Applied Epidemiology of Infectious Diseases and Environmental Health in the Australian Capital Territory

A thesis submitted for the degree of Master of Philosophy (Applied Epidemiology) of The Australian National University

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Originality Statement

I hereby declare that this submission is my own work, and, to the best of my knowledge, it contains no materials written or previously published by another person, nor substantial proportions of material that have been accepted for the award of any other degree or diploma at the Australian National University or any other education 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 projects' design and conception or style, presentation or linguistic expression is acknowledged.

Signed……

Algreg Gomez

23 October 2023

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Acknowledgements

Firstly, I would like to thank the ACT Health Directorate (ACTHD) and the National Centre for Epidemiology and Population Health (NCEPH) at the Australian National University (ANU) for funding and providing the Master of Philosophy in Applied Epidemiology (MAE) program. I would like to sincerely thank Timothy Sloan-Gardner and Rebecca Hundy, my field supervisors at the ACTHD. I feel very privileged to have worked under both such supportive and inspiring leaders. You have not only guided me but also motivated me to the best person that I can be. This journey would not have been the same without you both. Thank you to Dr Matthew Kelly as my primary academic supervisor at the ANU. Matt has been an incredible mentor who provided constant support and guidance. Thank you to Dr Davoud Pourmarzi for your ongoing guidance and support through the MAE. Both of your patience, knowledge and encouraging words throughout my candidature was well valued.

I would like to acknowledge my colleagues in the COVID-19 Response Branch and the broader directorate that I had the pleasure of working with during my candidature. This includes colleagues from the Communicable Disease Control (CDC) section, Health Protection Services (HPS). I would also like to acknowledge the World Health Emergencies (WHE) Programme for hosting me as an Epidemic Intelligence Officer within the Field Epidemiology Fellowship Program (FEFP) at the Western Pacific Regional Office (WPRO), World Health Organization (WHO). Thank you to my fellow cohort (special mention to the “Canberra crew”) for your support and entertainment during the two-year journey. To Aidan, Yasmin, Aruna and Meg, I’m thankful to have made genuine friendships. I feel very fortunate to have shared my MAE experience with and learn from such a talented and driven group of individuals.

Thank you to my family and friends for supporting me through the stress and uncertainty. I would like to dedicate this thesis to my dad, Cedric and mum, Sherry. You have supported me throughout my studies and have both sacrificed so much. I hope I continue to make you proud. To my brothers Jomar, Michael and Mric; thank you for all the laughs and constant reminder how lucky we are to have each other. Thank you to my extended family Greg, Jacqui and Ollie-Mai.

Finally, thank you to the most important person in my life, Brooke, for your unwavering love and support during my field epidemiology training program. I would not be the person that I am today, without you.

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Thesis Summary

From February 2021 to December 2022, I undertook a 22-month field placement within the COVID-19 Response Branch with the Health and Emergency Control Centre (HECC), ACTHD. The HECC was responsible for surveillance, prevention, and control of infectious and non-infectious disease emergencies in the Australian Capital Territory (ACT). This thesis presents the major projects along with additional public health experience to meet the competency requirements of the Master of Philosophy (in Applied Epidemiology) (MAE) program.

This thesis is presented in seven chapters. Chapter I introduces my experiences whilst completing the MAE. Chapter II through V describe the projects I completed as a core requirement of the MAE. Chapter VI focuses on the teaching activities I undertook during the MAE. Chapter VII summarises other public health activities and experiences throughout my candidature.

Chapter I

This chapter introduces my field placement and summarises my experiences during my candidature. It outlines my primary role within the COVID-19 Response Branch and public health activities that I undertook during my placement.

Chapter II

This chapter encapsulates the data analysis project component of my thesis. This project aimed to present new information about an emerging COVID-19 variant of concern at that time. This information was essential to inform future public health risk assessments, modelling studies and impacts on hospital capacity. The aim of my analysis was to characterise how SARS-CoV-2 Delta (B.1.617) and Omicron (B.1.1.529) variant infections vary in symptomology by sex, age and vaccination status throughout an individual's infection using cases identified between 12 August 2021 and 21 January 2022, in the Australian Capital Territory (ACT).

Chapter III

I conducted an outbreak investigation of a public health problem with the COVID-19 Response Branch on a cluster of SARS-CoV-2 Beta (B.1.529) infection in hotel quarantine in March 2021. An Acute Response Team (ART) was formed and an outbreak investigation was initiated, after two passengers were detected with acute SARS-CoV-2 infection whilst undertaking mandatory hotel quarantine. The main

objectives of this investigation were to utilise epidemiological evidence from case interviews, contact tracing, and laboratory evidence to support and inform the relevant decision makers for appropriate public health measures to prevent further spread of infection.

Chapter IV

This chapter contains the experiences and learnings from implementing an improved surveillance system for salmonellosis with the team at HPS, ACTHD. I was the lead investigator and project officer for this project. I was able to distribute a pre-implementation evaluation questionnaire that was used to inform how the system could be improved. Overall, the implementation of this system was aimed to improve the public health follow-up process through automated surveys. The implementation was deemed successful by key stakeholders, which resulted in time saved (both by individuals completing the automated surveys compared to a full routine case interview) and improved organisation of the respective data that could be used for future enhanced epidemiological analysis.

Chapter V

The fifth chapter describes an epidemiological study in which I investigated the association between environmental conditions and asthma-syndrome-related hospital admissions and community centre presentations in the ACT. This project provided an opportunity to explore other concepts and data analysis techniques that was outside of my routine activities within the COVID-19 Response Branch.

Chapter VI

This chapter in the thesis provides learnings from multiple teaching activities conducted as part of the MAE program, with reflections on the teaching sessions and lessons I learned. The teaching activities include peer-to-peer teaching to first-year MAE scholars, lessons from the field (LFF) and various teaching opportunities I undertook during my candidature.

Chapter VII

The seventh and final chapter of this thesis describes my experiences as an epidemiology fellow for WPRO, WHO deployed in Manila, Philippines between August-October 2022. In this chapter, I also outline my involvement with numerous COVID-19 outbreaks and related projects in the ACT and multiple foodborne outbreak investigations with the CDC section, HPS.

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Chapter I

Master of Philosophy in Applied

Epidemiology Experience

Overview

For my candidature with the MAE, I was placed with the COVID-19 Response Branch, ACTHD in Canberra, Australia.

The ACTHD's vision is outlined as 'A Healthier Canberra'. The Directorate's purpose is "to provide strategic leadership, direction and action that improves the health of our community and ensure our public system meets our community's needs, now and into the future." The ACTHD's values are respect, integrity, collaboration and innovation. My placement with ACTHD provided many unique opportunities outside of my core MAE projects.

Field Placement

The ACTHD Strategic Plan 2020-25 outlines the key objectives of Canberra's public health system, and how the Directorate is utilising leadership and direction in improving the health of the broader community. The ACTHD comprises of eight core divisions and program areas that is headed by the Director-General (DG):

- Health Systems, Policy and Research Group
- Office for Mental Health and Wellbeing
- Digital Solutions Division
- Strategic Infrastructure Division
- Corporate and Governance Division
- Office of the Director-General/Communications and Government Relations
- Workplace Culture Review Implementation
- Office of the Chief Health Officer (OCHO)
    - COVID-19 Response Branch

The organisational structure was updated in mid-2020 to include the COVID-19 Response Branch lead by the Chief Health Officer (CHO), who has oversight of the Policy and Support, Response Branch, Vaccine Program and HPS. The COVID-19 Response Branch is comprised by a subset of teams below:

- OCHO

- Deputy CHO
    - Executive Office
- Outbreak Preparedness and Response
- Medical Officer Team
- Surveillance and Reporting
- Case Investigation and Contact Tracing
- Support Systems
    - Logistics and Facilities
    - Planning
- Mental Health and Wellbeing
- Quarantine Management
- Epidemiology
- Testing and Vaccine

The placement with the ACTHD was an ideal one for me. Under the supervision of Timothy Sloan-Gardner and Rebecca Hundy, my primary role was to gain real life experience as an applied epidemiologist. My previous work experience was with the same branch in which I was primarily involved as a Systems Architect and a Public Health Officer (PHO) within the then Surveillance and Reporting team. This later became the Data and Reporting team. The duties and responsibilities of this new role was mainly the development and maintenance of systems, projects and databases related to COVID-19. The role also required me to assist with enhanced epidemiological analysis and reporting of COVID-19 related data. Being part of this multi-disciplinary team provided me with a broad range of experience that helped develop my interests in epidemiology, disease surveillance, and data analysis.

I spent the first six months of my candidature with the then Surveillance and Reporting team. As part of the day-to-day, I participated in several activities within the team, including:

- Attending daily and weekly meetings,
- Co-authoring of ACT's Public Health Monitoring report (sent to ACT's Chief Health Officer weekly to inform the ACT Security and Emergency Management Committee (SEMC) of Cabinet.
- Data analysis of ACT COVID-19 data (testing/screening, vaccination, including risk assessment of confirmed cases from surrounding regions of NSW).
- Technical support for systems regarding data capture;
    - Quarantine and Close-Contact Management databases,
    - International and Interstate Exemptions Declarations (public facing form),
    - Development of the COVID-19 Case Investigation Database,
    - Lead a team to work with ACT Policing and the Australian Federal Police (AFP) to develop an integrated compliance system for COVID-19 quarantine management in the ACT.
- Involved in multiple Government-Facilitated Flights (GFF) that landed in the ACT;
    - Technical assistance for the Surveillance and Reporting team,
    - Prepared and distributed routine (daily and weekly) enhanced COVID-19 public health monitoring report,
    - Contributed to the COVID-19 Section for the ACT Health Annual Report 2021,
    - Facilitated communications with National Focal Points (NFPs) through the International Health Regulation (IHR) mechanism,
    - Whole-genome sequencing (WGS) analysis,
        - Involvement in the implementation of a syndromic surveillance system for all hotel-quarantine staff involved in the above mentioned GFFs.

From August 2021, I was placed with the Epidemiology team in the COVID-19 Response Branch. This revolved around the ongoing response to the SARS-CoV-2 Delta and Omicron local outbreaks. I participated in several activities responding to public health problems within the branch, including:

- Conducted data analysis, drafted routine and ad hoc reports (sent to ACT Government Executives, CHO, Deputy CHO and Senior Directors),
- Conducted end-to-end COVID-19 case investigation (through phone-interviews),
- Contact tracing,
- Investigation of transmission pathways,
- Cluster/outbreak investigations,
- WGS interpretation and analysis,
- Implemented key variables in the database to improve reporting metrics.

I would like to acknowledge the help of other field epidemiology scholars, epidemiologists, and health professionals from NCEPH and the Australian Government Department of Health and Aged Care, that helped during the peak of the local SARS-CoV-2 Delta outbreak in August 2021; Prof Martyn Kirk, Dr Ben Polkinghorne, Dr Davoud Pourmarzi, Dr Meru Sheel, Alex Marmor, Dr Nevada Pingault, Rose Wright, Siobhan St George, Christina Bareja, Dharshi Thangarajah, Aruna Phabmixay, Yasmin Lisson, Leonie Williamson and Anna Rafferty.

As well as many COVID-19 related projects and responsibilities, in November 2021, I was also asked to help out HPS regarding an outbreak of gastrointestinal illness that affected patrons of a donut bakery. I was involved in the acute response by interviewing cases regarding their exposures prior to becoming ill. Due to my expertise in automated surveys, the team requested that I help in developing a standardised questionnaire that could capture the relevant food history of all complainants. The whole experience further consolidated my understanding of the concepts of an outbreak investigation (detailed lessons learned are outlined in **Chapter VII**). This foodborne outbreak investigation was then developed and published into the Communicable Diseases Intelligence (CDI) journal by a fellow MAE scholar.

I believe that my relevant experience and technical expertise in analysing public health datasets, management of data and databases was further strengthened through Australia's only Field Epidemiology Training Program (FETP). Throughout the MAE, I was able to further develop my skills, including, self-directed learning, reflective practice and building confidence and skills in data analysis, study design development and scientific writing. The transition into the COVID-19 Response Branch as an MAE was relatively easy due to my previous professional experience with several sections of the directorate. It is important to note that I still had to ensure that my role as an MAE scholar was understood so that I could separate myself from my previous role.

Summary of Degree Requirements

Major Requirements

Analysis of public health data

Assessment of severity and symptom characteristics between SARS-CoV-2 Omicron (B.1.1.529) and Delta (B.1.617.2) variant infections in the Australian Capital Territory

Investigation of an acute public health problem

Outbreak investigation of SARS-CoV-2 Beta (B.1.351) variant in hotel quarantine, Australian Capital Territory, March 2021.

Implementation/Evaluation of a Public Health Surveillance System

Evaluation and establishment of an improved surveillance system for salmonellosis in the Australian Capital Territory

Design and conduct an epidemiological study

Investigating the association between air pollution and asthma-syndrome-related emergency department and community health care presentations in the Australian Capital Territory, 2015-2019

Additional Requirements

Literature Review

A targeted literature search and synthesis of relevant information was undertaken for each project.

Prepare a scientific manuscript for a peer-reviewed journal publication

- I was the main author of a manuscript that was submitted to *BMJ Public Health*:
  Gomez A, Kelly M, Sloan-Gardner TS, Voo TV and Kirk MK. Assessment of severity and symptom characteristics between SARS-CoV-2 Omicron (B.1.1.529) and Delta (B.1.617.2) variant infections in the Australian Capital Territory: A Cross-Sectional Study *(In-review)*
- I was a co-author of an outbreak investigation submitted to *Communicable Disease Intelligence (CDI)* by a fellow MAE scholar from my cohort, Yasmin Lisson:
  Lisson Y, Marmor A, **Gomez A,** Hall R, Parry A, Wright R, and Lal A, 2023, Cohorting children in a childcare setting: a strategy to reduce SARS-CoV-2 Delta transmission, August-September 2021. Communicable Disease Intelligence, 47,
  DOI: https://doi.org/10.33321/cdi.2023.47.22

Conference/Oral Presentations

- "SARS-CoV-2 Beta variant outbreak investigation", presented at a Lunch'n'Learn session for the COVID-19 Response Branch Operations team, ACTHD, 10 June 2021.
- "Will there be hotel quarantine again? Lessons from an outbreak investigation", presented at Communicable Diseases and Immunisation Conference (CDIC2022), 20-22 June 2022.
- "Symptomology of SARS-CoV-2 variants in the Australian Capital Territory: A Cross-Sectional Study", presented at Communicable Diseases and Immunisation Conference (CDIC2022), 20-22 June 2022.
- "Oops, I got it again: multiple episodes of COVID-19 in the ACT", presented at Canberra Health Annual Research Meeting (CHARM2022), 26-29 July 2022.
- "Experience with the World Health Organization, Western Pacific Regional Offices", presented at the Education Sessions for the COVID-19 Response Branch, ACT Health, 18 October 2022.

Communication to a lay audience

On 11 August 2021, Tim Sloan-Gardner and I presented information through WIN News Canberra (local news television broadcast) on case follow-up, contact tracing and the utility of QR code ("CheckIn CBR application") technology on the response to COVID-19 outbreak investigations. The aim of the news broadcast was to educate the public regarding information on how ACT Health was helping the NSW Ministry of Health with their case investigation and COVID-19 situation (**Chapter III**).

On 31 May 2022, I developed a lay summary and interview guide for the COVID-19 Case Investigation team regarding standardised questions to ask for emerging variants/sub-variants of concern. This was to help understand the epidemiology of these newly identified variants (**Chapter II**).

On June 2022, HPS distributed a letter to General Practitioners and clinical practices in ACT regarding the change in processes of the public follow up of salmonellosis as part of one of my major projects (**Chapter IV**).

On 18 October 2022, I presented my experiences and lessons learned (in a hybrid presentation) during my time with the WHO as a FEFP fellow to the teams in the COVID-19 Response Branch and staff at HPS. The presentation detailed my involvement with the Health Emergency Information and Risk Assessment (HIM) team within the WHE. It highlighted the important work that the WHE conducts for the Western Pacific region and key public health surveillance concepts that was utilised during my time as an FEFP fellow (**Chapter VII**).

On 27 November 2022, my manuscript on severity and symptom characteristics of SARS-CoV-2 infections was highlighted by The Canberra Times newspaper. The article mentions that the Canberra community should remain vigilant even if there are little public health and social restrictions. This newspaper article was published at the time where there was an increase in reported COVID-19 cases in Australia (**Chapter II**).

Teaching of topics in field epidemiology

I participated in teaching to first year MAE scholars. Our teaching group, which comprised of half the MAE2021 cohort, chose to present a topic on notifiable conditions in Australia. We had come to an agreement that this was a topic that could have been highlighted better in one of our course blocks and could be helpful in providing a better platform for scholars that have had very little public health experience (**Chapter VI**).

I also prepared and conducted a teaching module on creating a survey using Research Electronic Data Capture (REDCap) to the MAE2021 cohort. REDCap is a data management platform that has various public health utilities. I chose this topic after developing multiple automated surveys for the ACTHD outlined in my outbreak investigation and surveillance project (**Chapter III and IV**, respectively).

Coursework

I successfully completed the following coursework units of the MAE program:

- POPH8920 - Outbreak Investigation (Semester 1, 2021)
- POPH8917 - Public Health Surveillance (Semester 1, 2021)
- POPH8913 - Analysis of Public Health Data (Semester 2, 2021)
- POPH8915 - Research Design and Methods (Semester 2, 2021)
- POPH8914 - Issues in Applied Epidemiology (Semester 1, 2022)

Additional field placement activities and experiences

In addition to projects related to the core requirements of the MAE, I was involved in the following activities and experiences which are all described in **Chapter VII**:

- FEFP Fellow at the WHO, WPRO at Manila, Philippines.
- Involved with the acute response to one of the largest ever foodborne outbreaks in the ACT, with the CDC section, HPS, ACTHD.
- Management of a data analysis project that investigated multiple episodes of SARS-CoV-2 infections in the ACT. The results of the project were presented at the research conference meeting at CHARM2022.

Summary of MAE Course Requirements

Table 1 provides a summary of how my projects and experiences meet the core MAE degree requirements.

Competency	Thesis Chapter						
	Chapter I	Chapter II	Chapter III	Chapter IV	Chapter V	Chapter VI	Chapter VII
Investigation of an acute public health problem		✓				✓	✓
Analysis of a public health dataset			✓				✓
Evaluate/Establish a surveillance system				✓			
Design and conduct an epidemiological study					✓		
Literature Review		✓	✓	✓	✓		
Conference abstract and presentation		✓	✓			✓	✓
Peer-reviewed publication		✓					✓
Field-reports					✓	✓	✓
Communication to a non-scientific audience		✓	✓	✓	✓	✓	✓
Group teaching and evaluation						✓	
Lessons from the field						✓	

Chapter II

Assessment of Severity and Symptom Characteristics between SARS-CoV-2 Omicron (B.1.1.529) and Delta (B.1.617.2) Variant Infections in the Australian Capital Territory, Australia: A Cross-Sectional Study

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List of Abbreviations

ACT	Australian Capital Territory
ACTHD	ACT Health Directorate
ANU	Australian National University
ART	Acute Response Team
CDNA	Communicable Diseases Network Australia
CDGN	Communicable Disease Genomics Network
CHECC	Clinical Health Emergency Coordination Centre
CHO	Chief Health Officer
CHS	Canberra Health Services
COVID-19	Coronavirus disease 2019
DoH	Department of Health (The Australian Government)
GISAID	Global Initiative on Sharing All Influenza Data
HECC	Health Emergency Control Centre
NCEPH	National Centre for Epidemiology and Population Health
PANGOLIN	Phylogenetic Assignment of Named Global Outbreak Lineages
PCR	Polymerase chain reaction
PHECC	Public Health Emergency Coordination Centre
PHO	Public Health Officer
RT-qPCR	Reverse transcription quantitative polymerase chain reaction
SARS-CoV-2	Severe-Acute-Respiratory-Syndrome Coronavirus-2
VOC	Variant of Concern
VOI	Variant of Interest
VUI	Variant Under Investigation
WGS	Whole-genome sequencing
WHO	World Health Organization

1.0 Prologue

1.1 Study Rationale

This chapter contains the research publication summarising my data analysis project that investigated the symptom and clinical characteristics between SARS-CoV-2 Delta (B.1.617.2) and Omicron (B.1.1.529) variant infection. The research concept and objectives were established during the beginning of the local SARS-CoV-2 Delta (B.1.617.2) wave on August 2021 in the ACT. An analysis on the symptom and clinical characteristics of the then dominant SARS-CoV-2 Delta strain was requested to inform the relevant public health risk assessments conducted at the time. Furthermore, I undertook this project in the middle of Course Block Two along with other mandatory assessment requirements. The situation added more complexity to the already busy schedule of the MAE during this time. I was the principal researcher for the data analysis project, and I was responsible for liaising with the multiple teams of the COVID-19 Response Branch. This includes (but is not limited to) obtaining appropriate datasets required for this project and validation of immunisation records for the study sample. This analysis was completed through routine data analysis and reporting that was being completed at the time. I was able to analyse the requested dataset and provide input to the ever-changing COVID-19 situation in the ACT.

On 1 December 2021, the first case of SARS-CoV-2 Omicron variant was notified in the ACT. As reported in other Australian states and territories, this became an important period regarding the transition from Delta to Omicron SARS-CoV-2 infection dominance across the Australian population. As an insight, there was an increase of case numbers from approximately 30 cases per day (as a 7-day rolling average) in August 2021 to a peak of 1,900 confirmed cases notified at the beginning of January 2022. Instead of completing the original proposed study of describing the symptom and clinical characteristic of Delta infections, we decided to include cases of Omicron infections. We identified the need to describe the symptom and severity of individuals infected with the Omicron variant compared with those who are infected with the Delta variant. This was in hope to bridge the knowledge gap between the emerging variant of concern at the time and inform future public health risk assessments, modelling studies and impacts on hospital capacity.

1.2 My Role

I was the lead investigator and analyst for this project. To complete the analysis, I was required to complete a comprehensive data analysis plan (and in-fact, it was required to be updated multiple times due to the evolving situation of the Omicron wave and data collection processes in the ACT). I needed to ensure that the research questions and objectives were measurable and attainable so that appropriate analysis could be completed to answer said research questions and objectives. I was required to extract the relevant datasets from multiple data sources and completed all of the data matching required. At the time of the study, the COVID-19 Operations within the Health Emergency Control Centre (HECC) was undertaking a transitionary phase of implementing a new notifiable diseases system. Although it posed difficulty in many aspects, I had enough in-depth knowledge of the systems and processes in place to be able to conduct the data analysis. I developed STATA scripts to analyse the dataset and produce complex statistical analysis through univariate and multivariate logistic regression. I was able to reshape the data so that the appropriate visualisation could be completed through R (statistical programming software).

1.3 Lessons Learnt

This project provided many lessons learnt. This project was my first real introduction to using STATA for complex statistical analysis. I used the project as an opportunity to develop my skills in the statistical analysis program. Through this process, it highlighted the importance of understanding how the relevant data is (or intended to be) collected. It emphasised how the data collection process(es) can have a direct reflection of how it's extracted and interpreted. The benefits of a clean dataset (or in my case, multiple datasets) were observed when I was writing the coding script through STATA. There were many instances where I had to conduct further research (as well as through trial and error) into why certain coding did and did not function the way it should have. In addition to this, I found the importance of annotating code. I was able to repurpose existing codes I had written for a previous version of the analysis. This also helped when explaining why certain outputs were presented in a particular way when questioned or interrogated by the research team. I had greater appreciation in learning new software and statistical languages, as it was pivotal to allow the reproducibility of the analysis. This helped tremendously with being able to extract an updated dataset, identifying errors and/or missing data, and producing a new output. This was an achievement that I'm proud of, as I was able to use the

teachings from course block two and apply it to this research project specifically. The proficiency I gained through this project was applied to other projects.

Over the course of the project, I found greater appreciation in being able to extract from multiple sources and match multiple datasets into one workable format. Whilst conducting this study, ACTHD were in the process of implementing a new centralised notifiable system which meant that there were multiple data sources that I needed to extract and match with my study sample. I had to complete data matching procedures multiple times due to the multiple versions of the data analysis plan (in which I had to include Omicron cases). Overall, I had to be flexible with my situation having to juggle course block, ongoing field work for the COVID-19 Response Branch and manage expectations regarding this project.

This major project was an opportunity to demonstrate my competency in writing an advanced draft of a manuscript for research publication. I was able to refine my skills in the management and wrangling of data, but also improved my writing style immensely. I have learnt how to manage expectations during periods where there was a high workload both in my field placement and regarding MAE course work. I have learnt to write often, and to write early. This meant that I could progress the project enough when self-imposed deadlines present itself sooner than anticipated. At the beginning of my candidature, I was worried that submitting incomplete or non-polished work would mean that it would bring negative viewpoints about the quality of work that I produced. I have learnt that submitting numerous drafts in, more often, meant that there was further potential in receiving constructive feedback from the research team. An abstract and presentation from this major research project was submitted and accepted into a Communicable Diseases and Immunisation Conference 2022 (CDIC 2022). This was one of the first hybrid public health conference sponsored by the Public Health Association of Australia (PHAA) since the beginning of COVID-19 pandemic.

