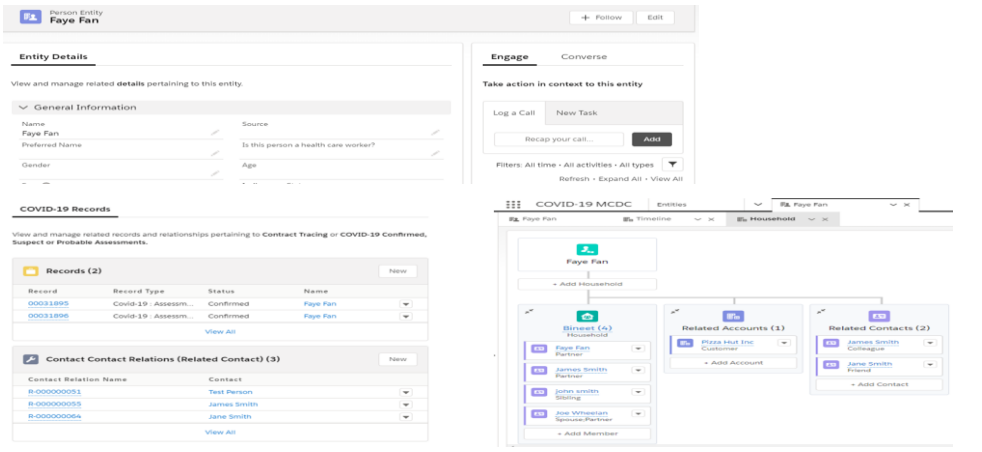
PHOCUS: A new system...

- "Salesforce" is customer management tool for businesses

- **"PHOCUS": Public Health Operations COVID-19 Unified System**
  - Can complete interview form online
  - Contacts details collected & can be entered into the system
  - AUTOMATED PROCESS!!!
    - Daily monitoring for cases & contacts is set up

Questions...

- What do you think some of the limitations could be of this system during a pandemic?
- What kind of changes would you implement to this system to make it more functional during a pandemic?

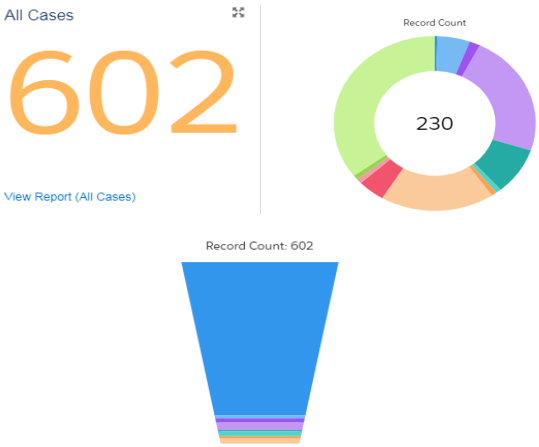


PHOCUS reporting

- Still use spreadsheet to some extent
- Once data was cleaned, PHOCUS could provide detail of cases quicker
- Dashboard able to be made with relevant reporting fields
- Contact details available but for further detailed analysis is still a manual process

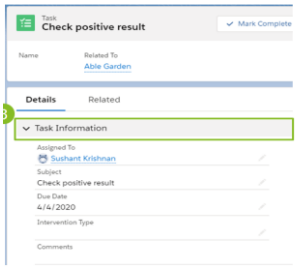
PHOCUS dashboard fields

All cases
All cases by PHU
Recovered
Active Community cases
Daily Cases
Hotel cases
Deceased
Hopsitalised cases
ICU cases
Cleared hospitalised
Cleared past 24hrs
Active healthcare workers
Cases on daily monitoring
Contacts on daily monitoring
Recovered hotel quarantine
Cruise Ship cases



Some advantages of PHOCUS

- Automated
  - Send SMS, emails to cases & contacts
- Assists with workflow:
  - Delegates tasks
  - Creates “lists” for PHOps
  - Timeline view enabled people to see the history of calls, texts, tasks
- Does not require technical knowledge to extract data or set up reports/dashboards
- Has potential to depict contacts/links



Challenges & lessons learned….