1.4 Public Health Implications

To our knowledge, this is the first study to analyse the symptomatology of SARS-CoV-2 Omicron and Delta variant infections in an Australian context. This study was able to utilise an automated survey tool that allowed for a collection of presentation (or lack therefore) symptoms through an individual's public health follow-up period. It used validated information regarding vaccination status and clinical outcomes such as hospitalisation. In the study, we have noted that understanding the associations between the number and type of symptoms, and its influence regarding clinical outcomes may inform future public health and control measures. It is important to note the importance of the rapid detection and characterization of new and emerging SARS-CoV-2 variants. This research project was also highlighted by local newspaper The Canberra Times, published on 27 November 2022 (Appendix 3).

1.5 Acknowledgements

I would like to thank Professor Martyn Kirk for contributing to the inception of the project and academic support. I would also like to thank my field supervisors Timothy Sloan-Gardner and Rebecca Hundy for their ongoing support through the fast-paced environment within the COVID-19 Response Branch. I received valuable academic advice from my academic supervisor Dr Matthew Kelly, and associate academic supervisor Dr Davoud Pourmarzi. I would like to place a special mention to Tze Vun Voo for the assistance in producing the visualisation for the study in R studio. I would like to make a special mention to Mric Gomez from the Case Investigation team for his work on validating COVID-19 Vaccination Status for this project.

I would like to express my gratitude and acknowledge all of the persons affiliated with the following organisation for their support and contribution to this analysis:

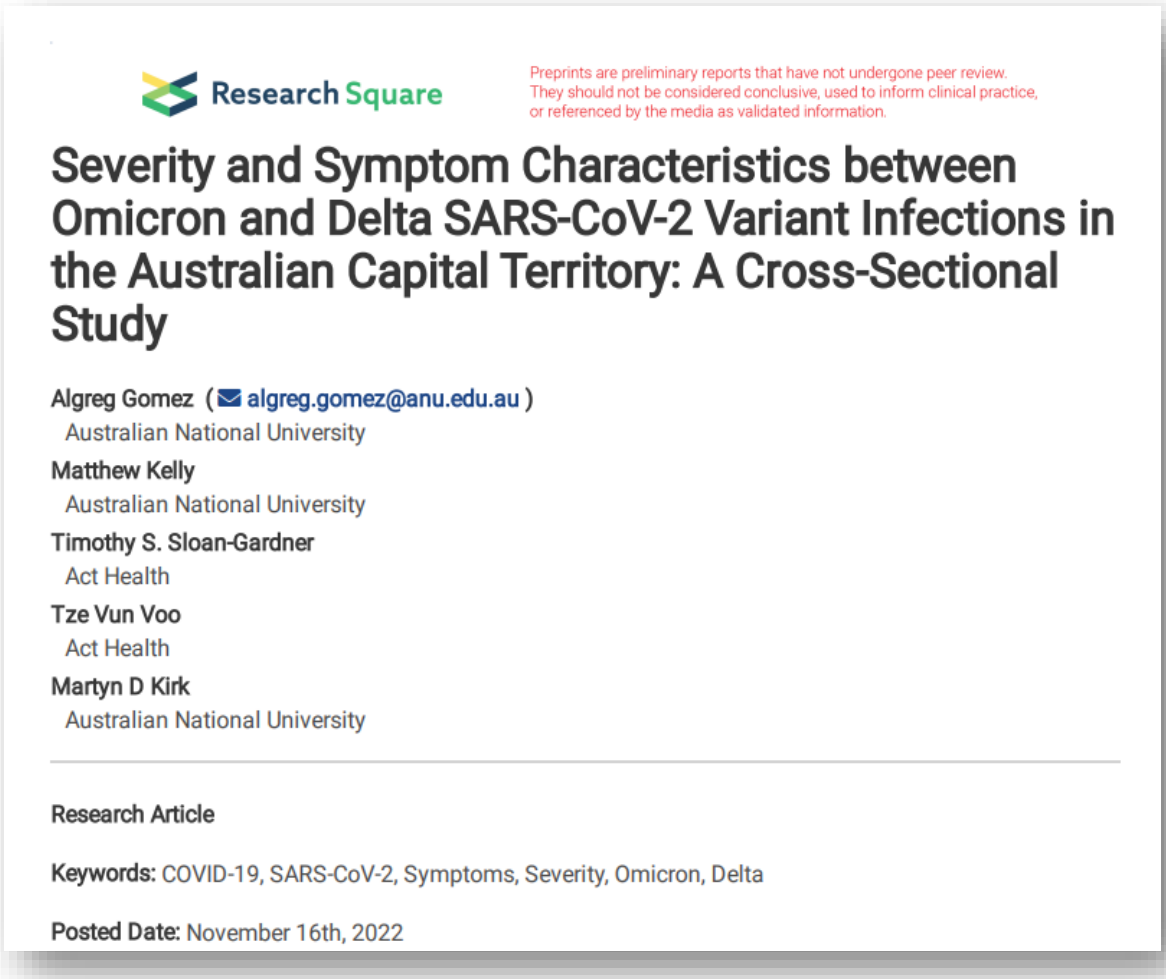
- Clinical Health Emergency Coordination Centre (CHECC), Canberra Health Services (CHS);
- Health Emergency Control Centre (HECC), ACTHD;
- The National Centre for Epidemiology and Population Health (NCEPH), Australian National University (ANU);
- The Schwessinger Laboratory, Australian National University (ANU)

1.6 Master of Philosophy in Applied Epidemiology core activity requirement

- Analyse a public health dataset
- Preparation of an advanced draft of a paper for publication in a national or international peer-reviewed journal,
- Report for a non-technical audience,
- Prepare an abstract and oral presentation of the project at a national or international scientific conference.

This following chapter is presented as an advance draft manuscript to **BMC Public Health**.

Advanced Manuscript to BMC Public Health, accepted as a preprint with Research Square.



Research Square

Preprints are preliminary reports that have not undergone peer review. They should not be considered conclusive, used to inform clinical practice, or referenced by the media as validated information.

Severity and Symptom Characteristics between Omicron and Delta SARS-CoV-2 Variant Infections in the Australian Capital Territory: A Cross-Sectional Study

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2.0 Abstract

Background: Despite the widespread dominance of SARS-CoV-2 Delta (B.1.617.2 lineage) and Omicron (B.1.1.529 lineage) variants, there has been little information detailing differences in the presentation of symptoms and clinical characteristics. Characterising symptom and severity profile is important for understanding emerging SARS-CoV-2 variants.

Methods: We conducted a retrospective cross-sectional study of all laboratory-confirmed SARS-CoV-2 infections notified in the Australian Capital Territory (ACT), Australia, between 12 August 2021 and 21 January 2022. Symptom data were ascertained through the initial case investigation interview, and by using either an automated survey or phone interview through routine public health follow-up. The symptom status (and the specific symptoms experienced) was collected during the routine follow-up for a case for their full isolation period. We used validated vaccination status through the Australian Immunisation Register (AIR). We used a multivariable logistic regression model to estimate adjusted odds ratios (aOR) for hospitalisation with the Delta and Omicron SARS-CoV-2 variants. We compared the difference in proportions of individual symptoms experienced using Pearson's $\chi 2$ tests, Wilcoxon rank sum test or Fisher's exact tests. We considered results significantly different where p-value was less than 0.05.

Results: We found that a higher proportion of individuals infected with Omicron (32% 144/452) were asymptomatic compared to those infected with Delta (12% 74/613). The most commonly reported symptoms for Delta infections were cough (62%, 381/613), headache (55% 338/613), fever (47% 290/613) and runny nose (47% 289/613). The most commonly reported symptoms for Omicron infections were runny nose (54% 242/452), cough (53% 240/452), sore throat (41% 181/452) and lethargy (39% 176/452). The regression results indicate that cases with the Omicron variant infection had a lower odds of hospitalisation (OR 0.29 95% CI 0.16-0.53 $p<0.01$) compared to cases infected with Delta variant independent of vaccination status, although the results were uncertain as it was not significant when adjusted.

Conclusion: We found that symptom characteristics were different across Omicron and Delta SARS-CoV-2 infections. Furthermore, we found that individuals infected with Omicron were more likely to report no symptoms at all, although vaccination status may have played a role in this cohort. Overall, infection with the Delta variant was more likely to result in hospitalisation.

Keywords: COVID-19, SARS-CoV-2, Symptoms, Severity, Omicron, Delta

3.0 Background

Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) is the virus responsible for COVID-19 (Coronavirus Disease 2019). The World Health Organization (WHO) declared a global pandemic on the 11th of March 2020. Since the first case of SARS-CoV-2 on 12 March 2020, the Australian Capital Territory (ACT), Australia had three distinct epidemic waves up to November 2022. The second and third waves were the result of community transmission of two SARS-CoV-2 variant of concern (VOC), Delta (B.1.617.2 lineage) and Omicron (B.1.1.529 lineage). Delta was first isolated in India and was designated a VOC on 11 May 2021, and predominated globally until Omicron. Omicron VOC was identified on November 9, 2021 in South Africa, a strain characterised by greater infectiousness and milder clinical course (1). These two strains have had major international impacts due to their dominance over other well-defined VOCs globally (1,2). In Australia, cases of Omicron increased in all states and territories following the emergence in the country in December 2021(3).

Australia's surveillance strategy for COVID-19 focused on testing individuals returning from international travel, those with symptomatic disease and people designated close contacts (4). Part of this active surveillance strategy relies on the specific symptoms experienced and their severity (5). The Delta variant is associated with more severe outcomes such as hospital and intensive care unit (ICU) admission compared to previously identified VOCs, Alpha (B.1.17), Beta (B.1.351) and Gamma (P.1) variant infections (6,7). Recent literature suggests that the Omicron variant significantly reduces the odds of hospitalisation compared to other previously identified VOCs (8,9). It is important to characterise and understand the clinical severity of infections based on strain type. In general, COVID-19 in adults predominantly manifests with fever, cough, anosmia, dyspnoea, and myalgia, whilst children and young adults are characterised to have mild symptoms or are completely asymptomatic (10-12). Less common symptoms include fatigue, confusion, arthralgia, haemoptysis and ageusia but these have been mainly described in previously identified prominent SARS-CoV-2 variants (12-15). Evidence to date supports the hypothesis that children are more likely to be asymptomatic or display fewer symptoms than adults (7,9). The absence of active surveillance, such as the lack of testing in people who are either asymptomatic (or in a pre-symptomatic phase: presence of illness before the appearance of symptoms), may lead to an underestimate of the true incidence of SARS-CoV-2 infections (16,17). Furthermore,

public health measures such as placing infectious individuals in quarantine may not be effective in slowing the epidemic progression if asymptomatic (or pre-symptomatic) individuals do not seek testing (16).

Currently, information regarding symptom characteristic and clinical features of SARS-CoV-2 Delta and Omicron infections are scarce. Many studies focus on specific symptoms at the initial case interview, although there have been a few longitudinal and repeated measurement studies of COVID-19 symptoms (13,14). In addition, there is very little data regarding how symptoms present by vaccination status. Describing the symptom characteristics of SARS-CoV-2 variants is not only important for clinicians to assist with early detection of acute infection, but also with informing health risk assessments and potentially reducing the likelihood of severe outcomes (17,18). Furthermore, there are public health benefits more broadly, such as informing appropriate messaging to the public, which in turn has an impact on health resources. The aim of our study was to characterise how SARS-CoV-2 Delta and Omicron infections vary in symptomology by sex, age and vaccination status throughout an individual's infection between 12 August 2021 and 21 January 2022, in one of Australia's eight states and territories—the Australian Capital Territory (ACT).

4.0 Methods

4.1 Study design and data sources

We conducted a cross-sectional study of all laboratory-confirmed SARS-CoV-2 infections notified in the ACT, Australia, between 12 August 2021 and 21 January 2022. We defined a case as an individual with a throat and nasopharyngeal swab specimen collected and analysed by reverse transcription quantitative polymerase chain reaction (RT-qPCR) by a public health laboratory pathology provider in the ACT. Our inclusion criteria take into account all confirmed cases managed by ACT Health Directorate at the time of notification. Notification data were extracted from a centralised Notifiable Disease Management System. Whole-Genome Sequencing (WGS) analysis were conducted by The Schwessinger Laboratory at the Australian National University (ANU). All cases in this study were confirmed as either Omicron or Delta strain.

4.2 Data collection

All data were stored in a Research Electronic Database Capture (REDCap, Vanderbilt University) or the centralised Notifiable Disease Management System for surveillance of confirmed COVID-19 cases in the ACT. The inclusion criterion was guided through the definition of a suspected and confirmed SARS-CoV-2 infection outlined by the Communicable Diseases Network Australia (CDNA) Series of National Guidelines for Public Health Units (version 6.4) (18). Public health officers, public health nurses, and epidemiologists collected data using standardised phone interviews. At the time of the data collection, there was a transition from 14-days of mandatory isolation requirement to 7-days. Most Omicron cases were subjected to 7-days of isolation compared to 14-days for Delta cases. The data collected during the initial interview included: demographic characteristics (date of birth and sex), SARS-CoV-2 test results (RT-PCR results), self-reported comorbidities, self-reported symptoms, and hospitalisation status. Hospitalisation status was defined as any admission and include multiple admissions to a private or public hospital in the ACT, Australia within an infected individual's active follow-up period. Hospitalisation status was validated by the Clinical Health Emergency Coordination Centre (CHECC). Self-reported comorbidities were defined as any identified health conditions that may place an individual at risk of severe complication which includes any one or more of the following conditions: asthma, immunosuppression condition/therapy, renal disease, diabetes, hypertension, liver disease and/or neurological disorder. The questionnaire included binary fields (yes or no questions) regarding specific symptoms experienced: fever, cough, dyspnoea, malaise, fatigue, loss of taste and/or smell, sputum/respiratory secretions, headache, sore throat, shortness of breath (defined as the subjective perception of shortness of breath or difficulty of breathing by the patient), myalgia, rhinorrhoea, chills, diarrhoea, vomiting and "other". The "other" option designates a free text field whereby other symptoms that were not listed could be described and collected. If a case is less than 18 years of age, the standardised phone interview and survey was conducted with or in the presence of a parent or guardian.

After the initial interview, all of the cases were followed up using either an automated survey or phone interview on a daily basis for the full duration of their isolation period that collected information regarding their symptom status (whether any symptoms were experienced at the time of survey) and specific symptoms experienced. The output from each daily survey is aggregated as a single value per person as symptom

is ever present or not. Isolation period was defined as the date for when a case entered self-isolation until they were cleared by medical and public health professionals of ACT Health's Public Health Emergency Coordination Centre (PHECC), defined by the national guidelines at the time. During the study period in January 2022, rather than conducting phone interviews for all laboratory detected SARS-CoV-2 infection, the ACT shifted focus on managing high risk and sensitive sites and individuals that may be affected by COVID-19, but still completed an online survey.

4.3 Vaccination Status

Public health staff conducted a validation procedure for an individual's vaccination status at the time of infection through a population-wide vaccination register—the Australian Immunisation Register (AIR). Vaccination status was defined as: (i) Unvaccinated: individuals who had not received any doses of a SARS-CoV-2 vaccine received or 1 dose receive with less than 14 days between diagnosis date, (ii) Partially vaccinated: individuals who have had only 1 dose received 14 days after diagnosis date, or 2 doses with less than 14 days between a diagnosis date and the second dose was received and (iii) Fully vaccinated: individuals who had received 2 doses with more than 14 days between diagnosis date and second dose received which included a third dose, if applicable. The COVID-19 vaccine doses that were approved for use at the time of investigation is one dose of COVID-19 Vaccine Janssen (Johnson & Johnson, New Brunswick, United States) for a full coverage, or two doses of Comirnaty (Pfizer/BioNTech, Mainz, Germany/New York, United States) or Vaxzevria (AstraZeneca, Cambridge, United Kingdom), Spikevax (Moderna, Cambridge, United States).

4.4 Statistical Analysis

We analysed a de-identified line-list of data using Stata Statistical Software, Release 17 (College Station, TX: StataCorp LLC) and R, version 4.1.0, statistical software (R Foundation for Statistical Computing, Vienna, Austria) (20,21). Categorical data were presented as frequency and proportions. Continuous variables were described using mean, Standard Deviation (SD), median, range and interquartile range (IQR). We compared the difference in proportions using Pearson's χ^2 tests, Wilcoxon rank sum test or Fisher's exact test.

Demographic data were presented as descriptive statistics. Age was collected as a continuous variable, but categorical aged-groups were applied. We compared SARS-CoV-2 Delta variant infections (where only Delta was present in the ACT) notified between August 12 and 30 September 2021, with cases sequenced with the Omicron variant between 1 December 2021 and 21 January 2022 (where all confirmed Delta cases were excluded). Univariable analysis was conducted, and a step-wise elimination strategy was employed to remove any variable that had no significant effect on the final multivariable model. All variables with *p* less than 0.25 was included in the final multivariable logistic model. We conducted multivariable logistic regression to examine the association of different variant infections with hospitalisation as a proxy for disease severity. We used a multivariable logistic regression model to estimate an adjusted odds ratio (aOR) for hospitalisation across all SARS-CoV-2 infections. The results were considered statistically significant where was *p* is less than 0.05.

5.0 Results

5.1 Demographic Characteristics

From 12 August 2021 to 21 January 2022, there was a total of 1065 confirmed cases that met the inclusion criteria for this study. Of these cases, 58% (613/1065) returned a genomic sequencing result with the Delta variant, with the remainder being the Omicron variant. Overall, the median age of cases was 28 years (range: 0 months to 95 years), with individuals infected with a Delta infection statistically younger in age (mean = 28, *SD* = 17 years) compared to cases infected with the Omicron variant (mean = 31, *SD* = 15 years). Most cases were in the 19–39-year-old age-group (54% 575/1065).

Overall, 51% (545/1065) of cases were male. Data regarding vaccination status was available for all cases in the study. Only 6.2% (38/613) of cases infected with Delta were fully vaccinated at the time of infection, which was significantly different to those infected with Omicron (85% 385/452). Overall, 21% (223/1065) of cases reported at least one comorbidity, which was similar for Delta and Omicron cases (Table 1).

5.2 Clinical Characteristics

In total, 6.6% (70/1065) of all cases were hospitalised, with 77% (54/70) of these being not fully vaccinated at the time of infection, 10% (7/70) of hospitalised cases were partially and 13% were fully vaccinated (10%, 7/70 and 13%, 9/54). The crude proportions of cases hospitalised was lower for Omicron (9%, 57/613) than Delta (3%, 13/452). Of all cases admitted to hospital, a small number of patients were admitted to the ICU (11% 8/70). A total of 43% (3/7) of these patients required oxygen support through mechanical ventilation whilst admitted in ICU. All cases admitted to ICU and subsequently requiring ventilation support due to COVID-19 complications were infected with the Delta variant (Table 1). There were no COVID-19-related deaths among the study population.

5.3 Symptom Characteristics

Overall, 80% (847/1065) of cases reported at least one symptom during their follow-up period. A higher proportion of individuals infected with Omicron were asymptomatic (32%, 144/452) compared to those infected with Delta (12%, 74/613) (Table 2). Headache, fever, joint pain, shortness of breath and chest pain were more predominant with Delta than Omicron (Figure 1). The vaccination status for the 0–12-year old age-group did not differ, therefore we deemed it appropriate to compare proportions of each individual symptoms. The presence of abdominal pain, sore throat, runny nose and cough were similar across the 0–12-year age group.

The most commonly reported symptoms for Delta infections were cough (62%, 381/613), headache (55%, 338/613), fever (47%, 290/613) and runny nose (47%, 289/613). The most commonly reported symptoms for Omicron infections were runny nose (54%, 242/452), cough (53%, 240/452), sore throat (41%, 181/452) and lethargy (39%, 176/452). Fever, nausea and loss of taste or smell was more prominent in the 0-12 year group for Delta infections compared to cases with Omicron (Figure 1). There were distinct symptoms that were different in proportion between Delta and Omicron variant infections, including: fever, cough, runny nose, headache, lethargy, myalgia (muscle pain), joint pain, diarrhoea, nausea/vomit, loss of taste or smell and night sweats (Figure 2). Overall, lethargy is the only symptom that was more common in proportion in Omicron infected individuals compared to those infected with Delta (Figure 3). The median number of symptoms reported was higher for cases infected with Delta (median=4, IQR=2-7) compared to cases infected with Omicron (median=3, IQR=0-6).

5.4 Regression Analysis Results

In multivariable logistic regression people aged 40-59 years (aOR 3.01, 95% CI 1.29-7.03 $p<0.05$) and over 60 years (aOR 5.95, 95% CI 1.53-16.67 $p<0.05$) had higher odds of hospitalisation (Table 2). People who were unvaccinated (aOR 6.38, 95% CI 3.32-27.46 $p<0.01$) had significantly higher odds of hospitalisation. The regression results indicate that cases with the Omicron variant infection had a lower odds of hospitalisation (OR 0.29 95% CI 0.16-0.53 $p<0.01$) compared to cases infected with Delta variant regardless of their vaccination status. The association did not reach statistical significance when adjusted for other variables.

6.0 Discussion

Our study found that infection with Omicron was less likely to result in hospitalisation and had different symptoms and clinical characteristics compared to Delta SARS-CoV-2 infections, even after accounting for vaccination status. Overall, we have shown that unvaccinated individuals had over six times higher odds of hospitalisation. This was during a period of major strain dominance transition from Delta to Omicron in the ACT.

In our study, the majority of SARS-CoV-2 infections (80%) reported symptoms within their follow-up period. Consistent with other research, we found that individuals infected with the Omicron variant were more likely to be asymptomatic compared to Delta infections (21,22). Individual symptoms that were less prominent in individuals infected with Omicron were fever, cough, headache, muscle pain, joint pain, diarrhoea, nausea/vomit, loss of taste or smell and night sweats. Recent literature has described the propensity for different variants to infect different cells in the respiratory tract (23,24). It has been observed that in individuals infected with the Omicron variant, the virus enters different cells compared to Delta infections (25). Furthermore, it has been shown that there is lower viral replication in the lungs with an individual infection with an Omicron variant (23). This may explain the lower propensity of respiratory symptoms, such as cough, sore throat and runny nose, with Omicron infections compared with other SARS-CoV-2 variants (5,12,26). Lethargy was the only symptom that was significantly common in proportion in Omicron infected individuals compared to those infected with Delta. Cough, sore throat and runny nose were prominent across all age-groups irrespective of vaccination status or infective variant (Figure 3). It should also be noted that diarrhoea, abdominal pain, loss of smell and taste were reported to be present across all age-groups in the unvaccinated Delta

variant cohort compared to the Omicron variant group that consisted of mostly fully vaccinated individuals. There were no significant differences between symptom presentation by sex. The timing of variants and vaccine availability may have influenced our findings, as different variants and vaccination rates can impact the prevalence and severity of symptoms observed in infected individuals. These factors should be considered when interpreting the results and may require further investigation to fully understand their implications on symptom patterns.

We found that individuals infected with the Omicron variant had lower odds of being hospitalised than those with a Delta variant infection. It is important to note that due to the small numbers and the different population group that had a higher vaccination rate at the time of Omicron dominance may have contributed to the aforementioned statement. In addition, older (specifically, 40-59 and over 60 year) age-groups and unvaccinated cases had higher odds of hospitalisation which supports current evidence (27,28). We observed significantly different self-reported symptoms reported by cases infected with the two variants. In addition, the results show that there was a significantly higher total of individual symptoms reported with the Delta variant compared to Omicron variant infections. Since Australia's current surveillance strategy continue to rely on testing symptomatic individuals, there must remain a focus on public messaging regarding specific symptoms experience (with or without exposure to a COVID-19 case) (5). A key value of this study is that it will give clinicians insight into symptoms that may be indicative of COVID-19.

A key strength of the study is that we followed up cases prospectively until they were cleared under public health requirements. This meant that we could collect data on individual symptoms that may have been experienced later in the infection, compared to other studies that captured information at the initial case investigation interview. Another strength of this study is that we used validated information regarding vaccination status for COVID-19 for Australian residents. This allowed for a more accurate representation of the cohort compared to using self-reported vaccination status. It is important to note that all SARS-CoV-2 variants have the potential to cause severe disease, especially vulnerable populations. We also defined cases by WGS confirmation, compared to other studies that utilise period of time where one strain is predominant compared to another time period (26). Understanding the associations between the number of symptoms, specific groupings of symptoms, vaccination

status, and its influence on clinical outcomes may have merit in the reduction (and prevention) of severe outcomes (14,15,26,29). The rapid detection and characterisation of new and emerging SARS-CoV-2 variants is imperative in informing public health and control measures, and decision making that has the potential to impact health care systems (29,30).

Self-reported data can be subject to recall and misclassification bias. Consideration must be taken when interpreting reported symptom and comorbidities. Further to recall bias, many children (aged 17-years or below) may have had their parent/s or guardian conduct the interview or survey questionnaire on their behalf and may not have been able to articulate the range of symptoms that were (or were not) experienced. As previously outlined, rather than conducting phone interviews for all laboratory detected SARS-CoV-2 infection, the ACT shifted focus on managing high risk and sensitive sites and individuals that may be affected by COVID-19. This meant that confirmed cases were provided with an online questionnaire rather than the full extent of a phone interview and was applied to the majority of notified cases from January 2022 onwards. This may have influenced the detail collected for each case record. Another limitation is that we only considered whether an individual had any self-determined pre-existing health or medical condition present rather than specific (or delineated between) acute and/or chronic conditions.

Risk factors such as diabetes, prior cardiac or pulmonary disease have been associated with worse prognosis (31,32). The inclusion whether an individual has had any pre-existing conditions was a significant variable that influenced the multivariable logistic regression analysis. Future studies could investigate the interaction between specific health or medical condition with symptomology of COVID-19 patient (30,33). Lastly, vaccinated cases in the Delta group account for a small proportion overall within the study cohort. This may not be generalisable due to the high vaccination rates in the ACT at the time of the investigation. This was due to the limited vaccine eligibility and uptake (between August and November 2021) of cases included in the study. This reflects why most of the SARS-CoV-2 Delta infections were unvaccinated. Furthermore, waning vaccine-derived immunity have been a contributing factor to the increase in Omicron infections during the study period (34,35).

7.0 Conclusion

In this study, we describe how SARS-CoV-2 Delta and Omicron variant infections differ in their presentation of explicit symptoms within an individual's full public health follow-up period. The result of this analysis has given further weight to existing evidence that Omicron variant infections are less severe than those of Delta infections and present with different symptoms. The rapid detection and characterisation of new and emerging SARS-CoV-2 variants are imperative in informing public health and control measures. Moving forward, the focus will continue in addressing waning immunity through booster vaccine doses, development of multivalent vaccines and active surveillance within high-risk settings.

List of abbreviations

AIR: Australian Immunisation Register; CDGN: Communicable Disease Genomics Network; CDNA: Communicable Diseases Network Australia; CHECC: Clinical Health Emergency Coordination Centre; COVID-19: Coronavirus Disease 2019; ICU: Intensive Care Unit; OR: Odds Ratio; PHECC: Public Health Emergency Coordination Centre; REDCap: Research Electronic Database Capture; RT-qPCR: reverse transcription quantitative polymerase chain reaction; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus-2.

8.0 Declarations

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Ethical Considerations

All methods were carried out in accordance with the *Public Health Act 1997* for the purpose of a public health investigation and system quality improvement protocol. All experimental protocols, consent and data collection were conducted under the guidelines and regulation of the *Public Health Act 1997* and was approved by the Chief Health Officer, ACT Health Directorate.

Consent for publication

All methods were conducted under the *Public Health Act 1997* for the purpose of a public health investigation and system quality improvement protocol. Approval of research and data release was approved by the data custodian of public health investigations in the Australian Capital Territory under the *Public Health Act 1997.* As

this was a retrospective study, all data used was considered and approved by the Chief Health Officer, ACT Health Directorate.

Competing interests

The authors declare no competing interests

Availability of data and materials

The datasets generated and/or analysed during the current study are available from ACT Health on reasonable request.

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Authors contributions

AG, MDK, MK and TSG conceived and designed the study. AG and TVV contributed to acquisition, statistical analysis and interpretation of the results. All authors critically reviewed and provided intellectual input for preparing the manuscript. All authors read and approved the final version of manuscript submitted for publication.

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Table 1. Sociodemographic, clinical and outcome characteristics by SARS-CoV-2 variant (Omicron or Delta) – Australian Capital Territory, 12 August 2021 to 21 January 2022.

Characteristic	**Overall**, N = 1,065[1]	**Variant of Concern**		**p-value**[2]
		Delta, N = 613	**Omicron**, N = 452	
Age (at time of notification) in years				<0.001
Mean (SD)	29 (16)	28 (17)	31 (15)	
Median (IQR)	28 (20, 39)	27 (15, 39)	28 (22, 38)	
Range	0, 95	0, 95	0, 88	
Age Group in years, n (%)				<0.001
0 - 12 years	154 (14%)	119 (19%)	35 (7.7%)	
13 – 18 years	83 (7.8%)	69 (11%)	14 (3.1%)	
19 - 38 years	575 (54%)	276 (45%)	299 (66%)	
39 - 59 years	203 (19%)	124 (20%)	79 (17%)	
≥ 60 years	50 (4.7%)	25 (4.1%)	25 (5.5%)	
Sex, n (%)				0.032
Female	520 (49%)	282 (46%)	238 (53%)	
Male	545 (51%)	331 (54%)	214 (47%)	
Vaccination Status (at time of notification), n (%)				<0.001
Fully Vaccinated	423 (40%)	38 (6.2%)	385 (85%)	

Characteristic	**Overall**, N = 1,065[1]	**Variant of Concern**		
		Delta, N = 613	**Omicron**, N = 452	**p-value**[2]
Partially Vaccinated	87 (8.2%)	80 (13%)	7 (1.5%)	
Unvaccinated	555 (52%)	495 (81%)	60 (13%)	
Comorbidity, n (%)[$]	223 (21%)	124 (20%)	99 (22%)	0.5
Hospitalised (due to COVID-19), n (%)	70 (6.6%)	57 (9.3%)	13 (2.9%)	<0.001
Admitted to ICU (due to COVID-19), n (%)	8 (0.8%)	8 (1.3%)	0 (0%)	0.024
Ventilated (due to COVID-19), n (%)	3 (0.3%)	3 (0.5%)	0 (0%)	0.3

[1] n (%)

[2] Wilcoxon rank sum test; Pearson's Chi-squared test; Fisher's exact test

[$]Comorbidities were defined as any identified health conditions that may place an individual at risk of severe complication which includes any one or more of the following conditions: asthma, immunosuppression condition/therapy, renal disease, diabetes, hypertension, liver disease and/or neurological disorder.

SD: standard deviation, IQR: interquartile range, ICU: intensive care unit.

Figure 1: Distribution of reported symptoms, age-group (years) by SARS-CoV-2 variant (Omicron or Delta) - Australian Capital Territory, 12 August 2021 to 21 January 2022.

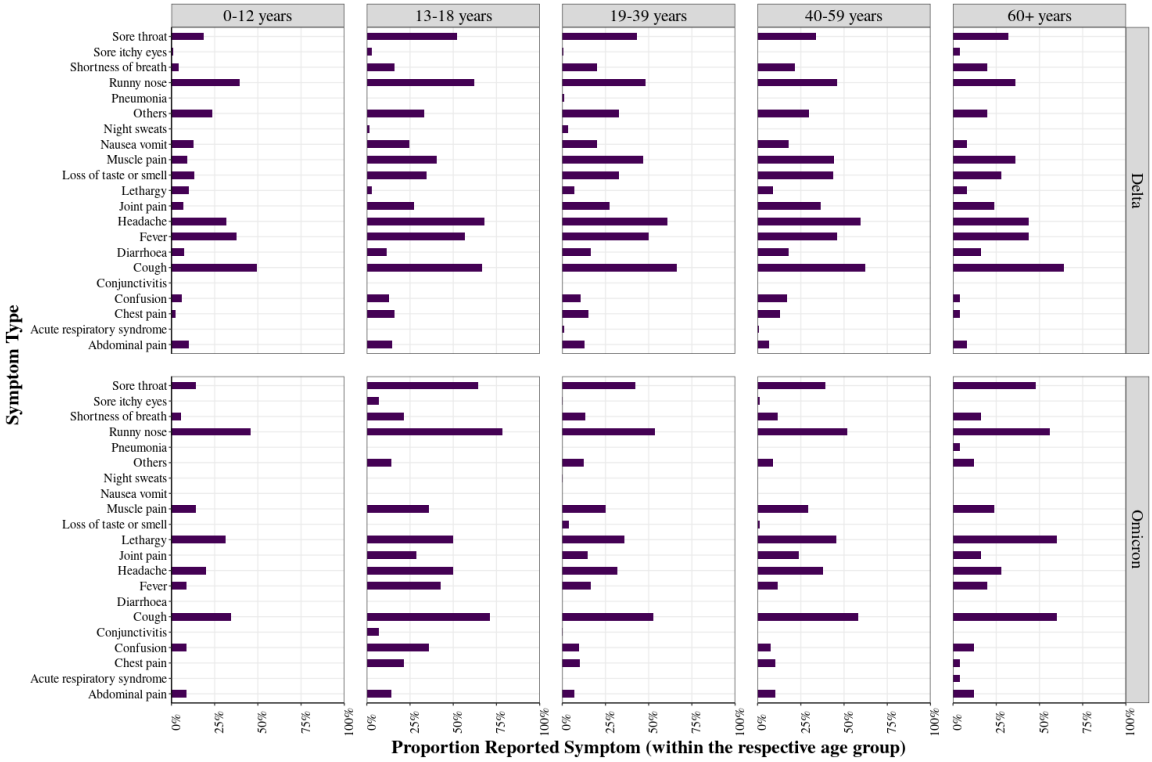


Figure 2: Heatmap distribution of reported symptoms, age (years) by SARS-CoV-2 variant (Omicron or Delta) - Australian Capital Territory, 12 August 2021 to 21 January 2022.

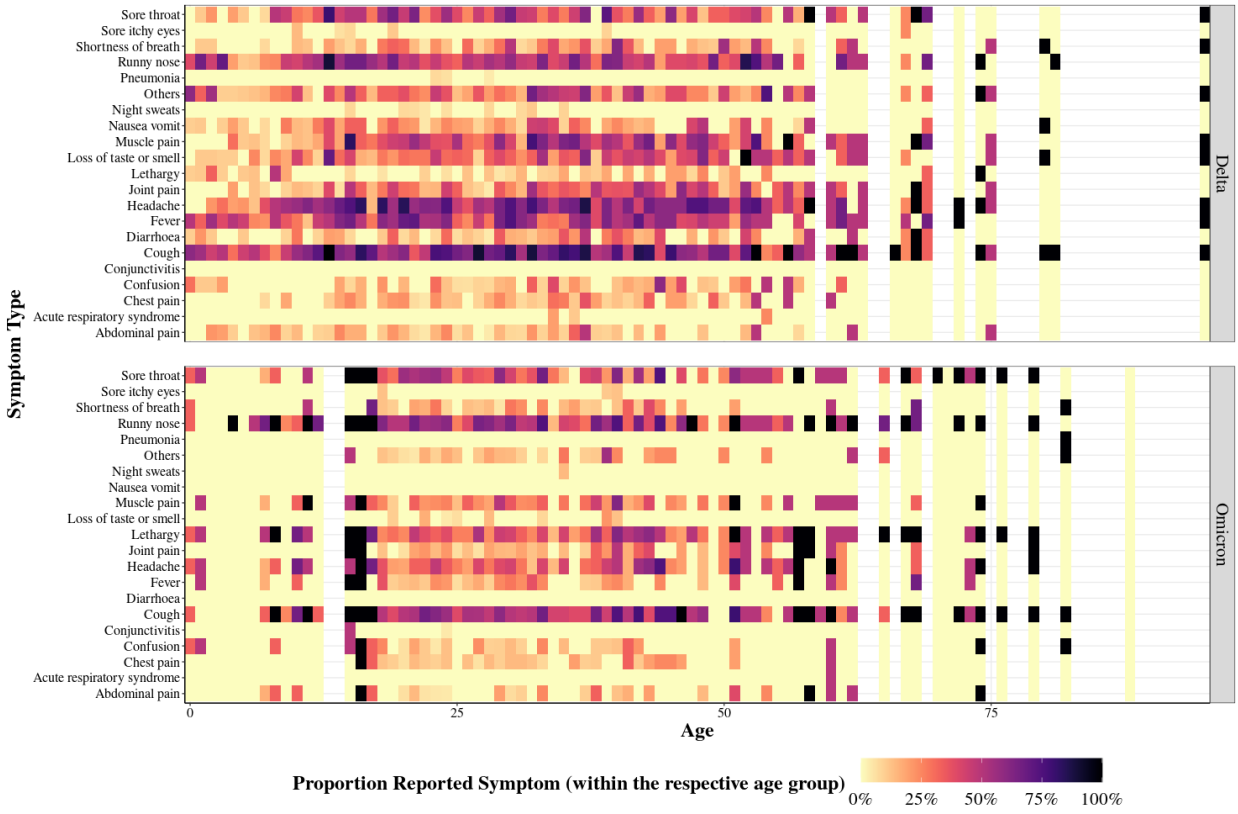


Figure 3: Heatmap of the proportion of reported symptoms by vaccination status and SARS-CoV-2 lineage type (Omicron or Delta).

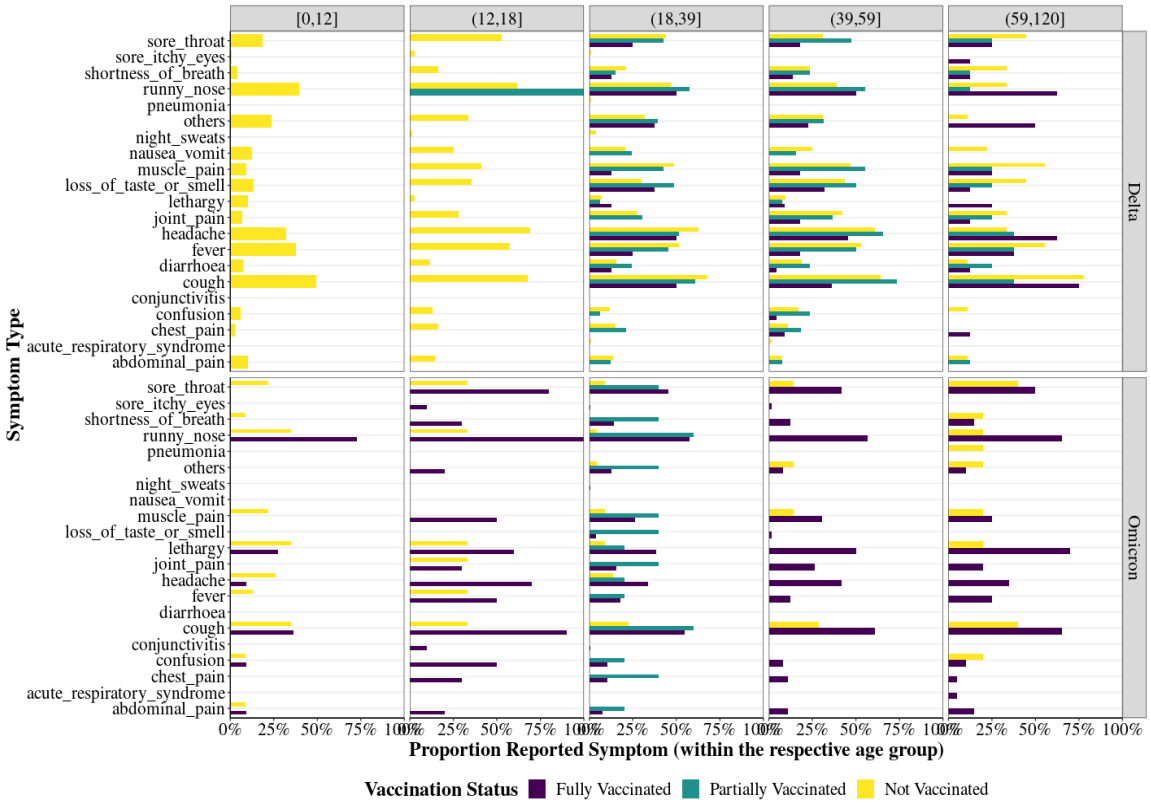
Table 2: Univariable and multivariable logistic regression (crude odds ratios [OR], adjusted odds ratios [aOR] and 95% Confidence Intervals) assessing key demographic and clinical factors associated with hospitalisation following SARS-CoV-2 infection.

Variable		Crude OR	95% CI*		P-value	aOR	95% CI*		P-value
			Lower Limit	Upper Limit			Lower Limit	Upper Limit	
Sex	Reference: Male	1	-	-	-	1	-	-	-
	Female	1.34	0.83	2.19	0.19	1.44	0.86	2.40	0.39
Age Group (in years)	Reference: 0-12 years	1	-	-	-	1	-	-	-
	13-18 years	0.92	0.30	2.80	0.89	0.92	0.30	2.82	0.89
	19-39 years	0.63	0.29	1.34	0.23	1.11	0.51	2.43	0.79
	40-59 years	1.57	0.71	3.47	0.26	**3.01**	**1.29**	**7.03**	**0.01**
	≥ 60 years	**4.06**	**1.61**	**10.26**	**0.00**	**9.55**	**3.32**	**27.46**	**0.00**
Vaccination Status	Reference: Fully Vaccinated	1	-	-	-	1	-	-	-
	Partially Vaccinated	**4.02**	**1.46**	**11.12**	**0.00**	2.71	0.80	9.18	0.11
	Unvaccinated	**4.96**	**2.42**	**10.16**	**0.00**	**6.38**	**2.46**	**16.54**	**0.00**
Comorbidity Status	Reference: No	1	-	-	-	1	-	-	-
	Yes	**1.68**	**0.99**	**2.87**	**0.06**	1.36	0.75	2.46	0.31
Symptoms Reported	Reference: No	1	-	-	-	-	-	-	-
	Yes	1.59	0.80	3.15	0.19	1.20	0.56	2.57	0.64
Lineage	Reference: Delta	1	-	-	-	1	-	-	-
	Omicron	**0.29**	**0.16**	**0.53**	**0.00**	0.75	0.33	1.72	0.50

*Confidence Interval. OR: Odds Ratio. aOR: adjusted Odds Ratio. Variables with a P-value less than 0.25 was included in the final multivariable logistic model. Highlighted in bold denotes statistical significance ($P < 0.05$) compared to the reference category.

Manuscript Appendices

Appendix 1: Proportion of reported symptoms by separated by age-group, vaccination status and SARS-CoV-2 lineage type (Omicron or Delta).

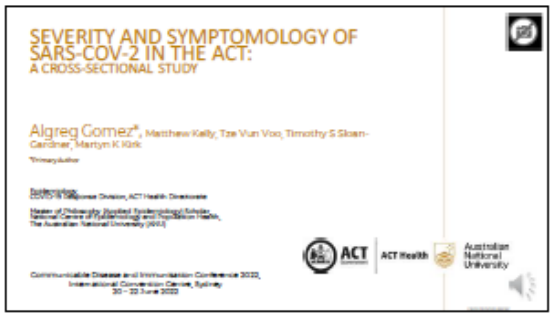


[End of advanced draft manuscript to BMC Public Health]

9.0 Appendices

Appendix 1: Presentation slides submitted and presented at the Communicable Diseases & Immunisation Conference 2022 (CDIC2022), 20-22 June 2022

International Convention Centre (ICC), Sydney, New South Wales



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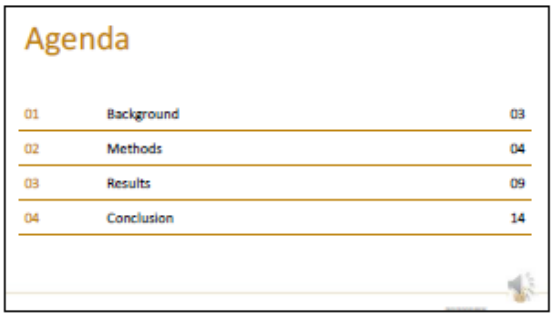

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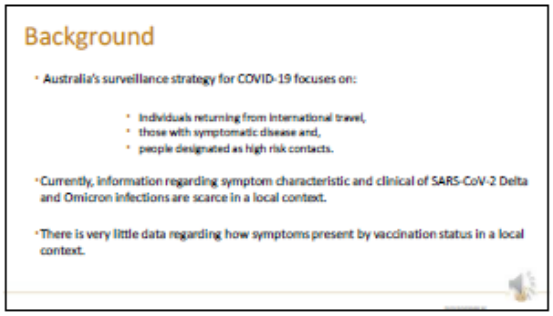

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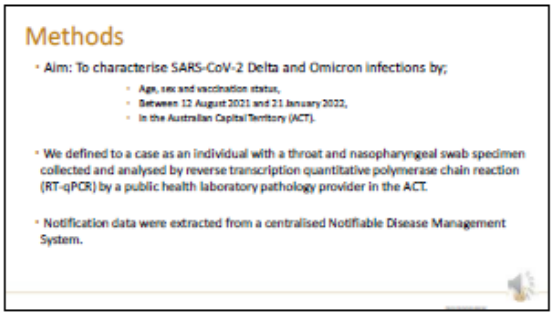

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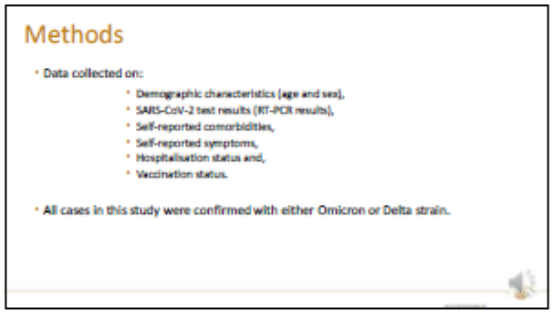

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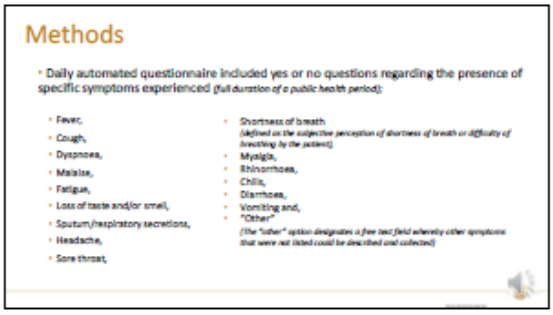

6

Methods

- Hospitalisation status: admission to a private or public hospital in the ACT, within an infected individual's active follow-up period.
- Vaccination status was defined as:
  - Unvaccinated: individuals who had not received any doses of a SARS-CoV-2 vaccine,
  - Partially vaccinated: individuals who have had only 1 dose received, or 2 doses with less than 14 days between a diagnosis date and the second dose administered,
  - Fully vaccinated: 2 doses with more than 14 days between diagnosis date or a third dose received.

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Methods

- Demographic data were presented as descriptive statistics.
- We compared:
  - Delta infections confirmed between August 12 and 30 September 2021 against,
  - Omicron infections confirmed between 1 December 2021 and 21 January 2022.
- Univariable analysis was conducted to examine the association of different factors with hospitalisation.
- All variables with a p-value less than 0.25 was included in the final multivariable logistic model.

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Results

- A total of 1065 confirmed cases that met the inclusion criteria for this study.
- 58% Delta vs 42% Omicron
- Clinical Characteristics:
  - 6.6% of all cases were hospitalised, with 77% of these not up-to-date with their vaccination status.
  - Cases with Omicron had a lower proportion hospitalised compared to Delta cases.
  - All cases required mechanical ventilation whilst admitted to ICU were all Delta cases.

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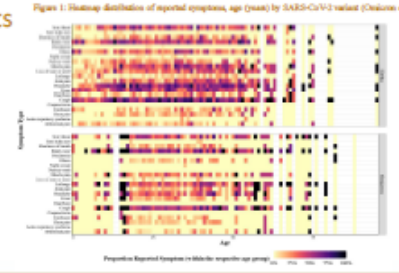
Results



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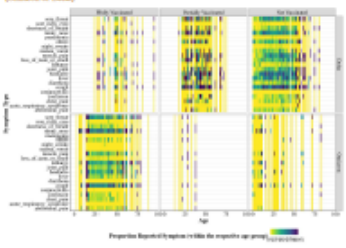
Results



11

Results

- Logistic regression analysis
- Higher odds of hospitalisation:
  - 40—59 years (aOR 3.01, 95% CI 1.29-7.03) and,
  - Over 60 years (aOR 6.38, 95% CI 3.32-27.46) compared to 0-12 years of age.
  - Unvaccinated individuals (aOR 6.38, 95% CI 3.32-27.46) compared to fully vaccinated cases.
- Lower odds:
  - Omicron variant had lower odds of hospitalisation compared to Delta.

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Strengths

- We followed up cases prospectively until they were cleared under public health requirements
- All cases were sequenced with either Delta or Omicron.
- First study to present data on symptoms that is adjusted by vaccination status and age.
- Validated vaccination status through Australian Immunisation Register (AIR).

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Limitations

- Presence of symptoms and comorbidities were self-reported, which can introduce information bias (recall and misclassification bias).
- In 2022, rather than conducting phone interviews for all laboratory confirmed SARS-CoV-2 infection, the ACT implemented an online questionnaire than the full extent of a phone interview.
- Vaccinated cases in the Delta group in this study account for a small proportion overall within the study cohort.

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Conclusion

- The result of this analysis has given further weight to existing evidence that Omicron variant infections are less severe than those of Delta infections and present with different symptoms.
- The rapid detection and characterisation of new and emerging SARS-CoV-2 variants are imperative in informing public health and control measures.
- Moving forward, the focus will continue in addressing waning immunity through booster vaccine doses, development of multivalent vaccines and active surveillance within high-risk settings.