- Pandemic was/is a constantly evolving situation
- Changing systems during a pandemic
- Transitioning to a new system in a short time frame
- Technical support

APPENDIX 2: TEACHING FIRST YEAR MAE STUDENTS

TEACHING SESSION OUTLINE

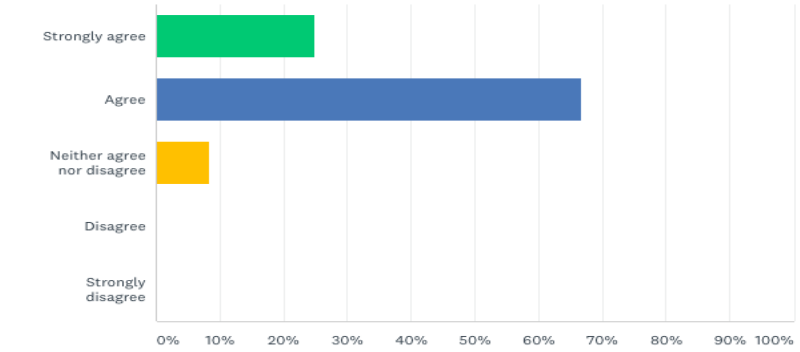
Date of session	Friday 28th August 2020
Leads	Hannah Vogt, Elenor Kerr, Laura Goddard
Topic	**Neglected Tropical Diseases**
Session Outlines	1. What are neglected tropical diseases (NTDs)? 2. Three examples of NTDs in the Asia Pacific region 3. Group work: challenges of NTDs 4. Summary and conclusion
Learning Objectives	Students are able to: • Define NTDs and list some of those in the Asia Pacific region • Identify some of the main challenges to addressing NTDs • Collaboratively work through a case study on NTDs • Recognise the public health significance of NTDs
Teaching	Introduce NTDs as a diverse group of communicable disease that: • affect a large population globally and many are endemic in the Asia Pacific region • have significant human and economic burden • are often preventable and treatable • have diverse challenges associated with their surveillance, control, and elimination efforts We'll focus discussion on three diseases (melioidosis, leptospirosis, lymphatic filariasis) which are present in the Asia Pacific region and help to promote discussion about the classifications of NTDs. I.e. leptospirosis and melioidosis are not within the WHO list but still considered by many to be NTDs.
Activity & Assessment	Students will be divided into three groups, to each work on an example NTD and to identify relevant challenges to addressing them. There will be 3 different scenarios to work on. Each group will be divided into a breakout room on Zoom with a facilitator. A representative from each group will present key points from their discussion back to the class and students will be asked to provide feedback on each group's presentation.
Time	10 mins – intro to NTDs, how they're defined, WHO list (pop quiz). 10 mins – group work based on three examples 10 mins – feedback of group work, wrap up and evaluation

APPENDIX 3: FIRST YEAR MAE STUDENT FEEDBACK

Q1

The content of the presentation was interesting

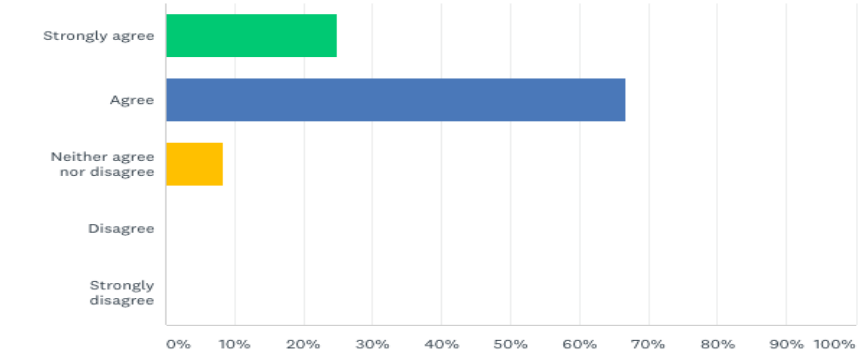
Answered: 12 Skipped: 0



Q2

The presentation material was presented clearly

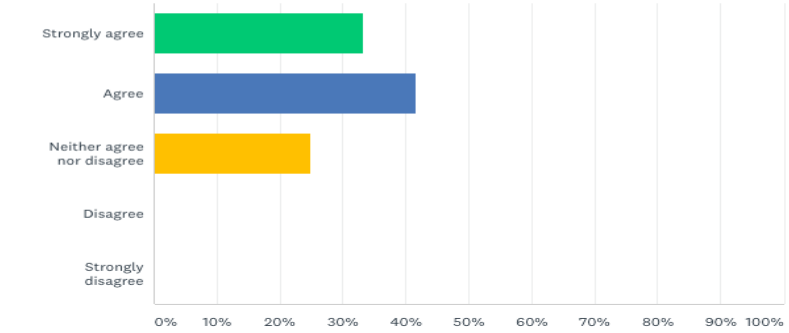
Answered: 12 Skipped: 0



Q3

The presentation has enabled me to meet the stated objectives

Answered: 12 Skipped: 0



Q4

The presentation was directed at an appropriate level for my knowledge and skills

Answered: 12 Skipped: 0