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THANK YOU

Acknowledgements

We would firstly like to thank the contributions of Alexandra Marmor, Dr Nevada Pingault, Dr Ben Pokinghorne, COVID-19 Epidemiology team and the broader COVID-19 Response Branch, ACT Health Directorate,

Dr Karina Kennedy, and the broader staff of ACT Pathology,

Dr Benjamin Schwessinger, Dr Robyn Hall and the team from the Schwessinger Laboratory, the Australian National University (ANU).

Australian National University

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Appendix 2: Lay summary document distributed to the broader Case Investigation and Management team of the COVID-19 Response Branch, ACT Health.

NOT FOR FURTHER DISTRIBUTION

ACT Government | ACT Health

SARS-CoV-2 Variants of Concern Interview Guide

31 May 2022

DESCRIPTION

Whole Genome Sequencing (WGS) in the ACT is currently being prioritised for COVID-19 cases from outbreaks in high-risk settings, recently returned overseas travellers, hospitalised cases, deaths, and a small proportion of other community cases. As SARS-CoV-2 continues to evolve, it is important to continue to monitor cases with new or emerging variants to inform and guide our public health response. A significant part of this response is the collection of exposure data from these new or emerging variants. Below are a set of questions that we would like asked of cases that have been flagged by the COVID-19 Response Epidemiology team.

Please document all the answers under the Case Notes section, including the date and time of the call. Once this is complete, please email both Cases.COVID and HECC.Epi letting people know that you have completed your interview.

QUESTIONNAIRE

Demographics

1. What was the reason for testing?

2. What is your occupation?
    a. Describe role if high risk* include dates worked during infectious period (72hrs prior to symptom onset or if no symptoms 72hrs prior to date specimen was collected)
    *High risk: healthcare and/or aged-care facility related.

14-days Exposure Period

International Travel

3. Have you been overseas in the past 14-days?
    a. If YES, include dates of travel and specific locations including layovers:
4. Have your high risk contacts (e.g. household contacts) been overseas in the past 14-days?
    a. If YES, include dates of travel and specific locations including layovers:

Interstate Travel

5. Have you travelled interstate in the past 14-days?
    a. If yes, include dates of travel and specific event details if it involved large gatherings:
6. Have you high risk contacts travelled interstate in the past 14-days?
    a. If yes, include dates of travel and specific event details if it involved large gatherings:

High Risk Contacts

7. Have any of your high risk contacts tested positive for COVID-19?
    a. If YES, collect all of their details (full name, DOB, contact number, address)
        i. If positive by PCR, look them up in NDMS and write down the NDMS DI.
        ii. If positive by RAT, recommend that they undertake a PCR.
    b. If NO, recommend for them to conduct a PCR test prior to ending their quarantine period.

8. Are you aware of any other known/potential COVID-19 exposure? List below as appropriate.

If there any queries, please contact hecc.epi@act.gov.au or algreg.gomez@act.gov.au.

Appendix 3: Canberra Times Newspaper article, 27 November 2022

← News Home

The Canberra Times

Share

Home / News / Health

Omicron cases were more likely asymptomatic than Delta in the ACT: study

By Jasper Lindell
November 27 2022 - 5:30am

1

Lethargy was a more frequent symptom reported by Omicron COVID infectees compared to people who caught Delta. Picture by Sitthixay Ditthavong

Canberrans infected with the Omicron sub-variant of COVID-19 were more likely to be asymptomatic than those infected in the previous Delta wave, preliminary research data has shown.

An infection of the Delta sub-variant was also more likely to result in hospitalisation, but researchers noted the increased rate of vaccination by the time of the later Omicron wave may have reduced

Online news article: https://www.canberratimes.com.au/story/7996113/omicron-cases-were-more-likely-asymptomatic-than-delta-in-the-act-study/

The study found 32 per cent of people infected with Omicron exhibited no symptoms, while just 12 per cent of people who were infected with Delta were asymptomatic.

The study, which gathered information from COVID infections in the ACT between August 12, 2021 and January 21, 2022, found notable differences in the symptoms reported by people who were infected with Omicron compared to Delta, and that an infection with the Delta sub-variant was more likely to result in hospitalisation.

The most commonly reported symptoms for Delta infections were cough, which 62 per cent of people reported; headache, reported by 55 per cent; and fever and runny nose, both reported in 47 per cent of cases.

Times Past: November 28, 1995

Here's to the Dreyfus-Dutton ICAC model blowing up in t...

A serious and weighty drama

Powered by Hindsight

Runny nose was the most common symptom among people who were infected with the Omicron variant, with 54 per cent reporting the symptom. Fifty-three per cent of cases reported experiencing cough, 41 per cent reported sore throat and 39 per cent reported lethargy.

"We found that symptom characteristics for Omicron and Delta SARS-CoV-2 infections were significantly different. Furthermore, we found that individuals infected with Omicron were more likely to report no symptoms at all, although vaccination status may have played a role in this cohort," the study authors, from the Australian National University and ACT Health, wrote.

The study said lethargy was the only symptom overall that was significantly more common in proportion in Omicron infected people than those who caught the Delta sub-variant. The study found no significant differences between symptom presentation by sex.

The study was published online earlier this month but is yet to be peer reviewed, meaning the results are not final.

Between August 12, 2021 and January 21, 2022, there were 1065 confirmed cases that met inclusion criteria for the study, with 58

The median age was 28, with cases in people aged 6 months to 95 years.

People infected with the Delta sub-variant were generally younger than those infected with the Omicron variant.

Just 19 per cent, or 118 of 613, of the Delta cases were fully vaccinated. Eighty-five per cent of those infected with Omicron were fully vaccinated.

READ MORE:

- Facing a state of pandemic denial, being allowed to ask the hard questions is critical
- COVID deaths highest among disadvantaged communities
- New GP guidelines to combat 'Dr Google'

The Delta wave began in the ACT before many Canberrans had had the opportunity to receive their full course of COVID-19 vaccinations. The first Omicron case was recorded in the ACT on December 1, 2021, after the city had reached world-leading vaccination rates.

"The rapid detection and characterisation of new and emerging SARS-CoV-2 variants are imperative in informing public health and control measures," the study's authors wrote.

"Moving forward, the focus will continue in addressing waning immunity through booster vaccine doses, development of multivalent vaccines and active surveillance within high-risk settings. Public health measures such as social distancing and mask use will still need to be in the forefront of the public's mind."

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Chapter III

Outbreak investigation of SARS-CoV-2 Beta variant (B.1.351) variant in hotel quarantine, Australian Capital Territory, March 2021

Table of Contents

List of Abbreviations

ACT	Australian Capital Territory
ACTHD	ACT Health Directorate
AHPPC	Australian Health Protection Principal Committee
ART	Acute Response Team
CDNA	Communicable Diseases Network Australia
CDGN	Communicable Disease Genomics Network
CHECC	Clinical Health Emergency Coordination Centre
CHO	Chief Health Officer
COVID-19	Coronavirus disease 2019
CT	Cycle threshold
DoH	Department of Health (Australian Government)
ELISA	Enzyme-linked immunosorbent assay
EMT	Emergency Management Team
GFF	Government-Facilitated Flight
GISAID	Global Initiative on Sharing All Influenza Data
HECC	Health Emergency Control Centre
IgG	Immunoglobulin G
IgM	Immunoglobulin M
NIR	National Incident Room
NNDSS	National notifiable diseases surveillance system
PANGOLIN	Phylogenetic Assignment of Named Global Outbreak Lineages
PCR	Polymerase chain reaction
PHECC	Public Health Emergency Coordination Centre
PHO	Public Health Officer
RNA	Ribonucleic acid
RT-qPCR	Reverse transcription quantitative polymerase chain reaction
SARS-CoV-2	Severe-Acute-Respiratory-Syndrome Coronavirus-2
SNP	Single nucleotide polymorphism
VOC	Variant of Concern
VOI	Variant of Interest
VUI	Variant Under Investigation
WGS	Whole-genome sequencing
WHO	World Health Organization

1.0 Prologue

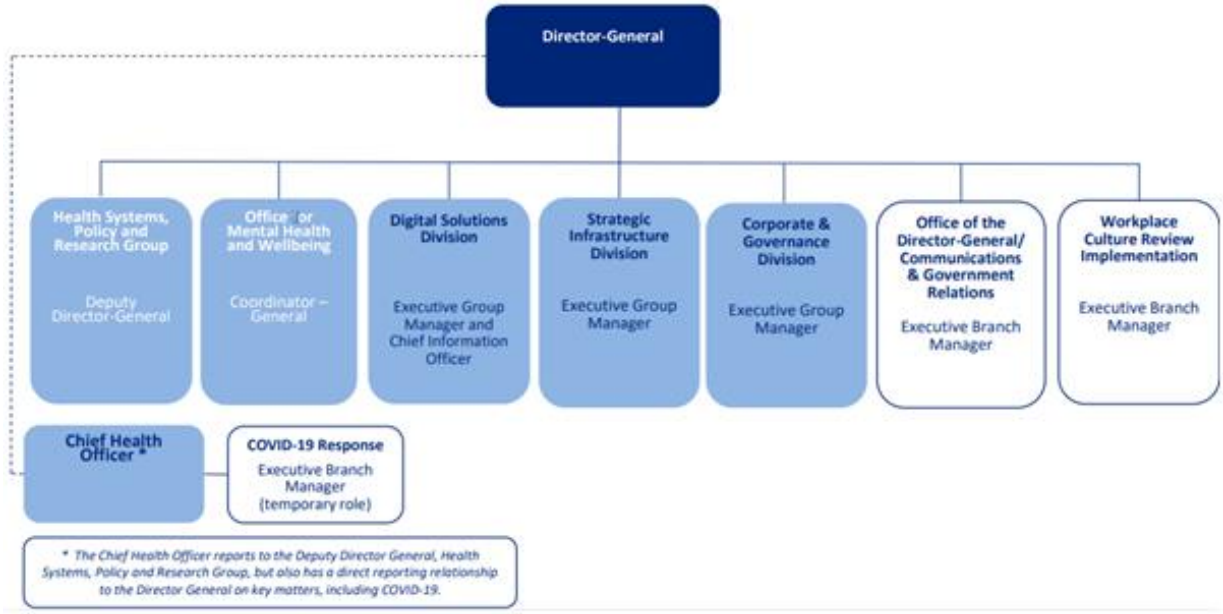
1.1 Study Rationale

This investigation was the first cluster of SARS-CoV-2 infections in hotel quarantine in the ACT. The COVID-19 Response Branch was required act swiftly and respond to the acute public health threat. This is important research due to the potential for such outbreaks to occur in similar settings. The first step in this investigation was to identify the source of the outbreak, in which was done by forming a response team under an Emergency Management Team (EMT). Our aim was to identify the likely source of exposure and transmission dynamics for all laboratory confirmed SARS-CoV-2 infections from the Government-Facilitated Flight (GFF) from Singapore to Canberra, Australia, March 2021. The findings from this epidemiological investigation would inform public health measures to prevent further confirmed cases of the virus. It is important to investigate any potential preventive measures that could have been implemented in order to reduce the risk of future outbreaks in similar settings.

1.2 Structure of the COVID-19 Response Branch, ACT Health Directorate

The ACT Health Directorate (ACTHD) consists of eight core divisions and program areas that is headed by the Director-General (Figure 1). The organisation structure includes the newly formed coronavirus disease 2019 (COVID-19) Response Branch lead by the Chief Health Officer (CHO), who has oversight of the Policy and Support, Response Branch, Vaccine Program and Health Protection Services (HPS). The COVID-19 Response Branch is comprised the following teams: Office of the Chief Health Officer, Deputy Chief Health Officer, Executive Office, Outbreak Preparedness and Response (which includes Medical Officers/Public Health Registrars), Surveillance and Reporting, Case Investigation and Contact Tracing, Health Emergency Coordination Centre (HECC) Support Systems (including Planning, and Logistics and Facilities), Mental Health and Wellbeing support and Quarantine Management. The Clinical Health Emergency Coordination Centre (CHECC) within the ACTHD is responsible for the clinical response to the impact of the COVID-19 pandemic in the ACT. This includes services such as clinical resourcing, workforce capacity, testing support (of individuals in isolation or quarantine) and off-site hospital accommodation (if isolation occurs outside the hospital such as a quarantine facility).

Figure 1: Organisational Structure - ACT Health Directorate, March 2021



An Acute Response Team (ART) is formed to rapidly assess, coordinate and respond to a public health incident. This includes incidents that may present ongoing risk to the health and/or safety of the ACT community, and/or an incident with the potential significant public and/or media interest. The ART may include an incidence team that involve various representatives from the HECC, CHECC and Public Information Coordination Centre (PICC). The PICC is responsible for developing and delivering messaging to the public. The purpose of an ART is to provide the current information of the incident to the relevant stakeholders and propose an appropriate response to the current situation. The Chair for the ART is mainly responsible for the management of the response. The Chair is also responsible for; the setup of the structure and responsibilities of the ART, establishment of clear tasks (and timeframes) between each business units/stakeholders and provide public health information.

The ART for this outbreak investigation outlined the clear responsibilities for each of the incident teams (including the Case Investigation and Contact Tracing team, Quarantine Management and the Surveillance and Reporting team). I was involved in the ART for the whole duration of the outbreak investigation working with both the Case Investigation and Contact Tracing team, and Surveillance and Reporting teams. The ART met daily (and twice daily if required) to provide necessary updates and

distribute critical tasks to the appropriate operations team of the HECC, CHECC and PICC.

The related legislation and policies regarding this public health incident include (but not restricted to):

- *Public Health Act 1997*
    - Public Health Emergency Direction (Notifiable Instruments)
- *Emergencies Act 2004*
- ACT Emergency Plan
- Health Emergency Plan
- Epidemic Infectious Disease Plan

The National Health Security Agreement under the *National Health Security Act 2007* outlines the framework for effective and coordinated responses to public health emergencies (either Public Health Event of National Significance or a Public Health Emergency of International Concern) agreed between the Commonwealth and all States and Territories of Australia. The International Health Regulations (IHR) National Focal Point (NFP) is a designated area (or areas) within the Australian Government Department of Health (DoH) that aim to facilitate the exchange of information and facilitate appropriate actions with national and international bodies in response to public health emergencies. In this outbreak investigation, we were able to utilise the Australian Government DoH NFP to attempt to communicate with the respective NFP's of Singapore and the Philippines.

1.3 My Role

This outbreak investigation was the first cluster of SARS-CoV-2 infection with a Variant of Concern (VoC) in the ACT. Responding to this incident was the primary focus of the COVID-19 Response Branch due to the increase in public health risk that the event imposed.

My primary role in this incident was to support the COVID-19 Branch, ACTHD by summarising epidemiological information and communication related to the laboratory confirmed SARS-CoV-2 infections in hotel quarantine. I collaborated with the Case Investigation and Contact Tracing team to conduct case management and close-contact interviews. Additionally, I was involved with the Surveillance and Reporting

team by writing daily epidemiological summaries of the outbreak that provided key information to internal staff members throughout the course of the investigation. I was also involved by drafting communications to external stakeholders such as the respective NFP's of Singapore and the Philippines. This included communications with the Schwessinger laboratory, from the Australian National University (ANU), who conducted the genomic sequencing analysis.

I organised a demonstration from Dr Robyn Hall (veterinary virologist who was part of the genomic sequencing team) of the end-to-end process of the sequencing analysis including the production of phylogenetic trees, after participating in various meetings and other formal discussions regarding WGS results to inform relevant public health actions. I then met with Dr Hall in her lab at Commonwealth Scientific and Industrial Research Organisation (CSIRO) for an in-depth tutorial.

The Surveillance and Reporting team initially involved me to analyse routine SARS-CoV-2 testing data, produce routine reports, and maintain the essential databases for the COVID-19 Response Branch. The cluster of SARS-CoV-2 infections in hotel quarantine provided a great opportunity to work as part of an ART. This MAE outbreak investigation was unique as it involved an international exposure setting, communications with multiple internal and external stakeholders (e.g., NFPs) and separate family/travel groups that had minimal interactions before boarding (and during) the flight.

1.4 Lessons Learnt

This section of the prologue reflects on the personal learnings from this outbreak investigation project. My participation in this outbreak investigation project offered valuable lessons, greater appreciation and understanding of the complexities of disease outbreak investigations. I experienced first-hand the complex functioning of an incidence team that formed the ART as well as the regulations and procedures in place to respond to a public health emergency. I gained an appreciation for the importance of clear communication within and across different response teams involved in an outbreak investigation, as well as the rapid pace at which an outbreak investigation can occur, including the formation of an ART to the incidence, the collection of epidemiological data through phone interviews, and future planning.

The Senior Case Investigation team leaders and I worked together to ensure that a short semi-structured questionnaire was formulated and administered at the start of their daily mental health and wellbeing calls. This enabled us to obtain answers in a timely fashion without impeding the main purpose of the daily call, which was to ensure that returned travellers were physically and mentally healthy. The pressure on the incidence team to make appropriate decisions and public health measures in a timely fashion was immense. I consulted multiple stakeholders to prioritise the additional questionnaire for returned travellers in quarantine, who were required to undertake daily wellbeing calls and scheduled COVID-19 testing. To ensure each team member could access the appropriate documents securely and capture the information required simultaneously, I organised multiple tasks within a limited timeframe. As time was limited during the daily phone interviews (due to staff capacity and logistical arrangements), I carefully considered the length of the questionnaire. Careful consideration must be taken between importance and feasibility when adding additional conditions to the busy schedule of returned travellers undertaking quarantine requirements, which had an impact on the questionnaire developed as not all questions of interest were included in the final questionnaire.

I was able to appreciate the efforts and the crucial role of a public health laboratory in the analysis of laboratory specimens (including viral genome sequencing and analysis). This also includes providing crucial and timely information that contribute to the appropriate public health decisions. The outbreak investigation occurred during the same time that I organised a public health laboratory visit on behalf of six first-year Canberra-based MAE scholars. The scholars visited ACT Government Analytical Laboratory (ACTGAL) at Health Protection Services (HPS) and ACT Pathology at The Canberra Hospital (TCH) on 3 and 18 March 2021, respectively. The laboratory visit provided valuable insights into the various testing methods, complicated processes and time taken to achieve a test result. In this outbreak investigation, pathology providers played a crucial role in the outbreak response. My experience with the outbreak investigation has outlined the importance of a public health laboratory, regarding the delivery of timely tests results that were crucial to appropriate public health action.

My experience of communicating with and through respective NFPs in a small jurisdiction (relative to total national population and land area) compared to other Australian states and territories revealed the difficulty of the situation. Emails and proposed video conference calls went unacknowledged and unanswered, complicating the public health investigation by preventing investigation of the full cohort potentially involved in the hypothesized transmission event at Singapore Changi international airport. This necessitated a retrospective case series instead of a conventional cohort study. I learned that standard procedures and systems in place to respond to public health threats may not always work as expected in the real world. Flexibility is key when conducting an outbreak investigation, as the situation can rapidly evolve and become more complex.

During course block one (two weeks prior to the beginning of the outbreak investigation) of the MAE, I was able to apply the theoretical concepts presented in an outbreak investigation lecture to the overall outbreak response. This included emphasizing the public health response (such as immediate control measures, determining who is at risk and executing prevention activities). Collaboration and communication with a broad range of internal and external stakeholders was also essential. I shared my preliminary findings in daily epidemiological summaries and presented my learnings and the findings in front of the operations team during a 'lunch and learn' session. Of the more than 40 cluster investigations I have been involved in with the COVID-19 Response Branch, this outbreak investigation stands out due to its complexity and pressure.

Lastly, I was able to develop my research and analytical skills by developing a research proposal and conducting a scientific review of the literature that outlined the epidemiology of Beta SARS-CoV-2 variant of concern in Australia, which was the SARS-CoV-2 variant that was found in all the cases in this outbreak. Working with the Data Science team from the Surveillance and Reporting team, I repurposed existing codes to produce appropriate tables and figures for this chapter. It is important to note that descriptive statistical analysis was conducted in informing the public health actions during the outbreak investigation.

Other lessons learnt:

- I was able to develop my skills regarding the use of statistical software's through R program and STATA,
- I was able to clean and prepare data sets to be able to run statistical analysis,
- I was able to broaden my writing by consulting with internal and external stakeholders regarding the public health investigation,
- I was able to write and present a report for a non-technical audience.

1.5 Public health implications of this work

The COVID-19 Response Branch, PHECC, CHECC and PICC all played a major role in limiting the spread of SARS-CoV-2 infections in hotel quarantine to other passengers and hotel-quarantine workers, thus preventing community transmission. My investigation retrospectively reviewed exposure, genomic and travel history of the cases to assess the likely source of the infection, and prospectively followed-up the cohort by collecting epidemiological data throughout their quarantine period. This informed the ongoing acute response to the incident and senior members of the Operations Team noted that the situation would not have been the same without it. My investigation will be useful in future preparedness and response to not only hotel-quarantine but also local SARS-CoV-2 outbreaks, such as the development of a standardised questionnaire for all SARS-CoV-2 infections from returning international travellers in the ACT, which will collect additional exposure details to help determine and understand the likely source of exposure and inform public health action.

1.6 Acknowledgements

I would like to acknowledge the following individuals for their assistance in my role in the ART, as well as their support for the whole duration of the outbreak investigation. Dr Kerryn Coleman, Dr Vanessa Johnston, Dr Miranda Harris, Toby Keene and all of the individuals involved in the ART, COVID-19 Response Branch, ACTHD. This includes the broader team; COVID-19 Case Investigation and Contact-Tracing team, Surveillance and Reporting team and Outbreak Response and Preparedness team, and Quarantine management team.

I would like to thank Tze Vun (Jakob) Voo for his assistance in writing and explanation for the R markdown coding scripts for descriptive analysis during this outbreak and for this project. I would like to outline a special mention and acknowledge Dr Robyn Hall for her patience with explaining the complex world of genomic sequencing and analysis. I would also like to acknowledge Dr Karina Kennedy and the broader staff from ACT Pathology; Dr Benjamin Schwessinger and the team from the Schwessinger Laboratory, ANU, for the analytical efforts regarding the clinical samples and producing the laboratory results.

1.7 Master of Philosophy in Applied Epidemiology core activity requirement

- Investigation of an acute public health problem or threat (typically a disease outbreak),
- Report for a non-technical audience,
- Presentation to a national conference.

2.0 Abstract

Background

On 1 of March 2021, during one of peak periods of the COVID-19 pandemic, an Australian Government-Facilitated Flight (GFF) from Singapore arrived in Canberra, Australian Capital Territory (ACT), Australia. An Acute Response Team (ART) was formed and an outbreak investigation was initiated by the Health and Emergency Control Centre (HECC), ACT Health Directorate (ACTHD), after two passengers were detected with acute SARS-CoV-2 infection whilst undertaking mandatory hotel quarantine. The main objectives of this investigation were to utilise epidemiological evidence from case interviews, contact tracing, and laboratory evidence to support and inform the relevant decision makers for appropriate public health measures to prevent further infection.

Methods

We conducted a case series analysis on all confirmed SARS-CoV-2 infections from a GFF flight. The outbreak investigation collected epidemiological, clinical and laboratory data through the routine public health investigation and phone interviews of confirmed cases with a SARS-CoV-2 infection. Oropharyngeal and deep nasopharyngeal swab specimens were collected on the second day of quarantine from all the passengers and were analysed through reverse transcription quantitative polymerase chain reaction (RT-qPCR) by ACT Pathology and were forwarded to the Schwessinger Laboratory, ANU, for Whole-Genome Sequencing (WGS) analysis. Descriptive data analysis was conducted using R statistical program.

Results

A total of five confirmed SARS-CoV-2 infections were identified, out of the 146 passengers onboard the GFF from Singapore to Canberra, Australia. The outbreak occurred over a 4-week period from the first onset of symptoms or detection of infection until date of clearance, with a case onset date from 3 March to 29 March 2021. WGS revealed that all cases were genetically linked and were associated with a Beta (B.1.351 Pangolin) SARS-CoV-2 infection. Based on the epidemiological, WGS and laboratory evidence, the international transit lounge at the Singapore Changi airport was the likely exposure site that initiated the COVID-19 cluster transmission event on 28 February 2021.

Conclusion

Public health measures that were implemented lead to the appropriate control of the infection. There were no onwards transmission to hotel-quarantine workers and subsequently, did not lead to community transmission.

3.0 Introduction

3.1 Background

The Coronavirus-Disease-2019 (COVID-19) pandemic, caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), continues to have a major impact in Australia and globally. In response, Australia declared a human biosecurity emergency under the *Biosecurity Act 2015* (the Biosecurity Act) (1). This allowed for the powers and directions under the Biosecurity Act to be enacted to further control the pandemic. Additionally, Australian states and territories implemented emergency plans under their respective state legislation (and Public Health Act's) that permitted for emergency powers to be activated (2). These included travel restrictions on individuals who have been to a COVID-19 affected areas, primarily through international border closures, mandatory hotel quarantine of international arrivals, and isolation of confirmed and suspected cases and their close contacts (3).

The Communicable Diseases Network Australia (CDNA) and the Australian Health Protection Principal Committee (AHPPC) have endorsed the Series of National Guidelines (SoNG) for COVID-19, which are responsible for generating standard guidelines and policies regarding COVID-19 case and contact management. This also includes laboratory testing and procedures for outbreak management that inform jurisdictional responses. The Australian government has continued to implement interventions and public health measures that focus on limiting the spread of the disease (3).

In response to the pandemic, the Australian government implemented border restrictions on outbound and inbound international travel (also referred to as an "international travel ban") early in the course of the pandemic, ceasing all commercial flights and impacting Australians overseas attempting to get home (4). To help repatriate vulnerable Australians overseas, the government introduced Government-Facilitated Flights (GFF) (5). Under the Biosecurity Act and relevant state legislation, individuals were restricted to quarantine in pre-arranged hotels or an appropriate quarantine facility for a minimum of 14-days at the port of entry (unless the individual holds a diplomatic visa or granted an exemption) (6). These guidelines aimed at reducing onward transmission of SARS-CoV-2 infection from individuals who may have been potentially exposed to the pathogen (6).

The COVID-19 pandemic has highlighted the importance of Whole-Genome Sequencing (WGS) for public health surveillance and informing the ongoing public health response (7). In particular, there has also been a focus on tracking SARS-CoV-2 genomic evolution through emerging SARS-CoV-2 variants of concern (VOC) and variants of interest (VOI). The World Health Organization (WHO) has outlined working definitions for VOIs and VOCs, which includes;

> "*either one or more changes in public health significance: increase in transmissibility or detrimental change in COVID-19 epidemiology; increase in virulence or change in clinical disease presentation; decrease in effectiveness of public health and social measures or available diagnostics, vaccines, therapeutics*." (8)

The emergence of SARS-CoV-2 variants has highlighted the importance of rapid and real-time viral sequencing capacity (9). At the time of investigation, there were three designated VOCs; Alpha, Beta and Gamma (WHO nomenclature) also referred to their Phylogenetic Assignment of Global Outbreak (PANGO) lineage designation (PANGOLIN) B.1.1.7, B.1.351 and P.1., respectively (8). There is increasing biological and epidemiological evidence suggesting that these variants may be associated with increased transmissibility, disease severity, reduced vaccine effectiveness and other epidemiological fitness advantage (8,9). This has been acknowledged as a public health concern by the Communicable Diseases Genomics Network (CDGN) and pathogen genomics experts within the Public Health Laboratory Network (PHLN). Additional precautions have been outlined by the series national guidelines, which addresses the increased risk involved regarding individuals infected with a SARS-CoV2- VOI/VOC (3). Beta variant infections emerged in December 2020 in South Africa and was found to be circulating around the globe shortly after (8). At the time of investigation, Australia had only detected Beta infections in individuals who had overseas travel history and were subjected to home or hotel quarantine (8,10).

3.2 Description of the Incidence

This report details an outbreak investigation of a laboratory-confirmed SARS-CoV-2 cluster among international travellers on 28 February 2021 from Singapore to

Canberra, Australian Capital Territory (ACT) that arrived on 1 March 2021. All passengers were required to have a negative COVID-19 Polymerase Chain Reaction (PCR) test 48-hours prior to departure from Singapore, except for those who boarded the flight in London, England and did not have to exit the plane. The designated terminal and gate for the Canberra-Singapore GFF was T3 and A14, respectively (Appendix 1) (11). This terminal had nine other gates, as well as three bathrooms/washrooms situated around A14. All passengers who checked-in for their flight and were cleared by the security clearance process, as well as airport workers (including cleaners and vendors of small food kiosks/stalls) had 24/7 access to the terminal (11).

According to the Australian national guidelines for COVID-19 at the time of the investigation, a SARS-CoV-2 Reverse Transcription quantitative Polymerase Chain Reaction (RT-qPCR) test was mandatory for all returned international travellers within 48-hours of arrival in hotel quarantine (3). This 'entry test' detected SARS-CoV-2 infections in two passengers, both returning high cycle threshold (Ct) values, indicating low amounts of SARS-CoV-2 viral RNA. As the incidence was low in Australia at the time, the positive predictive value (PPV) was correspondingly low, and all the positive tests were confirmed. Repeat tests 24 hours later showed lower CT values, indicating an acute infection, leading to a cluster of SARS-CoV-2 infection at the hotel. Follow up testing of the GFF cohort identified three other infected persons on days 5, 7 and 9 post-arrival. An Acute Response Team (ART) formed by members of the Public Health Emergency Coordination Centre (PHECC) and Clinical Health Emergency Coordination Centre (CHECC), ACTHD. The response team had a major focus on providing health and wellbeing support of the confirmed cases, their close-contacts, other passengers from the flight and the associated quarantine staff. Control measures were also implemented to limit further transmission of the disease.

3.3 Aims and Objectives

The primary aim of this study was to investigate the likely source of exposure and subsequent transmission dynamics for laboratory confirmed SARS-CoV-2 infections associated with the GFF from Singapore to Canberra, Australia, which arrived on 1 March 2021.

The objectives of this study were:

1. To understand the associations between the SARS-CoV-2 infections in the outbreak.
2. To investigate the likely original source of the infection cluster.
3. To assess the risk of onward transmission from the GFF to the wider community.

4.0 Methods

4.1 Study Design

A retrospective case series study design was conducted to follow-up on all confirmed SARS-CoV-2 cases from a GFF flight that travelled from Singapore to Canberra, Australia, on 1 March 2021. The study investigated the epidemiological, clinical and laboratory data that were collected through the routine public health investigation and follow-up of confirmed cases of SARS-CoV-2 by the Operations Branch, COVID-19 Response Branch, ACTHD.

4.2 Case definition

A case was defined as a person who was on the GFF from Singapore to Canberra that arrived on 1 March 2021 AND meets the Series of National Guidelines (SoNG version 4.5) definition of a confirmed SARS-CoV-2 case at the time of investigation (as presented in Box 1) (3).

The study cohort included all the passengers on the GFF from Singapore to Canberra that arrived on 1 March 2021 and the quarantine staff involved in the operation. The quarantine staff were considered as at-risk individuals, as they had direct contact with potentially infectious individuals and/or were in a potentially contaminated environment. According to the national guidelines, international aircrew who were considered close contact of a confirmed COVID-19 case were permitted to leave

Australia if the individual is asymptomatic and the aircraft does not carry any passengers. The criteria for clinical clearance from isolation is as shown in Box 2.

Box 1: National SARS-CoV-2 notification case definition according to the SoNG (version 4.5).

A confirmed case requires laboratory definitive evidence (where not classified as a historical case).

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 Immunoglobulin G (IgG) seroconversion or a four-fold or greater increase in SARS-CoV-2 antibodies of any immunoglobulin subclass including 'total' assays in acute and convalescent sera, in the absence of vaccination.

Box 2: Release from isolation criteria for all confirmed SARS-CoV-2 cases according to the SoNG (version 4.5).

SARS-CoV-2 cases can be released from isolation if they meet one of the criteria below:

1. Confirmed cases who have remained asymptomatic for the duration of their isolation period may be released if at least 14 days have passed since the first positive SARS-CoV-2 by PCR was taken.
   OR
2. Confirmed cases with at least 14 days passed since symptom onset; and resolution of fever and substantial improvement of respiratory symptoms of the acute illness for the previous 72 hours.
   OR

3. Confirmed cases without resolution of fever and acute respiratory symptoms with at least 20 days since symptom onset AND the case is not significantly immunocompromised OR;
   if an individual can meet all the criteria below:
   - At least 14 days have passed since the onset of symptoms;
   - There has been resolution of fever for the previous 72 hours;
   - There has been substantial improvement in respiratory symptoms of the acute illness; and
   - The case has had two consecutive respiratory specimens negative for SARS-CoV-2 by PCR taken at least 24 hours apart after day 10 from symptom onset.
4. Significantly immunocompromised persons may be released from isolation if they can provide PCR negative results on at least two consecutive respiratory specimens collected at least 24 hours apart after day 7 from symptom onset.

4.3 Data Collection

4.3.1 Epidemiological Investigation

The Case Investigation team of the COVID-19 Response Branch conducted a standard procedure of telephone interviews of all passengers who were on the GFF to collect enhanced epidemiological information. Data were collected on demographics, exposure factors, travel history, comorbidities, symptoms, genomic sequencing information, COVID-19 testing, and vaccination history. The data collected for the returned travellers were entered into a custom quarantine and case investigation database (once laboratory confirmed), which was held in a secure web application (REDCap) and hosted on a secure server by ACTHD. The data extracted for this outbreak investigation was collected by the *Public Health Act 1997*. Authorised public health officers (PHO), public health nurses, epidemiologists, senior case investigation and contact tracing officers of the Operations Branch were involved in the primary and subsequent interviews of all cases and their contacts in the ACT. Furthermore, after the preliminary data indicated that the transit lounge in Singapore Changi International airport was the likely point source, we were able to obtain further epidemiological data by constructing a semi-structured questionnaire regarding the potential source(s) (including the type and duration) of exposure(s) to the SARS-CoV-2 infection.

Further supplementary information such as the flight manifest and seat map were requested by the incidence team of the ART and obtained from airline company “X” and provided by the National Incident Room (NIR), the Australian Government Department of Health and Ageing.

4.3.2 Public Health Measures

Quarantine and hotel workers that had primary contact with all the passengers were enrolled in a syndromic surveillance program monitored by the COVID-19 Response Division. This was the first instance of this program and was aimed to continue as a standard procedure for all operations related to GFFs. The syndromic surveillance program was primarily aimed at mitigating the risk of SARS-CoV-2 transmission into the community from quarantine and hotel staff who have increased risk of exposure. The program involved automated text messaging that either reminded an individual to get tested (by either throat or deep nasopharyngeal or by saliva swab) on specific days or tested immediately if the individual was symptomatic (Appendix 3). The saliva test was conducted every day that an individual worked for a minimum of 14-days and throat and/or deep nasopharyngeal swab was conducted every 7-days during specific windows. The participants received daily monitoring for 14 days after their last shift at the quarantine designated hotel. The program required all the quarantine staff who had face-to-face contact with the returned passengers to report whether they had any COVID-19 related symptoms, and whether they had been tested for SARS-CoV-2 and their last rostered shift in the hotel quarantine program. All quarantine and hotel staff were tested immediately if they were symptomatic (with any similar respiratory symptoms). The staff enrolled in the syndromic surveillance program had direct access to registered nurses from the CHECC at the quarantine facility at Hotel “X” for the collection of throat or deep nasopharyngeal, and administration staff that were able to collect saliva swabs. This approach was based on recommendations of AHPPC (3). At the time of the investigation, Australia had not yet achieved widespread vaccination against SARS-CoV-2 and none of the quarantine or hotel workers were fully vaccinated.

International air crew were not subjected to the testing and quarantine requirements in the ACT. According to the SoNG, aircrew who are considered as a close contact of a confirmed COVID-19 case are permitted to leave Australia if the individual is asymptomatic and the aircraft does not carry any passengers (3,6).

4.3.3 Laboratory Investigation

Under ACT Public Health Direction, an instrument under *the Public Health Act 1997*, a person arriving from any international location are required to undertake SARS-CoV-2 PCR testing on day 1-2 and 13-14 of their quarantine period (6). Initial oropharyngeal and deep nasopharyngeal swab specimens were collected from all the passengers to meet mandatory requirements whilst undertaking their quarantine period in the ACT. Further oropharyngeal and deep nasopharyngeal swab specimens were collected on day 5 (voluntary), and day 13-14 of their quarantine period from all the passengers. Additional testing was employed to any persons who develop COVID-19 related symptoms. The testing regime of returned international travellers was consistent with the Australian national guidelines on SARS-CoV-2 whereby individuals were subjected to RT-qPCR testing on entry (day 0, 1 or 2) to and exit (day 10, 11, 12, 13 or 14) from hotel quarantine, irrespective of COVID-19 related symptoms. The specimens were analysed through reverse transcription quantitative polymerase chain reaction (RT-qPCR) by ACT Pathology. The RNA extraction was performed using a MagNA Pure Compact RNA Compact System (12), as per manufacturer's instructions.

SARS-CoV-2 isolates were forwarded to the Schwessinger Laboratory, for Whole-Genome Sequencing (WGS) analysis. For subsequent virus sequencing, complementary DNA (cDNA) was synthesised and overlapping amplicons spanning the viral genome were generated using ARTIC v3 primers, according to established protocols (13). Pooled amplicon libraries were prepared using the ARTIC protocol and libraries were sequenced on a MinION flowcell (Oxford Nanopore). Basecalling, demultiplexing, and read filtering was completed with Guppy (https://artic.network/ncov-2019/ncov2019-bioinformatics-sop.html). Assembly and consensus calling was done using the nCoV-2019 novel coronavirus bioinformatics protocol (https://artic.network/ncov-2019/ncov2019-bioinformatics-sop.html). The consensus sequences are available in GISAID under accession numbers EPI_ISL_1170946 – EPI_ISL_1170947 and EPI_ISL_1208400 – EPI_ISL_1208402. Global lineage assignment was performed using pangolin-2.3.2 and confirmed using the pangolin webserver (14). A neighbor-joining phylogenetic tree was estimated using the Geneious Tree builder as implemented in Geneious Prime 2021.1.1 with a Tamura-Nei distance model with no outgroup and no resampling.

4.4 Data Analysis

The data were analysed using Stata version 16 (StataCorp, College Station, Texas: StataCorp LLC) (15). Data analysis for this report was limited to descriptive analysis by person, place, and time, where continuous variables were summarised using median (or within a category such as age) and range. All individuals in the study population were characterized by age (categorised by 10-year age group), sex, case, and hospitalisation status for all GFF and quarantine staff.

4.5 Ethical Consideration

Ethical aspects of the research were approved by the ANU Human Research Ethics Committee (HREC) Protocol: 2017/909. Additional data were collected under the *Public Health Act 1997* for the purpose of a public health investigation.

5.0 Results

5.1 Epidemiological Investigation

Out of the 146 passengers onboard, a total of five (3.4%) confirmed COVID-19 cases were discovered from the GFF from Singapore to Canberra, Australia on 1 March 2021 (Table 1). The GFF was considered an outbreak after the detection of two cases on entry (day 1) test, during their mandatory 14-day hotel-quarantine period at hotel X in Canberra on 3 March 2021. The outbreak occurred over a 4-week period, from the date of the GFF arrival on 1 March to the public health clearance of all confirmed case on 27 March 2021. One case was female (20%), and 4 cases were male (80%). Three (60%) cases reported experiencing symptoms over the course of their quarantine period. No cases required hospitalisation.

A total of 204 quarantine staff were involved with the returned passengers, which included the Australian Federal Police (AFP), ACT Policing, authorised PHO's and hotel staff. All quarantine staff were required to follow strict protocols regarding the use of personal protective equipment and hand hygiene and were additionally enrolled in a syndromic surveillance program for the duration of the operation. No SARS-CoV-2 cases were detected through this staff syndromic surveillance program for the whole duration of the outbreak investigation, including 14-days after the last case was clinically cleared on 27 March 2021.

Table 1. Descriptive epidemiology of the passengers and quarantine staff involved in the Australian Government-Facilitated Flight (GFF) from Singapore to Canberra, Australia, 1 March 2021.

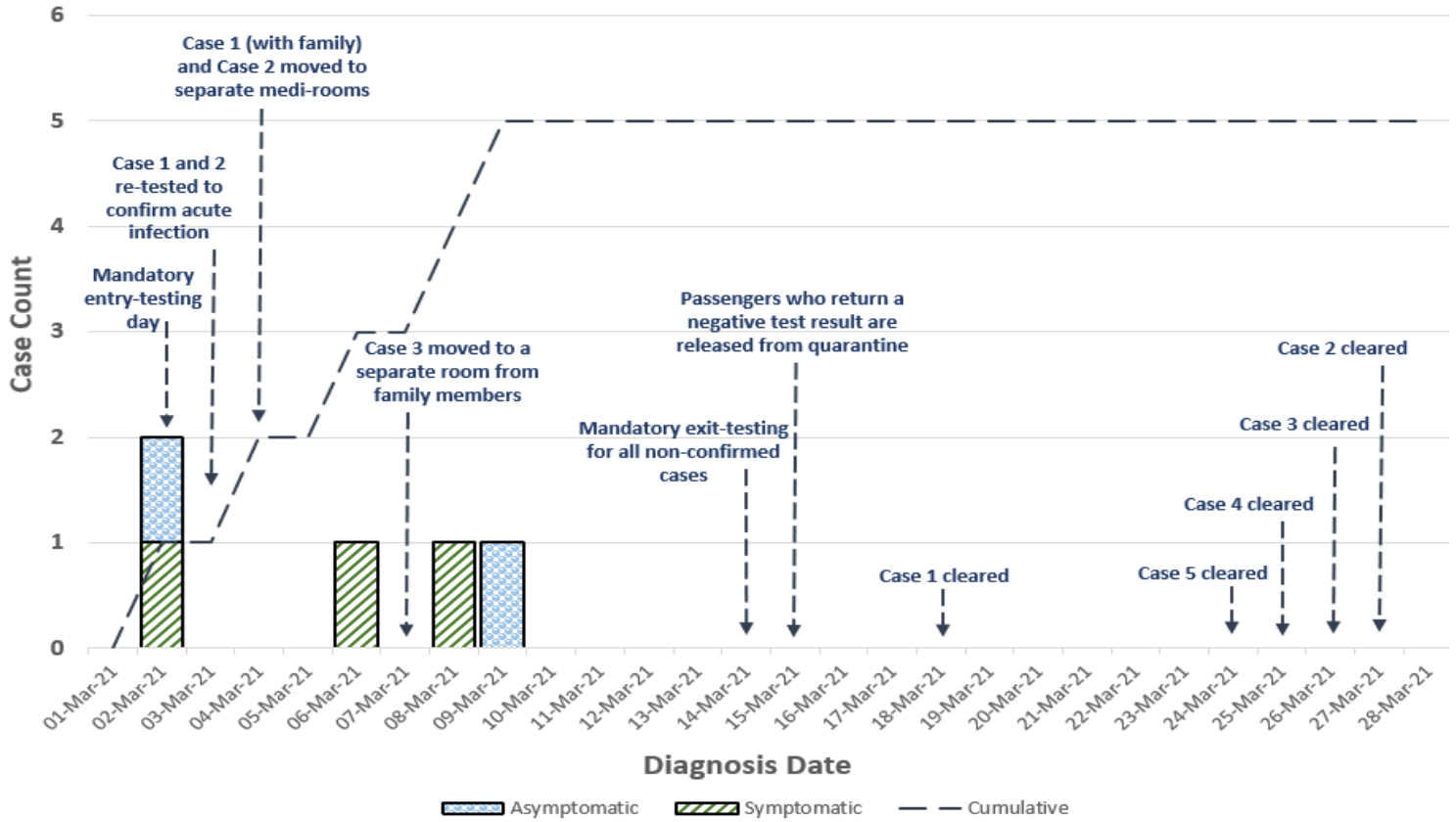
		GFF Passengers		Quarantine Staff	
		Cases * *n (%)*	**Non-Cases** *n (%)*	**Cases** *n (%)*	**Non-Cases** *n (%)*
Sex	Male	3 (60)	79 (56)	0	108 (53)
	Female	2 (40)	62 (44)	0	96 (47)
Age category (years)	0-9	0	28 (20)	0	0
	10-19	2 (40)	14 (10)	0	3 (1)
	20-29	0	17 (12)	0	75 (37)
	30-39	0	29 (20)	0	49 (24)
	40-49	3 (60)	28 (20)	0	34 (17)
	50-59	0	13 (9)	0	33 (16)
	60-69	0	7 (5)	0	9 (4)
	70-79	0	5 (4)	0	0
	80-89	0	0	0	0
	90+	0	0	0	0
Total		5 (100)	141 (100)	0	204 (100)

* Cases: A confirmed SARS-CoV-2 case defined by the Series of National Guidelines for COVID-19.

GFF: Government-Facilitated Flight.

.

Figure 1. Epidemic curve and metadata of SARS-CoV-2 infections by symptom onset date or asymptomatic specimen collection date from the Government-Facilitated Flight from Singapore to Canberra, Australia, March 2021.



Cases were categorized as (i) asymptomatic (ii) symptomatic, whereby specimen collection date and symptom onset date were used, respectively. Medi-room: designated hotel room with medical support from the CHECC. The case number is in order of detection.

5.2 Detection of Confirmed Cases

Two individuals from the flight initially returned positive RT-qPCR tests with CT values that were considered high on the mandatory entry (day 0-2) testing window on 2 March 2021 (Figure 1). The two suspected cases were re-tested (by serology as well as by RT-qPCR on deep oropharyngeal and nasopharyngeal specimens) to distinguish between acute and historical infections. These confirmatory samples, completed on the 3 March 2021, were negative on serological testing (IgG on ELISA) but returned positive RT-qPCR results. This constituted a cluster of COVID-19 in hotel quarantine. Results from genomic sequencing showed that the infections were caused by the SARS-CoV-2 Beta variant (B.1.351). To reduce the risk of further transmission, a voluntary testing day was held on 6 March 2021 for all passengers who had not been classified as confirmed cases. Of the 144 passengers, 136 (94%) agreed to the testing and two additional cases were identified. One of them was asymptomatic and the other reported cold and flu-like symptoms that began on 4 March 2021. The fifth case was detected on 9 March 2021 due to close-contact testing procedures. All five confirmed cases had to remain in quarantine for longer than the usual 14 days, as per national guidelines. To be released from quarantine and isolation, they had to meet the public health clearance criteria outlined in Box 2. If a person tested positive on a PCR test but did not have any COVID-19 symptoms, they did not need to be re-isolated.

5.3 Investigation of likely transmission chains

Prior to boarding the GFF, all passengers were required to present a negative SARS-CoV-2 RT-qPCR result from 48-hours prior to departure. At the time of the investigation, none of the returned passengers or hotel-quarantine workers had been vaccinated against COVID-19. All individuals (including flight staff) were required to wear a facemask for the duration of the flight, except when eating or if they were a child under 10 years of age. The five confirmed SARS-CoV-2 cases spent between 12 and 17 hours in Singapore Changi airport international transit lounge before departing on the GFF. According to a semi-structured interview questionnaire given to all returning international passengers, travellers spent between 0 and 24 hours in Singapore Airport before the flight. Five (3%) of the 146 passengers did not spend any time in the transit lounge as they were from London, United Kingdom, and did not leave the plane prior to departure, and all did not return a detectable result for SARS-CoV-2.

Case 1, a male aged 10-19 years, was the first laboratory-confirmed outbreak case. He was asymptomatic when he tested positive for SARS-CoV-2 RT-qPCR on 2 March 2021. He and his two primary close contacts (Case 4, a female aged 40-49 years; Case 5, a male aged 10-19 years) had all tested negative for SARS-CoV-2 PCR in Hanoi, Vietnam on 26 February 2021. The family had spent 17 hours in the transit lounge at the airport prior to their departure. All three members of the family spent time in the shared space during hotel quarantine. Due to the ages of the children, it was preferred that they were not separated with their guardian at the time. When Case 1 returned a positive result, he was moved to a separate room to the family members. Case 1 was clinically cleared on 18 March 2021, and his two family members were cleared on 24 and 25 March 2021, respectively. During their isolation, the Case Management team monitored their health risks, as well as their mental health and wellbeing.

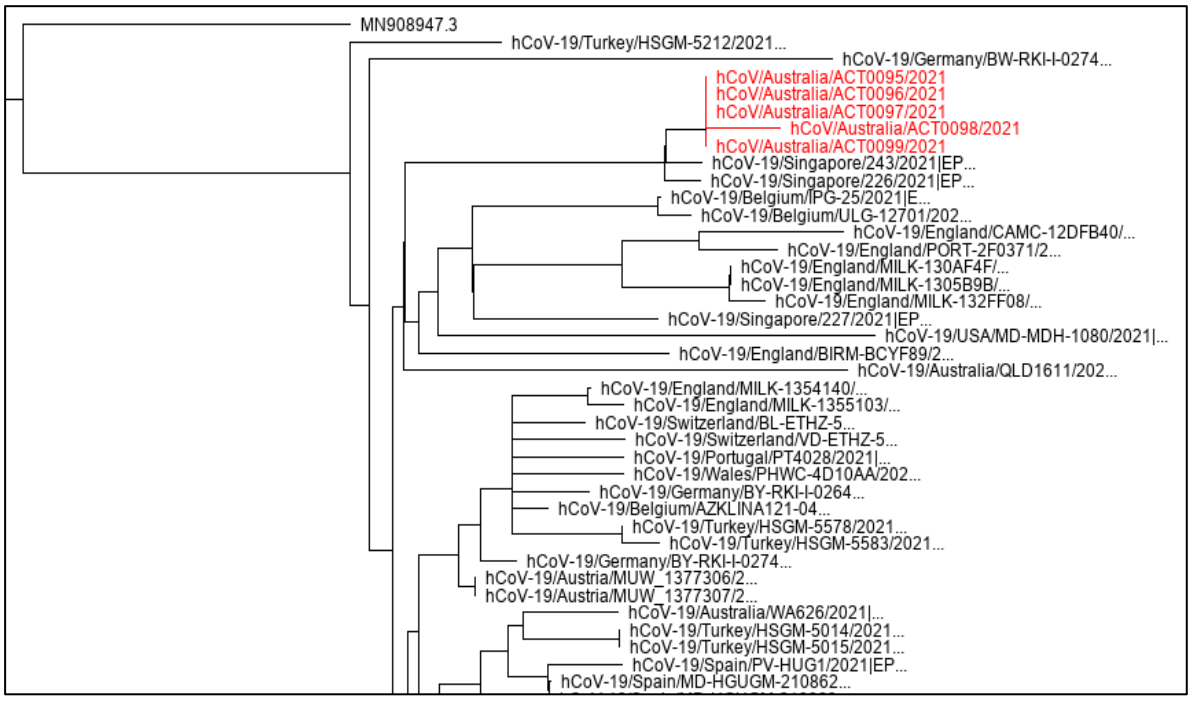
Case 2 was a 40-49 year old male who tested positive for SARS-CoV-2 by RT-qPCR on 2 March 2021. He had been in Chiang Mai, Bangkok and Thailand since 30 November 2020, and did not have prolonged or face-to-face contact with anyone for 3 weeks prior to his flight departure. He only went out in public (with a face mask) for essential reasons such as buying groceries. During his 15 hours of stay at Singapore Changi international airport, he was in contact with one other individual who was also wearing a face mask, and he purchased food and beverages using cash at a small kiosk. During his hotel quarantine period, he had two close contacts, neither of whom became cases.

Case 3 was a male aged between 40-49 years who presented with symptoms two days after returning a detectable SARS-CoV-2 RT-qPCR result on 8 March 2021. He was in quarantine with three other family members but was moved to a separate room when diagnosed as a case. None of the three close contacts became infected. The case returned a negative SARS-CoV-2 PCR result 48-hours prior to departure. The case and his family travelled from Bangkok to Singapore prior to GFF flight departure. During the 12 hours in the transit lounge of Singapore Changi airport, he spent time in the smoking area with one other person not in his travel party and purchased food and beverages from a small food service cart in the transit lounge. He stated that he wore a face mask in the transit lounge for the whole duration prior to departure, except when smoking or eating.

5.4 Whole-Genome Sequencing

All of the confirmed cases had their SARS-CoV-2 isolates forwarded from ACT Pathology to the Schwessinger Laboratory, ANU. Figure 2 portrays a neighbor-joining phylogenetic tree that was estimated using the Geneious Tree builder with a Tamura-Nei distance model with no outgroup and no resampling. The five GFF confirmed cases from the outbreak investigation are highlighted in red. The phylogenetic tree also outlined two sequences from Singapore (hCoV-19/Singapore/243/2021 and hCoV-19/Singapore/226/2021) that were situated in the same clade as the cases from the Singapore-Canberra GFF.

Figure 2. Tamura-Nei neighbor-joining phylogenetic tree for ACT0095, ACT0096, ACT0097, ACT0098 and ACT0099 (highlighted in red) based on SARS-CoV-2 Beta variant sequences collected since 19 February 2021 and publicly available in GISAID.



Data extracted from GISAID on 1 May 2021. ACT0096 = Case 1, ACT0095 = Case 2, ACT0097 = Case 3, ACT0098 = Case 4 and ACT0099 = Case 5.

Partial SARS-CoV-2 genomes were recovered from all five cases (97.9–98.9% complete). Notably, all five sequences were missing a 218 nt (nucleotide) region spanning from position 22,325 to 22,542 (based on MN908947.3 reference sequence) and sequences from cases 1–4 lacked a 295 nt region from position 19,276 to 19,570. These were considered to be failed amplification at the PCR amplification stage and

not true deletions, since they would result in nonsense mutations if they were biological. All five sequences were assigned to the B.1.351 lineages. The five GFF-associated sequences formed a monophyletic cluster within the diversity of publicly available B.1.351 sequences reported in the 4 weeks prior to the analysis. The sequences from cases 1,2,3 and 5 (ACT0095, 0096, 0097, and 0099) were identical across regions sequenced (Figure 2). The sequence from case 4 (ACT0098) differed from the other sequences at two nucleotide positions (A20662G and C29077T). The A20662G substitution resulted in a serine to glycine change at position 6800 of the ORF1ab protein, while C29077T was a synonymous substitution.

Investigation hypothesis

Based on the epidemiological evidence such as negative SARS-CoV-2 tests prior to travel, case interviews, contact tracing and genomic analysis, we hypothesised that the Singapore Changi International airport transit lounge was the likely exposure site that initiated the SARS-CoV-2 infection transmission event between 27 to 28 February 2021.

6.0 Discussion

The PHECC and CHECC formed an ART to quickly manage the acute public health risks associated with the first SARS-CoV-2 Beta cluster outbreak in Canberra, ACT. Epidemiological data, laboratory evidence and WGS identified the transit lounge in Singapore Changi international airport as the likely source of exposure. Fortunately, the response operation was successful in preventing onward transmission of SARS-CoV-2 infections to other returned travellers or hotel-quarantine staff, thus averting community transmission.

Identifying sources of exposure to COVID-19 is essential for controlling the pandemic (3,7). The primary source of exposure is contact with an infected person, including close contact with someone who has tested positive for the virus or contact with someone who is exhibiting symptoms (16). However, contact with an infected person does not guarantee infection, as the virus is spread through respiratory droplets, which can be spread through coughing, sneezing, or talking (17). In addition to contact with an infected person, exposure to COVID-19 can also occur through contact with contaminated surfaces, such as doorknobs, countertops, and other objects (18). It is

important to note that the virus can survive on surfaces for several hours, so it is important to clean and disinfect surfaces regularly (18). There were no information on the ventilation and cleaning standards of the airport at the time of the investigation. SARS-CoV-2 infection can also spread through contact with contaminated air, such as when an infected person coughs or sneezes in close proximity or when in an enclosed space with poor ventilation. The virus can remain suspended in the air for several hours and can survive on food and water for several hours as well (18). To prevent the spread of the virus, it is essential to avoid contact with infected persons, clean and disinfect surfaces regularly, ensure proper ventilation, and handle food and water properly (17,18).

Sequencing of the B.1.351 cases in this outbreak revealed a distinct cluster, suggesting a single introduction. Case 4 had two nucleotide substitutions which could indicate potential onwards transmission from Case 1, potentially indicating infection from the same source. These two substitutions could have occurred spontaneously or closely related B.1.351 cases could have been present in the airport lounge, suggesting two separate chains of transmission. Although less parsimonious, two separate chains of transmissions were possible. In-flight transmission was less likely, as none of the cases were likely to be infectious during the flight. The sequencing results thus suggest a point source outbreak, and epidemiological data support the theory that there was an exposure event at transit lounge 24-hours prior to departure (19).

Using WGS, researchers have uncovered numerous benefits, such as producing a thorough image of the virus's genetic make-up, the detection of mutations, and the tracking of the virus' evolution through time (20). These discoveries can be used to create more potent vaccines and therapies, pinpoint those who have contracted the virus, and spot infection clusters (21,22). This information can then be used to improve public health initiatives like contact tracing and vaccine development (22). Additionally, it can be used to identify individuals who have been infected with the virus, allowing for more targeted interventions, as well as to identify clusters of infections, which can help inform public health strategies such as social distancing and travel restrictions (23). However, WGS is expensive and time-consuming to perform, and the data it produces can be difficult to interpret (7,23,24). Furthermore,

there are ethical considerations associated with its use, such as privacy concerns and the potential for misuse of the data.

WGS is costly and time-consuming, requiring specialised equipment and expertise. Sequencing a single genome can take days or even weeks, making it difficult to use WGS to track the spread of the virus in real time. Furthermore, WGS is limited in its ability to provide information about how the virus is transmitted, as it can only provide information about the genetic makeup of the virus, not how it is spread from person to person (24,25). Additionally, without epidemiological evidence, WGS cannot distinguish between the directionality of infections (26). The potential risk of acquiring COVID-19 during domestic or international travel, with or without the use of facemasks and social distancing, is uncertain due to the limited certainty associated with genetic inferences. This is because available sequence data may not accurately reflect the potential of virus spread in all cases (26,27). Therefore, epidemiological and other available data should be considered when interpreting sequencing results (27). Additionally, there may have been other SARS-CoV-2 infections with the Beta variant that were not tested nor sequenced, and thus not analysed under the investigation. Furthermore, empirical data on SARS-CoV-2 transmission risk at airports is very limited (28,29).

When conducting outbreak investigation through self-reported information, there are various forms of bias that can occur. Response bias is when the answers given by participants are influenced by how the questions are asked. Recall bias is when participants have difficulty accurately remembering past events or exposures (30). Both forms of bias were considered throughout this outbreak investigation. This was due to the busy schedule of the returned travellers, to ensure that the appropriate public health questions were asked at an appropriate time during mandatory quarantine period. These biases were accounted for and rigorously managed throughout the investigation process. The impact of response and recall biases, though acknowledged and carefully navigated, did not substantially compromise the integrity of the results.

7.0 Conclusion

The investigation of the GFF cluster has provided valuable insight into the transmission of SARS-CoV-2 in a travel setting. The findings of this investigation suggest that the most likely source of infection was an unknown case in the Singapore Changi International airport transit lounge. The COVID-19 Response Branch was able to effectively respond to the cluster and reduce the risk of further outward transmission. A targeted approach was employed to mitigate outward transmission effectively. Additional testing measures were implemented, aimed at detecting asymptomatic cases that might have gone unnoticed otherwise. Moreover, stringent exit testing protocols were enforced, ensuring that departing passengers were thoroughly screened to identify any potential carriers of the virus. This investigation highlights the importance of public health measures in travel settings to reduce the risk of SARS-CoV-2 transmission. The practices at the time were adequate and appropriate to continue without change.

8.0 References

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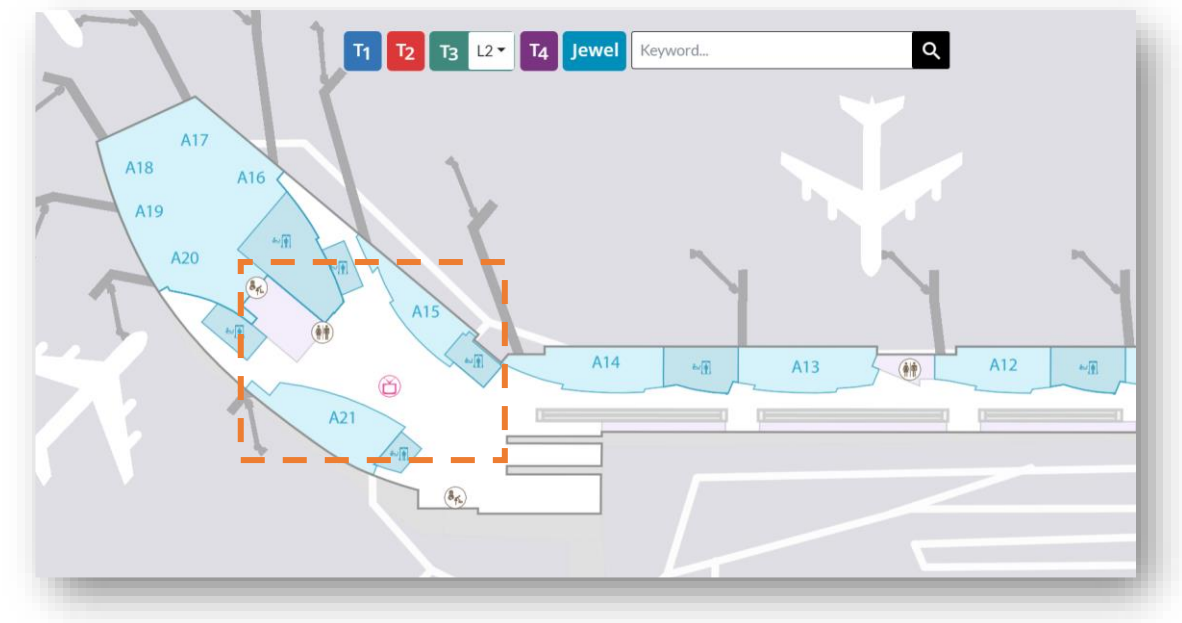
9.0 Appendices

Appendix 1: Transit Lounge, Terminal 3 (T3), Singapore Changi international airport layout



Source: Singapore Changi international airport map (11).

Appendix 2: Additional semi-structured questionnaire for the passengers of the GFF from Singapore to Canberra, Australia, 1 March 2021

Location

1. Can you confirm that you stayed in the transit lounge adjacent to Terminal Gate A14?

   a. If not, which transit lounge did you stay in (i.e. private/premium lounge)?

   b. Did you remain the private/premium lounge the whole duration prior to departure?

2. Was there a designated space in the transit lounge sectioned off for the passengers of the Singapore to Canberra flight on 1st of March 2021 (including airport staff)?
   i.e. physical barriers between sections of the transit lounge.

3. What area of the transit lounge did you spend the most time?

4. Were there control of access to aisles and bathrooms (to minimise contact with other people)? i.e. limit to the amount of people in the bathroom at one time.

5. Any further comments?

Interaction

1. Did you have any prolonged conversations or interactions (more than 15 minutes face-to-face) with any other members of the public other than the people you are travelling with?

   _____

   _____

2. Were you wearing a mask for the whole duration prior to departure?

   _____

   _____

3. Any further comments?

   _____

   _____

Food

1. Was there food or beverage service available in the transit lounge?

   _____

   _____

2. What kind of food or beverage options were available? *i.e. restaurant chain or buffet (self-serve) etc*.

   _____

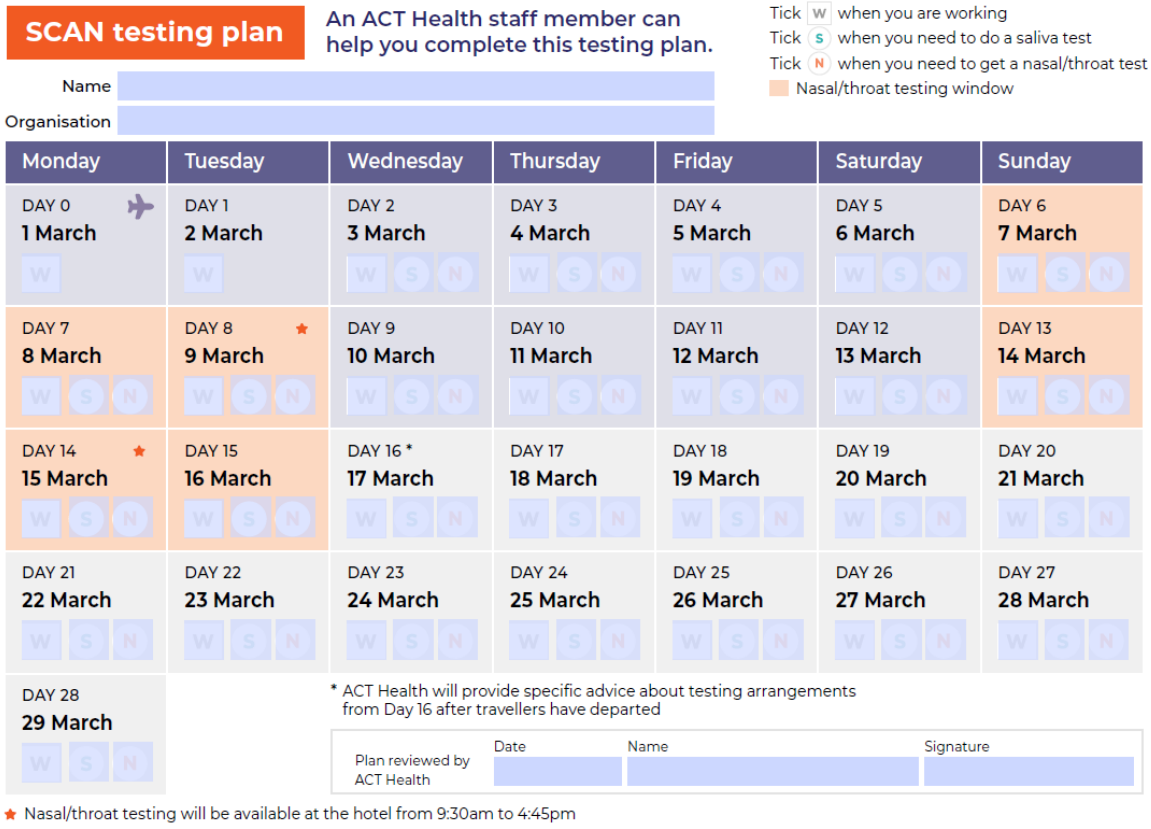
   _____

3. Any further comments?

   _____

   _____

Appendix 3: Syndromic Surveillance SARS-CoV-2 testing calendar for hotel and quarantine staff working with the GFF from Singapore to Canberra, Australia, 1 March 2021



Source: Public Information Coordination Centre (PICC), ACT Health Directorate.

Appendix 4: Outbreak summary presentation, ACT Health Lunch 'n' Learn session, June 2021

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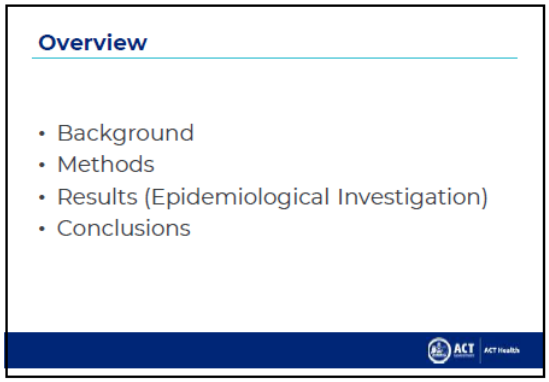

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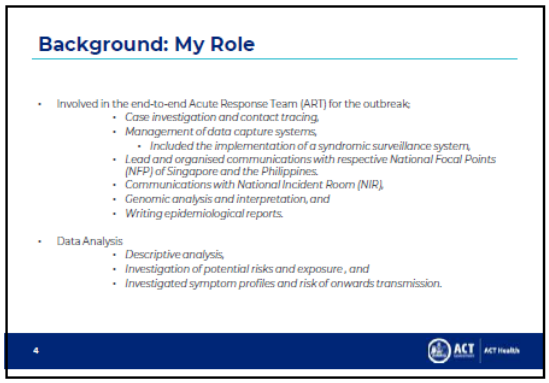

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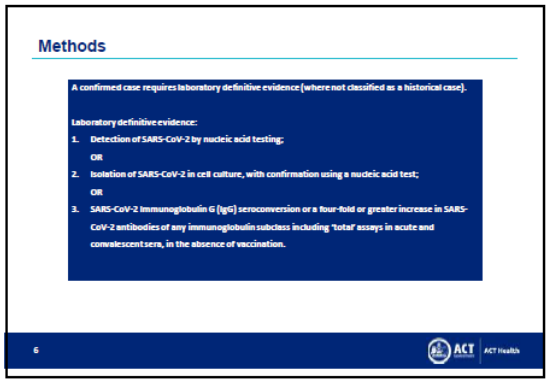

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Results

- Descriptive epidemiology
- Epidemic curve
- Exposure history: transit lounge
- WGS analysis and results

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Table 1. Descriptive epidemiology of the passengers and quarantine staff involved in the Australian Government-Facilitated Flight from Singapore to Canberra, Australia, 1 March 2021.

		GFF Passengers		Quarantine Staff	
		Cases * n (%)	Non-Cases n (%)	Cases n (%)	Non-Cases n (%)
Sex	Male	3 (60)	79 (56)	0	106 (53)
	Female	2 (40)	62 (44)	0	96 (47)
Age category (years)	0-9	0	28 (20)	0	0
	10-19	2 (40)	14 (10)	0	3 (1)
	20-29	0	17 (12)	0	75 (37)
	30-39	0	29 (20)	0	49 (24)
	40-49	3 (60)	28 (20)	0	34 (17)
	50-59	0	13 (9)	0	33 (16)
	60-69	0	7 (5)	0	9 (4)
	70-79	0	5 (4)	0	0
	80-89	0	0	0	0
	90+	0	0	0	0
Total		5 (100)	141 (100)	0 (0)	204 (100)

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Figure 1. Epidemic curve of the confirmed SARS-CoV-2 cases from the GFF from Singapore to Canberra, Australia, 1 March 2021 by onset date.

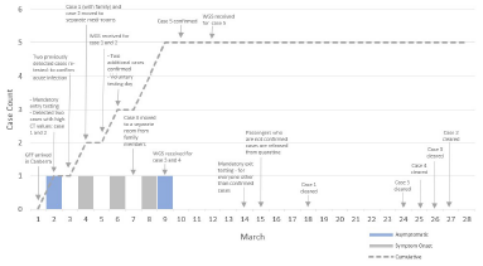

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Figure 2: Transit Lounge, Terminal 3 (T3), Singapore Changi International Airport Layout

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Figure 3: Syndromic Surveillance SARS-CoV-2 testing calendar for hotel and quarantine staff

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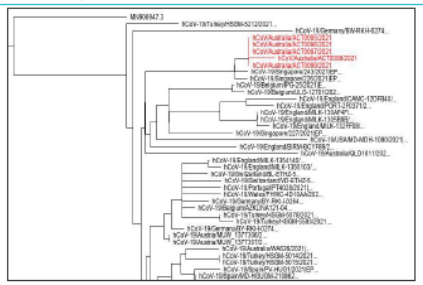
Figure 4: Phylogenetic tree for 5 confirmed COVID-19 cases from the GFF, March 2021



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Conclusion

- Source was most likely originated from an unknown case in the Singapore Changi International airport transit lounge.
  - Due to available evidence from genomic sequencing, clinical and epidemiological data.
- Limited empirical data on SARS-CoV-2 transmission risk at airports.
- No further onwards transmission of the infection to hotel and quarantine staff that worked during the operation.
  - The coordination and implementation of the syndromic surveillance was deemed successful.

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THANKS FOR LISTENING

QUESTION TIME

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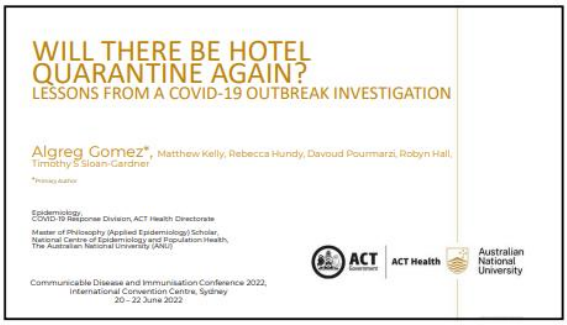
Appendix 5: Presentation slides submitted to the Communicable Diseases and Immunisation 2022 (CDIC2022), 20-22 June 2022

International Convention Centre (ICC), Sydney, New South Wales



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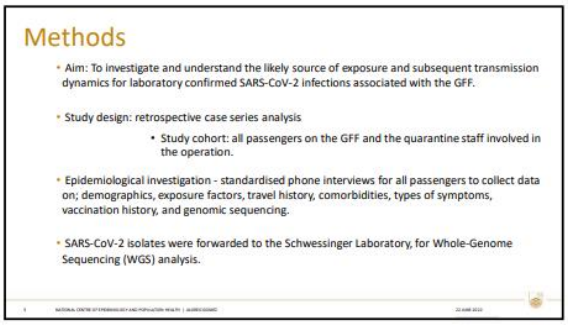

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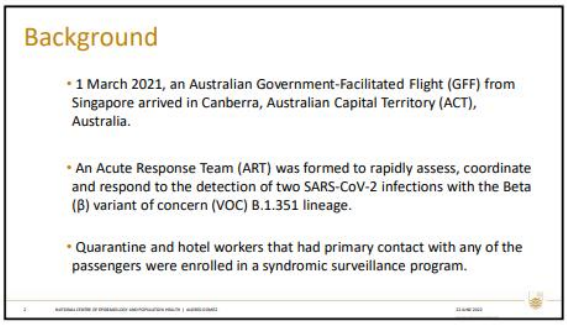

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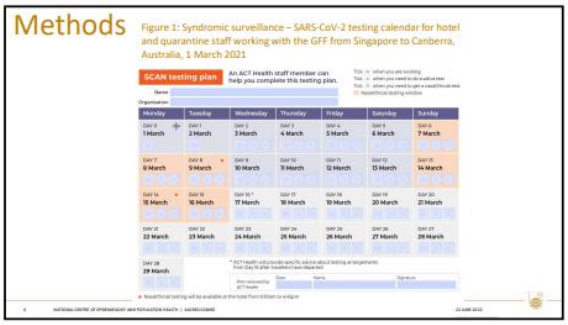
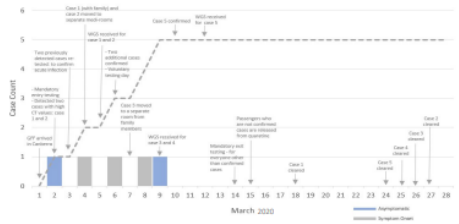


4

Results

Figure 2. Epidemic curve of SARS-CoV-2 infections by symptom onset date from the Government-Facilitated Flight from Singapore to Canberra, Australia, March 2021.



5

Conclusion:
Public Health Implications

- Syndromic surveillance systems are one public health measure that can be effective in the reduction of SARS-CoV-2 transmission risk.
- There are increased transmission risk of SARS-CoV-2 infection at airports.
- Hotel-quarantine could still serve as an effective public health strategy, even in the age of high vaccination rates and effective treatments for COVID-19.
- The outbreak investigation was deemed to have been a successful response operation as it did not lead to the onward transmission of SARS-CoV-2 infections to other returned travellers or hotel-quarantine staff and subsequently, did not lead to community transmission.

6

THANK YOU

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Chapter IV

Evaluation and Establishment of an Improved Surveillance System for Salmonellosis in the Australian Capital Territory

Table of Contents

List of Abbreviations

ACT	Australian Capital Territory
ACTHD	ACT Health Directorate
ANU	The Australian National University
ART	Acute Response Team
CDC	Communicable Disease Control (ACT Health)
COVID-19	Coronavirus Disease 2019
DSD	Digital Solutions Division
ED	Emergency Department
EH	Environmental Health
GP	General Practitioner
HECC	Health Emergency Control Centre
HPS	Health Protection Services
MJOI	Multi-jurisdictional Outbreak Investigation
MLST	Multilocus sequence typing
MLVA	Multiple Locus Variable-Number Tandem Repeat Analysis
NDMS	Notifiable Disease Management System (ACT Health)
NNDSS	National Notifiable Diseases Surveillance System
OFN	OzFoodNet
PHO	Public Health Officer
REDCap	Research Electronic Data Capture
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
US-CDC	United States Centers for Disease Control and Prevention

1.0 Prologue

1.1 Study Rationale

This chapter contains reflections on the experience and learnings from implementing an improved surveillance system. The research project was completed in consultation with the Communicable Disease Control (CDC) section, Health Protection Services (HPS), ACT Health Directorate (ACTHD). This project used the recommendations from an evaluation study completed through a short research program funded by ACT Health's Vacation Study Program completed in 2019-2020. This study evaluated *Salmonella* questionnaires in the Australian Capital Territory (ACT) and reviewed the timeliness and completeness aspects of the routine follow-up process. The evaluation study found that the paper-based data collection process had limitations to its flexibility and usability. As a result, the project converted the paper-based data collection process into an online form and database using Research Electronic Database Capture (REDCap) software. Based on a further evaluation, the surveillance system which was held within an internal server was found to have several limitations to its flexibility and usability. This project aimed to address these limitations in two phases: first, by conducting a pre-implementation evaluation of the system and secondly, establishing an improved and automated system.

1.2 My Role

I led the project as the lead investigator and project officer, designing and developing the data capture system. I coordinated stakeholder engagement, consultation, and developed an implementation plan. I identified key stakeholder groups to engage in the initial evaluation and implementation of an improved surveillance system for the follow-up of salmonellosis in the ACT. One of the major parts of this process was to analyse the system requirements to ensure that the new surveillance system would meet the criteria for the team. This evaluation was guided by the United States Centers for Disease Control and Prevention (US-CDC) framework for evaluating surveillance systems. Amidst all this work, the ACTHD was in the process of implementing a centralised Notifiable Diseases Management System (NDMS). This posed other challenges during the consultation process, which are outlined in the lessons learnt section below. I was able to develop and deliver training materials to the broader team of CDC to ensure that the proposed changes were communicated in a clear manner. I also lead the development of a standard operating procedure (SOP) document that described the step-by-step process of the data entry into the system. This document also outlined the specific user rights, responsibilities and

management of data (Appendix 4). Additionally, I developed system guides that explained specific troubleshooting instructions since there were limited resources in the web, which I shared with the Surveillance and Reporting team (my usual team), within the COVID-19 Response Branch. These efforts are outlined in the lessons learnt section below.

1.3 Lessons Learnt

This project was both challenging and rewarding. I gained valuable insights into the importance of stakeholder engagement and consultation. I had previous experience with the team at CDC, but I still wanted to further strengthen my professional relationship with them. This was important as there were existing processes that needed to be modified and I needed to build trust and ensure that my technical skills were accepted in order to complete the task. I created workshop modules that were presented before and after the implementation of the system, which catered to the technical expertise of the team. I enjoyed being able to explain complex system requirements to a non-technical audience and developing workshops that addressed real-world problems that the team may encounter when using a different data capture system. Through this project, I learnt a tremendous amount in data management principles. I was also able to strengthen my professional relationship with technical officers from the Digital Solutions Division (DSD), who are responsible for managing health systems in the ACT.

Secondly, I have learnt that research projects can be unpredictable and that I need to be flexible and understand that some situations are out of my control. I have also developed my project management skills to ensure that project milestones and deadlines are met, while allowing for delays in the process. The first proposed concept paper and data analysis plan was submitted in March 2021. Stakeholder engagement and consultations were completed shortly after, and the database was deemed ready by the research team by June 2021. Although, staff from the CDC section, HPS were deployed to help with the local COVID-19 outbreak within the Health Emergency Control Centre (HECC), ACTHD. This meant that the OzFoodNet (OFN) portfolio was undertaken by the CDC Surveillance Coordinator, where the OFN position was vacant for the majority of 2021. I had to be flexible and understand that the situation was out of my control. I was required to re-direct my attention on other MAE projects and COVID-19 Response operational requirements at the time. This experience has

reinforced the importance of being able to adapt and adjust to changing circumstances.

Thirdly, I learned that surveillance systems are rarely perfect. As previously mentioned, a centralised surveillance system for all notifiable diseases and conditions in the ACT was being implemented. This meant that there were considerations (and limitations) for the surveillance system that I intended to implement. I was able to appreciate the importance of consulting with a range of stakeholders, including the team at CDC regarding all of the proposed changes and improvements to the surveillance system, as well as the respective process changes that come along with a new system. This enabled us to ensure that the system was as effective and efficient as possible.

1.4 Public health implications of this work

The implementation of this system was successful in achieving its goal of improving data collection through automated surveys. This will result in significant time savings for individuals completing the surveys, as well as improved organisation of data points for both routine and ad-hoc analysis. The improved quality and time data should also lead to faster detection and implementation of public health interventions.

1.5 Acknowledgements

I am grateful to my supervisors for their expertise and guidance throughout this project. From the outset, my field and academic supervisors demonstrated their trust in my technical abilities by entrusting me with the design and implementation of the system. Their faith in me gave me the confidence to take charge of all aspects of the project. I would like to provide special thanks the CDC section, HPS for allowing me to lead this project. I would like to provide a special mention to Alexandra Marmor, Nevada Pingault, Jenny Post, Felicity Greenville and Evelyn Pappas. They all played an important role in either the development, implementation and/or testing of the system.

1.6 Master of Philosophy in Applied Epidemiology core activity requirement

- Implementation or an evaluation of a public health surveillance system
- Report for a non-technical audience

2.0 Abstract

2.1 Background

Public health surveillance of *Salmonella* infections in Australia is an important part of the country's efforts to reduce the incidence of foodborne disease. In the Australian Capital Territory, attempts are made to conduct a telephone interview with all notified laboratory-confirmed cases of *Salmonella* infection to gather epidemiological information to help identify sources of infection, particularly any foodborne sources, and to identify any potentially linked cases.

2.2 Methods

This research aimed to evaluate the salmonellosis surveillance system in the ACT, using the US-CDC Guidelines for Evaluating Public Health Surveillance Systems as a framework. I used this framework to evaluate the following system attributes; simplicity, flexibility, data quality, acceptability, representativeness, timeliness, and stability. This research was also used to inform the feasibility of recommended changes and implement an improved automated surveillance system for the ACT.

2.3 Results

Key stakeholders were consulted throughout the process, and the evaluation results revealed several areas for improvement, including a need for increased communication between stakeholders, improved data collection and analysis, and better coordination of resources. Focus group discussions further identified key areas for improvement, such as the need for more comprehensive training and education for stakeholders. The findings of this research project provided valuable insights into the current salmonellosis surveillance system in the ACT. The findings of this study also offered recommendations to establish an improved surveillance system which was also agreed upon and actioned.

2.4 Conclusion

This research project successfully employed the US-CDC framework to evaluate the current salmonellosis surveillance system in the ACT. As a result of this study, an improved and automated salmonellosis surveillance system was established.

3.0 Background

Salmonella is a type of bacteria that is one of the leading causes of acute foodborne gastroenteritis in Australia (1,2). It is estimated that 4.1 million cases of salmonellosis occur each year in Australia (3). *Salmonella* infections have substantial negative effects on public health in Australia, with the potential for serious illness and, in some cases, death (3). All Australian states and territories require notification of salmonellosis (4). Public health surveillance of *Salmonella* infections in Australia is an important part of the country's efforts to reduce the incidence of foodborne disease (3). Australia attempts to lower the frequency of foodborne illness by conducting crucial salmonellosis public health surveillance. Contaminated foods such as unpasteurized milk and dairy products, raw or undercooked eggs, poultry, meat, and shellfish, as well as water from rivers, lakes, and other streams that has picked up animal faeces can all cause salmonellosis in Australia (5).

The Australian Government Department of Health and Age Care monitors public health surveillance of *salmonella* in Australia, working with state and territory health departments to monitor the incidence of salmonellosis in the population through laboratory testing, epidemiological investigations, and public health campaigns (3,5). In the Australian Capital Territory (ACT) under the *Public Health Act 1997,* health professionals (doctors, pathology laboratories and/or nurse practitioners) must notify the Disease Surveillance Unit of the Communicable Disease Control (CDC) section, Health Protection Services (HPS) of any confirmed human cases of salmonellosis detected in the ACT (6). Public health officers (PHO) within the team at CDC perform the routine public health follow-up of all notified cases of salmonellosis. In 2021, there were 158 notifications for salmonellosis in the ACT with a case notification rate of 36.6 per 100,000 population. This was a significant increase of 37% compared to the 115 notifications in 2019.

In the ACT, attempts are made to conduct a telephone interview with all notified laboratory-confirmed cases of *Salmonella* infection to gather epidemiological information to help identify sources of infection, particularly any foodborne sources, and to identify any potentially linked cases. The CDC team were able to interview most of the salmonellosis cases (85%, 150/158) in 2021, though this mode of follow-up was considered time-consuming and data entry heavy. Infections that are likely to be overseas acquired are out of the scope for the surveillance survey although it still

is important to note that the mechanism to track antibiotic resistance remains significant in adding to the body of knowledge about the specific types being reported nationally (other Australian states and territories) and internationally (7,8). In 2021, only 1 (0.6%) *Salmonella* infection was deemed to be overseas acquired in the ACT. The goal of interviewing confirmed cases of an infectious disease is to identify the source and to act rapidly to prevent further cases associated with that source, and therefore routine surveillance is important from a public health perspective (9).

Where multiple cases of salmonellosis occur at the same time, in the same place or of the same serotype or Multiple Locus Variable-Number Tandem Repeat Analysis (MLVA) or sequence derived multilocus sequence typing (MLST), it is possible that the cases share a common source of infection (10). In the ACT, the majority of isolates (86%, 137/158) had serotyping performed. The most important, difficult, and time-consuming section of a standard *Salmonella* interview are ascertaining the cases' recent food history (11). When trying to identify the cause of a foodborne disease, the recent eating history of the patient can be helpful. On the one hand, it can offer useful details regarding the meals that were consumed and when, which can assist to reduce the number of possible offenders. On the other hand, it can be challenging to precisely recollect every food that was ingested as well as the precise moment that it was eaten, which can result in incorrect findings (11). The timeliness of response (in public health surveillance systems) remains an important aspect of public health action (5,12). Delays in case investigations hinders the timely reporting, further surveillance and response to potential cluster or outbreak of *Salmonella* infection (12). In the ACT, the term 'outbreak' is defined as:

"An increase in the number of cases of disease

- *Above what is normally expected in a given area, and*
- *Among a specific group of people, and/or*
- *Over a specific time period*
- *Where illness is associated with a common source or vehicle of transmission."*

Surveillance systems are designed to identify, investigate, control and report rapidly on outbreaks of infections and diseases (13). This is an important aspect of a surveillance system, as it must consider how cases can be orientated by person, place or time. Furthermore, the system must be flexible in accounting for further

epidemiological investigation to review the source of illness when numbers exceed what is normally expected. Public health response in the ACT currently relies on the experience and initiative of the OFN Epidemiologist and public health nurses with limited resources available for ongoing analysis.

The recommendations of a previous internal evaluation were addressed, and a basic electronic form (through Research Education Data Capture system, REDCap) was created in an internal server (14). The REDCap database that was held within an internal server had limitations to its flexibility and usability. The main benefit of implementing this research project is to design and employ an improved surveillance system to increase the efficiency of each follow-up data collection process of key epidemiological data through automated external surveys. As outlined previously, the current system is not flexible and requires unnecessary manual processes which add to the risks of human error when transferring data from one system to another. The system is also very limited to its ability to adapt to new reporting metrics, which in turn, impacts future analysis of public health data.

4.0 Methods

This research project had three consecutive aims. Firstly, to evaluate the current salmonellosis surveillance system in the ACT and make recommendations for improvement, using the US-CDC Guidelines for Evaluating Public Health Surveillance Systems as a framework (15). I used this framework to evaluate the following system attributes; simplicity, flexibility, data quality, acceptability, representativeness, timeliness, and stability (Table 1). Secondly to scope out the feasibility of implementation of the recommended changes and thirdly, to establish a new and improved automated surveillance system for the ACT.

Objectives

The objectives of the pre-implementation evaluation were to;

- Describe the operation/data flow of the surveillance system,
- Engage internal stakeholders and assess their perspectives through survey and small group discussions,
- Identify areas for improvement and provide recommendations,
- Implement an improved surveillance system.

I identified key stakeholders through consultations with my field supervisors. This was made easier since I was familiar with the teams within HPS, ACTHD. Stakeholder engagement was an important stage of the project (further details in section 5.2). In CDC, there are only a few public health nurses who carry out a wide range of operational tasks related to notifiable conditions in the ACT. There is also one designated OFN Epidemiologist who carries out enteric disease surveillance activities and investigations, mainly through passive surveillance. This process relies on the mandatory reporting of public health laboratories, hospitals, and clinical staff. I worked closely with the OFN Epidemiologist during multiple stages of stakeholder engagement. The results from the small group discussions and surveys were intended to inform how I could improve the user experience and reduce the time spent on each salmonellosis follow-up.

Surveillance System Requirements

4.1 Stakeholder Engagement and Consultation: Surveillance System Structure

The system structure, process of follow-up and case definitions for salmonellosis surveillance in the ACT are sourced from internal standard operating procedures (SOPs) and publicly available guidance documents (Box 1). Discussions with the team within the CDC section of HPS also informed this process. Figure 1 outlines the previous system's flow of surveillance data for salmonellosis in the ACT. Laboratory confirmed salmonellosis notifications are received via facsimile and manually entered by a surveillance officer into the Notifiable Disease Management System (NDMS). For all laboratory confirmed salmonellosis notifications, a full phone interview is conducted using a standardised foodborne questionnaire (an adapted version of the OFN standard *Salmonella* questionnaire). All respective enhanced epidemiological data are stored in a basic REDCap survey database placed within an internal facing server, which is not capable of external messaging or automated survey functionality. The OFN Epidemiologist is responsible for coordinating enteric diseases surveillance and investigating the epidemiology of foodborne diseases. They provide information to food safety agencies for risk assessment and enhance surveillance of foodborne

pathogens in the ACT, as illustrated in Figure 1. This role is a critical function of the OFN.

Box 1: Salmonellosis public follow-up procedure extracted from the Manual for the Public Health Management of Notifiable Conditions in the Australian Capital Territory, Version 1.0.

Responsible Officer: OFN Epidemiologist

Public Health Priority: High – within one (1) working day

Case definition: Only confirmed cases should be notified in line with the national Salmonellosis Case Definition.

Public Health Response: To be conducted in accordance with the *NSW Health Salmonellosis (excluding S. Typhi and Paratyphi Infections) Control Guideline*.

Local Public Health Actions:

- Initial data entry to be completed by the Surveillance Officer within one (1) working day of notification.
- Attempt to interview all salmonellosis cases with the *Salmonella* case investigation form within 48hrs notification being entered in to NDMS.
- If the case attended childcare whilst symptomatic, phone the facility to verify that surveillance and appropriate infection control measures are being carried out.
- Notify Environment Health section if the source of infection of more than one case is suspected to be food premises.
- Children who have diarrhoea should be kept home from preschool, childcare or play group until 24 hours after symptoms have ceased.
- Food handlers and caregivers (of sick, children or the elderly) should not resume duties for at least 48 hours after symptoms cease.
- If a cluster is identified, follow the Suspected foodborne outbreak SOP.

Box 1: Salmonellosis public follow-up procedure extracted from the Manual for the Public Health Management of Notifiable Conditions in the Australian Capital Territory, Version 1.0 (Continued)

Data Collection:

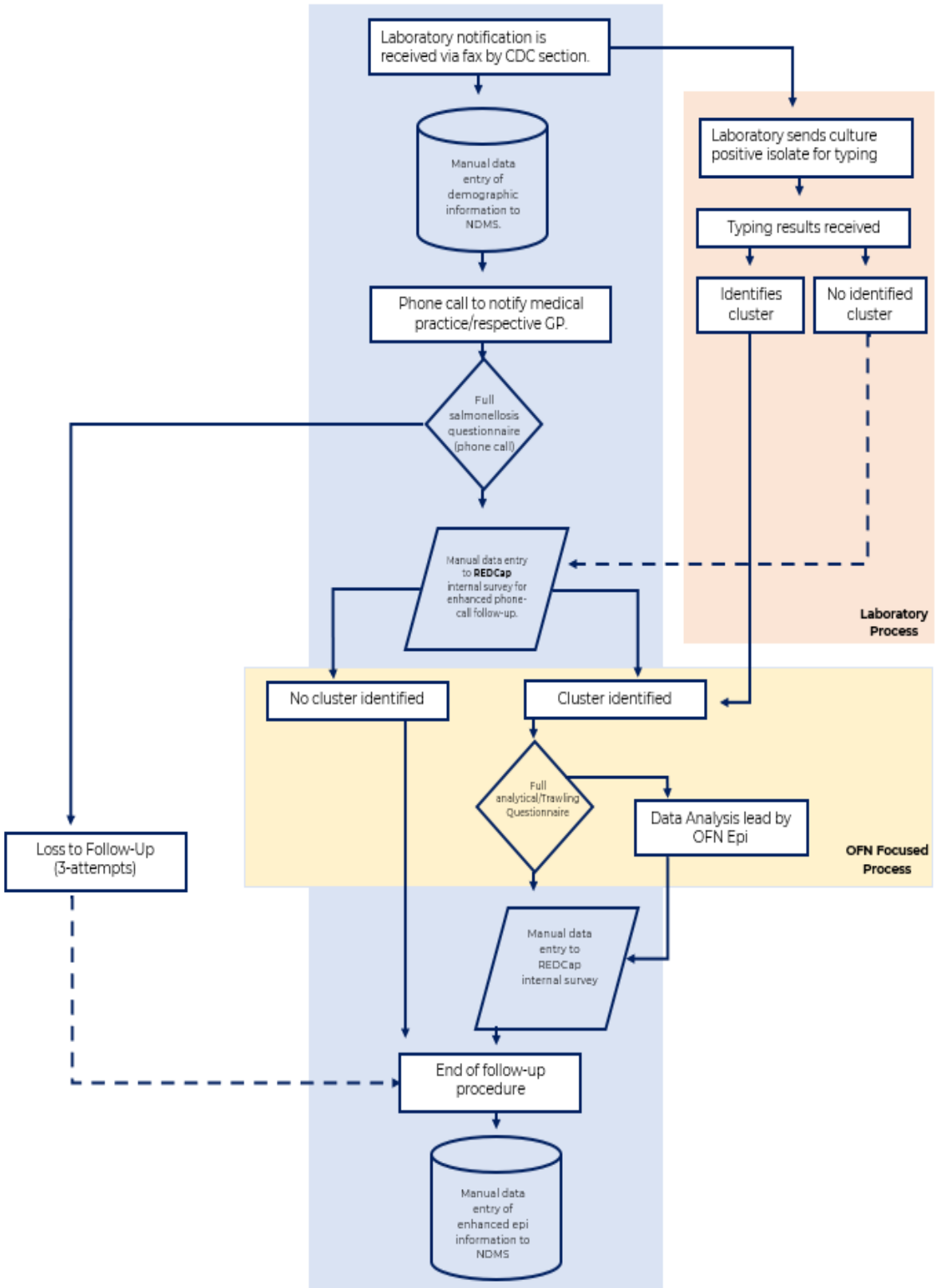
Once follow up is completed, the OFN Epidemiologist must:

- Ensure all core data fields are completed in NDMS.
- Update the Onset date, Hospitalisation, ED Visit, and Died NDMS fields.
- Enter the likely place of acquisition (specific food source/premises or country/geographic region) in the *Suspected Source Details* NDMS field.
- Enter the outbreak reference in the *Outbreak* NDMS field (if applicable); and

Enter any additional details in the *Comments* NDMS field.

Isolates of *Salmonella* serovars are sent to either the NSW Enteric Reference Laboratory, Institute of Clinical Pathology and Medical Research (ICPMR) or the Microbiological Diagnostic Unit (MDU), University of Melbourne for analysis. MDU uses Multi-Locus Sequence Typing (MLST) while ICPMR provides antigenic structure analysis. If multiple cases of salmonellosis occur in the same place or typing cluster, an Acute Response Team (ART) may be formed to investigate the outbreak and respond to the public health threat. All relevant data are entered into either the internal REDCap database and/or NDMS. Demographic and enhanced epidemiological information stored in NDMS is also sent to the National Notifiable Diseases Surveillance System (NNDSS), which is managed by the Department of Health and Aged Care, the Australian Government.

Figure 1: Flowchart of salmonellosis surveillance system in the ACT



The ACTHD was implementing a new notifiable diseases surveillance system at the time of this project. In September 2022, the system was rolled out to collect and report public health data on SARS-CoV-2 infections in the ACT, which was considered "Phase 1". This was followed by "Phase 2", which involved the roll out for other notifiable diseases in the ACT. However, technical issues caused delays in the scheduled roll out for both phases. As a result, the relevant team at the CDC was in a position of using the old NDMS system, an internal REDCap survey to capture enhanced epidemiological information for salmonellosis, and testing a brand-new surveillance system, all for Phase 2.

4.2 Stakeholder Engagement and Consultations: Surveillance System Attributes

In April 2021, I conducted consultations with key stakeholders in multiple stages. The first stage was used to consult on the system requirements and understand the current system and how it can be improved. To review the current system, I designed and distributed an evaluation questionnaire (Appendix 1) based on the US-CDC guidelines for evaluating public health surveillance system framework (15). This questionnaire evaluated the following system attributes; simplicity, flexibility, data quality, acceptability, representativeness, timeliness, and stability (Table 1). The consultation was successful in informing an implementation plan and target key objectives of the surveillance system.

The second stage of consultation involved the development and presentation of training materials to the team. These training materials were aimed at ensuring that team was comfortable with the new proposed system. These materials included a SOP for the notification data entry flow with supporting system guidelines (Appendix 2). The third and final stage of consultation was to present the new and improved disease surveillance system.

Table 1: Methods use to evaluate the current system against system attributes and usefulness

Attributes	Evaluation Definition
Stability	Stability refers to the reliability, and availability of the system (considering its ability to collect, manage, and provide data properly without failure).
Simplicity	How easy it was to enter in notification data into the system, as well as extract relevant data out.
Usefulness	How well the system meets its defined objectives.
Flexibility	Capacity to adapt to changing information needs or operating conditions with limited additional time, personnel, or allocated funds.
Data Quality	Completeness and validity of the data recorded by the surveillance system.
Acceptability	The willingness of persons and organisations to participate in the surveillance system.
Timeliness	The time taken between key steps in the surveillance process.

A questionnaire (Appendix 1) was distributed to evaluate the current salmonellosis surveillance system in the ACT. This evaluation was adapted from the US-CDC updated guidelines for evaluating public health surveillance systems. The aim of the questionnaire was to undertake a qualitative and quantitative evaluation of the REDCap database for collecting epidemiological information regarding all *Salmonella* infections in the ACT.

The objectives of the evaluation were to describe the operational requirements of the system, engage stakeholders and assess their perspectives, identify areas for improvement and make recommendations. A desktop review of all documents related to the public health follow-up of salmonellosis in the ACT, including relevant SOPs, was also conducted. An electronic survey was designed using REDCap to gather internal stakeholder perspectives on the perceived objectives of the system, its performance against these objectives and their views on the system performance with respect to each of the system attributes defined by the US-CDC guidelines (15). The internal stakeholders were members of the Disease Surveillance unit of CDC section,

HPS who either directly used the system, would actively be involved in acute public health responses relating to salmonellosis notifications, or had a vested interest in the data produced by the system.

Ethical Consideration

Ethical aspects of the research were approved by the Australian National University (ANU) Human Research Ethics Committee (HREC) Protocol: 2017/909. This project was undertaken as a system quality improvement which all methods were carried out in accordance with the *Public Health Act 1997,* which provide territory level legislation on the collection of public health data on notifiable diseases.

5.0 Results

Four team members from CDC completed the evaluation questionnaire, which was considered an acceptable response rate given the size of the team compared to other teams in HPS and other sections within ACTHD. Not all questions were answered, and the system attributes were determined through internal stakeholder survey, follow-up discussions, and/or a review of internal documents/SOPs. The evaluation results are provided in the relevant sections below.

Stability

The Surveillance unit of the CDC section of HPS manages a routine disease surveillance program. This program currently uses a fax-based system, with a designated officer to process each laboratory result and manual data entry to multiple online systems. When asked if there were any risks that could destabilise the operation of the surveillance system, 75% (n=3/4) of respondents answered "Yes". This response highlights the main flaws of the current process and surveillance system.

> Respondent One: "*Reliance on paper and Surveillance Officer - currently notifications are received by fax and are only progressed after the Surveillance Officer has processed the fax and printed the lab report. Lab reports are not saved in current database as attached and our current team is averse to saving an electronic copy on REDCap…"*

The group discussions highlighted the potential risk of a missed follow-up due to the lack of an automated and electronic data capture system. This was further discussed in staff forums, where it was noted that the current NDMS may experience unexpected outages, resulting in potential data loss. However, the evaluation questionnaire revealed that 66% (n=2/3) of respondents reported no incidents of system destabilisation in the last 3 years. Below are additional responses to the risk of system destabilisation.

> Respondent One: *"The manual entry process can be slow, and we may not know about a salmonella notification until the next day. The reliance on paper necessitates everyone being in the office for the process to flow, or multiple points of contact to get all the relevant points of information off the pathology form. If our Surveillance Officer is away, or we are required to work remotely, there are risks to how promptly we will receive information to commence public health action. Lack of tasking - as we rely on paper and face-to-face interactions, we have no formal procedure to task cases for follow up. This could result in someone being missed for follow up. Ideally, an electronic system to task cases would have some added accountability and a paper trail to follow up."*
>
> Respondent Four: "*staff shortages, IT outages at any step".*

The questionnaire revealed that the NDMS has not experienced any unexpected outages in the past 3 years. Although the internal REDCap system was not directly evaluated for stability, the COVID-19 Response Branch team was believed to have adequate support through Digital Solutions Division (DSD) within ACTHD and enough expertise within the COVID-19 Response Branch to troubleshoot and rectify any inconsistencies caused by an unexpected outage. The CDC team outlined that they were confident that they could handle any such issues.

Simplicity

The surveillance process and current system for salmonellosis notifications is considered to be straightforward and have been described as "uncomplicated". This was in relation to its structure and ease of operation. All of respondents

agreed that the current system is capable of easily distinguishing between different types of *Salmonella*.

Notifications are received by fax or email from either a public health laboratory based in the ACT or are received through routine cross-border notification processes. The REDCap questionnaire includes fields for basic demographic and enhanced epidemiological information within the one form. The majority (75%, n=3/4) of the internal stakeholders have agreed that it is easy to notify a confirmed or suspected case. Currently, manually data entry processes rely on paper laboratory notification receipts and a surveillance officer to process the relevant data points into the system. Additionally, the current database collects enhanced epidemiological in free text fields. During discussions, it was suggested that an automated online notification system would reduce the amount of data entry required. This would allow for bulk uploading of information, rather than manual entry of individual records. It was also noted that this would lead to a decrease in the time needed to complete certain sections of the notification process, which are addressed in the timeliness section.

Usefulness

The usefulness of a surveillance system is determined by its ability to prevent and control adverse health events. According to the evaluation questionnaire, 75% of respondents agreed that the current database is able to collect and report data for local and national reporting requirements. However, one respondent disagreed and during small group discussions it was noted that the process of reporting data from NDMS was still manual. It was recommended that data collection and reporting procedures could be improved by using an automated survey linked to a centralised data repository. This repository could also be linked to other identifiable information that could link mandatory reporting fields.

One of the main purposes of surveillance systems is the ability to identify and report rapidly on outbreaks of infections and diseases. The majority (75%m n=3/4) of respondents agreed that the current database is able to detect local outbreaks, while 25% (n=1/4) disagreed. However, only 50% (n=2/4) of respondents indicated that the current database is able to inform multi-jurisdictional outbreak

investigations (MJOI). Regarding the statement “Overall, the current database serves its purpose”, 75% (n=3/4) of respondents agreed, while one person disagreed and suggested that the system could be improved by adding relevant fields to report on outbreaks and MJOIs.

Flexibility

Flexibility of a public health surveillance system is the capacity to adapt to changing information needs or operating conditions with limited additional time, personnel or allocated funds. This allows for the system to be tailored to different populations and contexts, ensuring it is relevant and useful. It also allows for the system to be adapted to different levels of resources, making it accessible and affordable. In the ACT, the current NDMS system is not flexible, while the internal REDCap database has some flexibility in adapting to changing information needs. 50% (n=2/4) of respondents agreed and had a neutral view on the two statements: “the current database is able to adapt to changes in case definitions” and “IT support for the current database is easily accessible”. Additionally, the majority of respondents either disagreed or strongly disagreed that it is easy to make changes to the database to collect additional information.

The current NDMS system is very manual and does not allow for the addition of new variables or the modification of existing ones. As a result, much of the enhanced epidemiological data collected from the REDCap database is stored in a free-text field. This means that there is no central data repository, making it difficult to use analytical/programming software for ad-hoc data and reporting requests. The OFN Epidemiologist is responsible for investigating foodborne diseases in the ACT but extracting and reporting on enhanced epidemiological information from the current NDMS system is difficult. There are also no operational reports out of the internal REDCap that are routinely analysed for cluster analysis. If there were potential changes, adding new variables that would flag whether a case or group of cases could belong to a cluster (by person, place and/or time) should be possible.

The ability to automatically send the routine questionnaire via an online survey would also address the lack of flexibility. The majority of respondents (66%, n=2/3)

outlined that they either disagreed or had a neutral attitude to the statement: "*the current database can be managed effectively (still meets objectives) at reduced staff capacity*". This also highlights the need for further staff training which will be outlined in the section for data quality.

Data Quality

Data quality is essential for public health surveillance systems to be effective. Poor data quality can lead to inaccurate results and incorrect decisions. To ensure data is accurate, complete, and up to date, it must be collected in a consistent manner, stored and managed properly, and free from errors. Good data quality also helps to ensure the data can be used for meaningful analysis and interpretation. This is important for providing reliable and timely information that can inform public health decisions. In this evaluation questionnaire, I was interested in if the appropriate data type was being collected and if field validation was being undertaken. This is an important aspect of data integrity, as both demographic and enhanced epidemiological data must be imported to the current centralised NDMS and meet NNDSS reporting requirements. The majority of the respondents (75%, n=3/4) noted that the data from the current database is of high quality (is accurate and contains no errors). The response was consistent to the following question that ask whether the data is able to be extracted from the current database to be entered into the current NDMS and to the NNDSS. There were 50% (n=2/4) that responded that they were aware of quality assurance processes within the system were being completed to ensure high quality data was being collected.

Acceptability

The acceptability of a surveillance system is largely determined by the perceived benefits and risks of participation, as well as the perceived privacy and confidentiality of data. When individuals believe that their participation will bring them or their community benefits, such as improved access to health care or better public health outcomes, they are more likely to take part. Conversely, if they perceive that their participation could put them at risk, such as the potential for data misuse or personal information being shared without consent, they are less likely to participate. From the group discussions, there was a consensus that the current system could be improved for a more person-centric database.

All participants (100%, n=4/4) noted strongly agreed that they believe that notifications of confirmed cases of salmonellosis is important and that within their respective roles, they believe that time spent on salmonellosis surveillance is worth their time. There were 50% (n=2/2) that marked agree and the other marked disagree to question that the time taken to notify the case, process of notification and ease of notification are reasonable.

Timeliness

Timely data is essential for public health surveillance systems. It enables public health officials to quickly identify and respond to potential health threats, as well as informing decisions about resource allocation and interventions to prevent or mitigate the spread of disease. Timely data can also help identify emerging health trends and inform public health policy, as well as provide the public with the information they need to make informed decisions about their health (16,17). In the ACT, passive surveillance relies on voluntary reporting of cases by public health laboratories and clinical staff. To evaluate the timeliness of this system, we investigated multiple aspects. Firstly, we asked staff for their views on whether the surveillance system is capable of timely public health follow-up of confirmed cases. All respondents from the focus group sessions and evaluation questionnaire agreed that the system allows for timely follow-up of persons with a *Salmonella* infection. According to the public health manual (Box 1), a salmonellosis notification must be followed up within 48-hours of the notification receive date (when it is received by facsimile).

In this evaluation, we also reviewed whether the surveillance system could extract information in a timely manner. The respondents were split, with 50% agreeing and 50% disagreeing. The question asked if the structure and process of the system (notifications, data input, extraction and analysis) allowed for a timely response to potential outbreaks. During stakeholder discussions, it was revealed that the current system posed difficulties in extracting and analysing data for outbreak investigations. In many cases, Microsoft Excel was used to manage outbreak datasets.

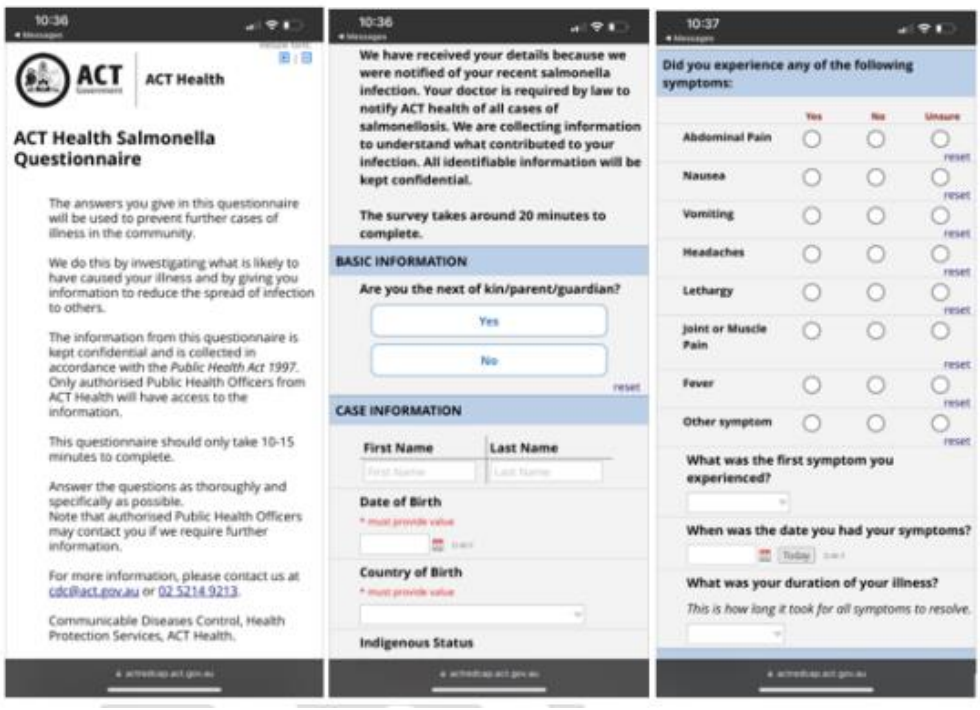
Surveillance System Outcomes

The evaluation of the current system and the topics for improvement were covered in the preceding section. The installation of the new system, which was influenced by the evaluation of the current system, is covered in the following section. The evaluation of the previous system was completed in August 2021, and in April 2022, a new improved surveillance system was established.

5.1 Implementation of a new automated REDCap database

This research project was successful in using the US-CDC framework for the evaluation and establishment of an improved surveillance system for the ACT. Internal procedure documents, stakeholder workshops, and pre-implementation surveys were reviewed to scope the feasibility of creating the system. Additionally, an automated external survey was designed to meet web and online accessibility guidelines (Figure 2). This process resulted in improved SOPs and internal guiding documents, including a section on system management and troubleshooting system errors (Section 5.5). To ensure the team was comfortable in the use and management of the new system, it was deemed crucial to consult them throughout the process.

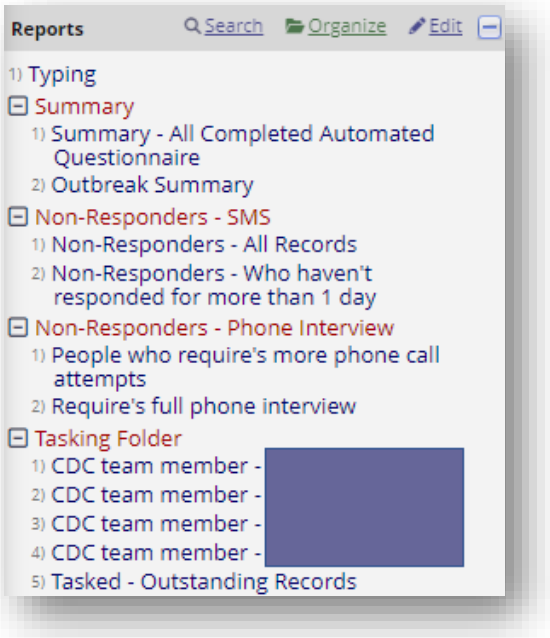
Figure 2: Preview of the REDCap automated external salmonellosis survey through a smart phone.



The results of the pre-implementation survey revealed that it was important for the surveillance process and current system to be simple. The stakeholder discussions suggested that an automated online notification system would reduce the amount of manual data entry. It was also noted that this would lead to a decrease in time needed to complete most of the notification process. The new REDCap automated external surveys addressed this concern from the team. It allows for the initial trawling phase of the public health follow-up to be more efficient by providing an opportunity to collect the data more quickly by sending a shortened case questionnaire to cases, reduce the amount of time needed to collect the data, reduce the costs associated with conducting individual interviews by a PHO and ability to ensure that the data collected is done in a consistent manner.

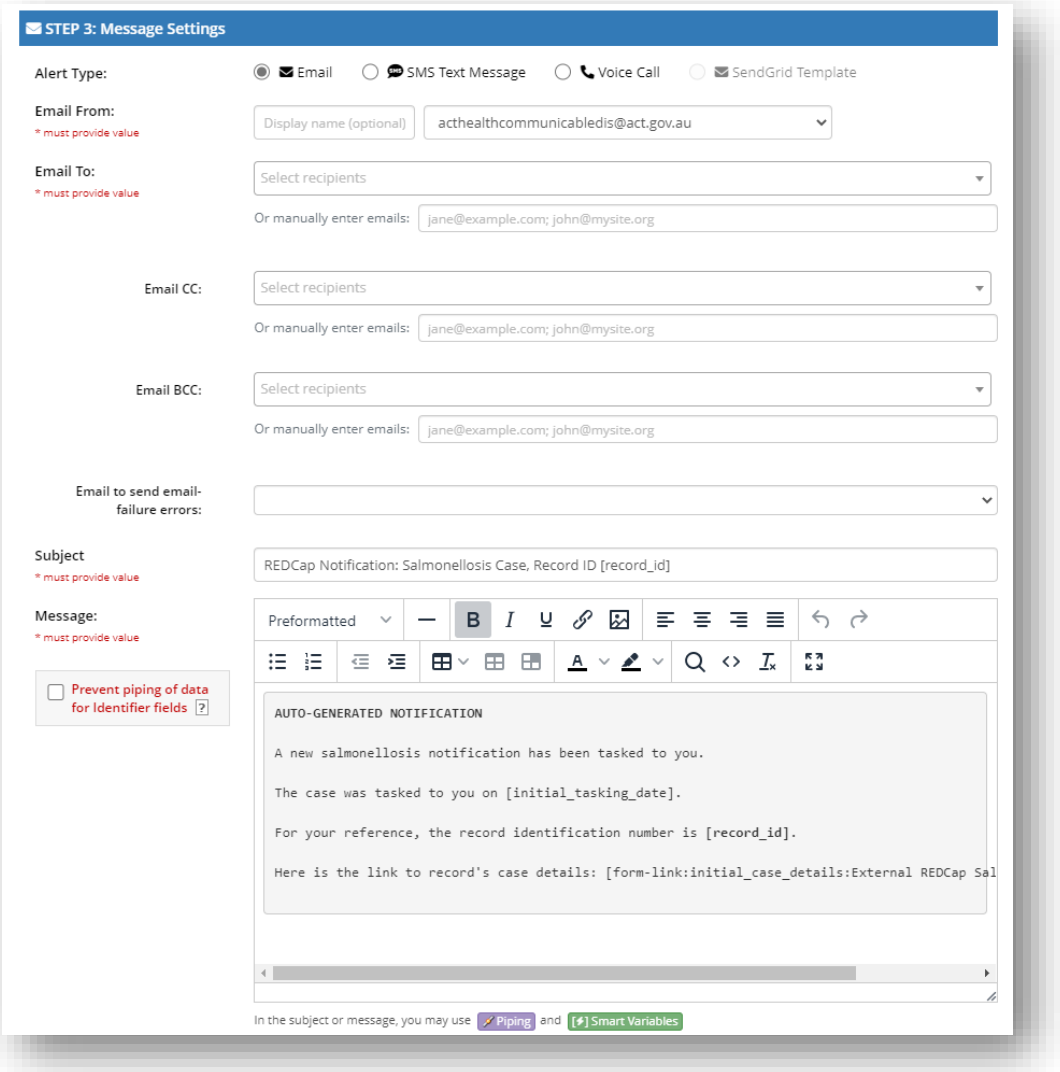
The new improved system also collected information on individuals who did not respond to their automated survey and those who may require further phone call attempts (Figure 3). This improves the ability to identify non-responders quickly and easily, and the opportunity to follow-up with non-responders in a timely manner. Additionally, this allows for the ability to ensure that all participants are included in the data collection process and reduces the loss-to-follow rate.

Figure 3: Screengrab of the report folders within the new automated REDCap salmonellosis surveillance system for the ACT.



The stakeholder discussions highlighted the potential risk of a missed follow-up due to the lack of an automated and electronic data capture system. Figure 3 portrays a tasking folder, which is a new aspect that was implemented in the new system. This allows for the individual team members involved in salmonellosis follow-up procedures to track each case and their respective status. It addressed the concern of the “lack of tasking” as it was outlined that there was very minimal formal procedure to task cases for follow-up. This also allows improve the accountability of each PHO involved in this process. Another way of improving this process is to employ an automated notification to the respective PHO who has been tasked with the follow-up of a suspected salmonellosis case (Figure 4).

Figure 4: Screengrab of the automated alert sent to a Public Health Officer when tasked a record for a public health follow-up.



Another important component of the evaluation was its findings that addressed the usefulness of the surveillance system. One respondent noted that the process of reporting data from NDMS was very manual. It was recommended that the data collected by the improved system could also be linked to a centralised data repository. This would allow for the key demographic and epidemiological information to be collected and stored in a more automated process. As part of the "usefulness" section of the evaluation, the recommendation of adding relevant fields to report on outbreaks and MJOIs were actioned. A radio button (single toggle button) would allow a particular person-record to be flagged as a part of an outbreak (and/or an MJOI) and a subsequent dropdown would allow for an association with a particular identification number. This will aid the OFN Epidemiologist and relevant PHOs, who are responsible for the analysis of epidemiological data on patients notified with a notifiable foodborne or environmental disease or condition.

Data quality is essential for public health surveillance systems to be effective (15,17). In the stakeholder discussions, respondents outlined it was important to have a system that was simple, and that it could collect relevant data for meaningful analysis and interpretation. The new system that has been established to consider the previous data collection fields (also known as variables) to also align with nationally consistent required fields. This has been noted as part of the recommendations of this project (Box 2). Another important component that the new surveillance system addressed its flexibility. It was decided that REDCap was the most suited platform as the data collection tool. The flexibility of this system allowed for a tailored system for the automated alerts associated to the ACT context. The previous system was held in an internal server which restricted the team's ability to send external surveys to individuals with a *Salmonella* infection. This was addressed by transitioning the entire platform to an external server, that allowed for external surveys and other functions that was not possible previously. It was also accompanied by in-depth procedure documents and system training of the data collection process (Section 5.5).

5.2 System Management Training and Development of Standard Operating Procedures (SOP)

System management training and internal guidance documents are important aspects of ensuring that team members are familiar with the system and its processes (18). To ensure the team was comfortable in the use and management of the new system,

it was deemed crucial to consult them throughout the process. The main benefit of conducting this research project is to design and employ an improved surveillance system to increase the efficiency of each follow-up data collection process of key epidemiological data. This process included the development of system guides and respective tutorials to discuss the new system and its capabilities (Appendix 3). The training addressed the topics of data structure and data flows from NDSMS to REDCap, and vice versa. Additionally, advanced techniques of how to utilise REDCap were presented. This ensured that there was a consistent set of guidelines for how the system should be used, so that the appropriate data is collected accurately and consistently.

6.0 Discussion

I conducted an evaluation of the current salmonellosis follow-up process and surveillance system against the US-CDC's Updated guidelines for evaluating public health surveillance systems (15). To do this, I examined seven system attributes through a combination of a desktop review, stakeholder survey and discussion groups. This evaluation enabled me to implement an improved and automated surveillance system, propose key improvements and then develop and implement an updated system.

The evaluation of the current process and surveillance system revealed that it was not flexible and did not allow for timely response to potential outbreaks. To address these limitations, an improved surveillance system was implemented. This new system incorporated feedback from stakeholders that were collected throughout the project, which included focus group discussions that were used to develop a system that was acceptable, appropriate and targeted to the end-users. These end-users included the public, who would use automated surveys, as well as internal staff members of the CDC team who would manage, analyse, report on the data collected. The database was designed to improve timeliness by providing tailored surveys and outward messaging. This was intended to reduce the time-to-contact for salmonellosis cases in the ACT. Automated surveys, alerts and reminders are also available, allowing the respective PHO to be alerted of any outstanding follow-up and review records quickly. This addresses the issue of timeliness, as previously 1-2 PHOs had to oversee multiple foodborne related follow-ups for the PHU, which could lead to an increase in time-to-contact if there were other competing priorities or outbreaks.

Public health surveillance of *Salmonella* infections is an important tool for quickly and accurately identifying outbreaks (5,12). By tracking cases, public health officials can identify the source of the infection and take steps to prevent further spread (17). Additionally, surveillance data can be used to inform public health policies and interventions (19). It also helps to identify high-risk populations, such as young children and the elderly, who are more likely to become ill from salmonella. With this information, targeted interventions can be developed, such as food safety education campaigns, to meet the needs of the community (20). By tracking the number of cases, PHOs can determine which interventions are most effective in preventing and controlling salmonella infections. Finally, public health surveillance of *Salmonella* infections helps to ensure that food safety standards are being met. By tracking cases of *Salmonella*, public health officials can identify food establishments that are not following proper food safety protocols and take steps to ensure that these establishments follow regulations.

It was acknowledged that there were inherent differences in experience and roles among the team members. To counterbalance any potential discrepancies in responses, we implemented the structured data collection method via the standardised questionnaire. The project investigation team conducted regular team meetings with the encouragement of open exchange of ideas and perspectives. While the team was small, meticulous care was taken to engage all relevant individuals, ensuring a comprehensive understanding of the research project and objectives.

It is recommended that a post-implementation evaluation is conducted 3-months after the surveillance system is fully operational (Box 2). This will allow the team at CDC evaluate whether the new surveillance has addressed the recommendations and improved the metrics as described above. A short descriptive report should be distributed from the post-implementation evaluation to inform the status of the improved system.

7.0 Conclusions

This research project was successful in using the US-CDC framework for the evaluation of the current salmonellosis system in the ACT. Key stakeholders were

consulted from the start and through the process. The evaluation results, combined with focus group discussions, provided recommendations, and identified key areas for improvement in the surveillance system. The identified improvements were used to develop an updated system which was implemented and supported with training and SOP documents.

Box 2: Recommendations for the surveillance system

8.0 Recommendations

1. It is recommended that an evaluation is conducted 3-months post-implementation.

The post-implementation evaluation could use the US-CDC guidelines with a similar questionnaire that was employed in this project. The results in this project could be used as the pre-implementation data and be compared with the results of the new surveillance system. This comparison can be used to assess the effective of the new system by measuring the differences in outcomes between the two systems. This comparison can provide insight into how well the new system is performing relative to the previous system and can help identify areas for improvement.

2. It is recommended that regular data quality checks are conducted.

Regularly reviewing data and making sure that discrepancies are addressed is an important part of data management. This process involves analysing data to identify any errors or inconsistencies, and then taking corrective action to resolve them. This could include updating records, correcting errors, or making changes to processes or systems. It is important to ensure that data is accurate and up-to-date, as this can help improve decision-making and ensure that data is reliable. Regularly reviewing data can also help to identify potential problems before they become major issues.

3. It is recommended that a regular meeting with the relevant teams from DSD and experts from the Data Science team of the COVID-19 Response Branch are set-up to troubleshoot any issues that may arise post-implementation.

It is important to ensure that the surveillance system is properly maintained. This can be done by regularly communicating with experts and relevant system administrators of ACTHD to ensure that the system is functioning as it is intended. This also is related to technical aspects such as improving the process of linking key demographic and epidemiology data collected into a centralised repository. The experts in this field are the team from DSD.

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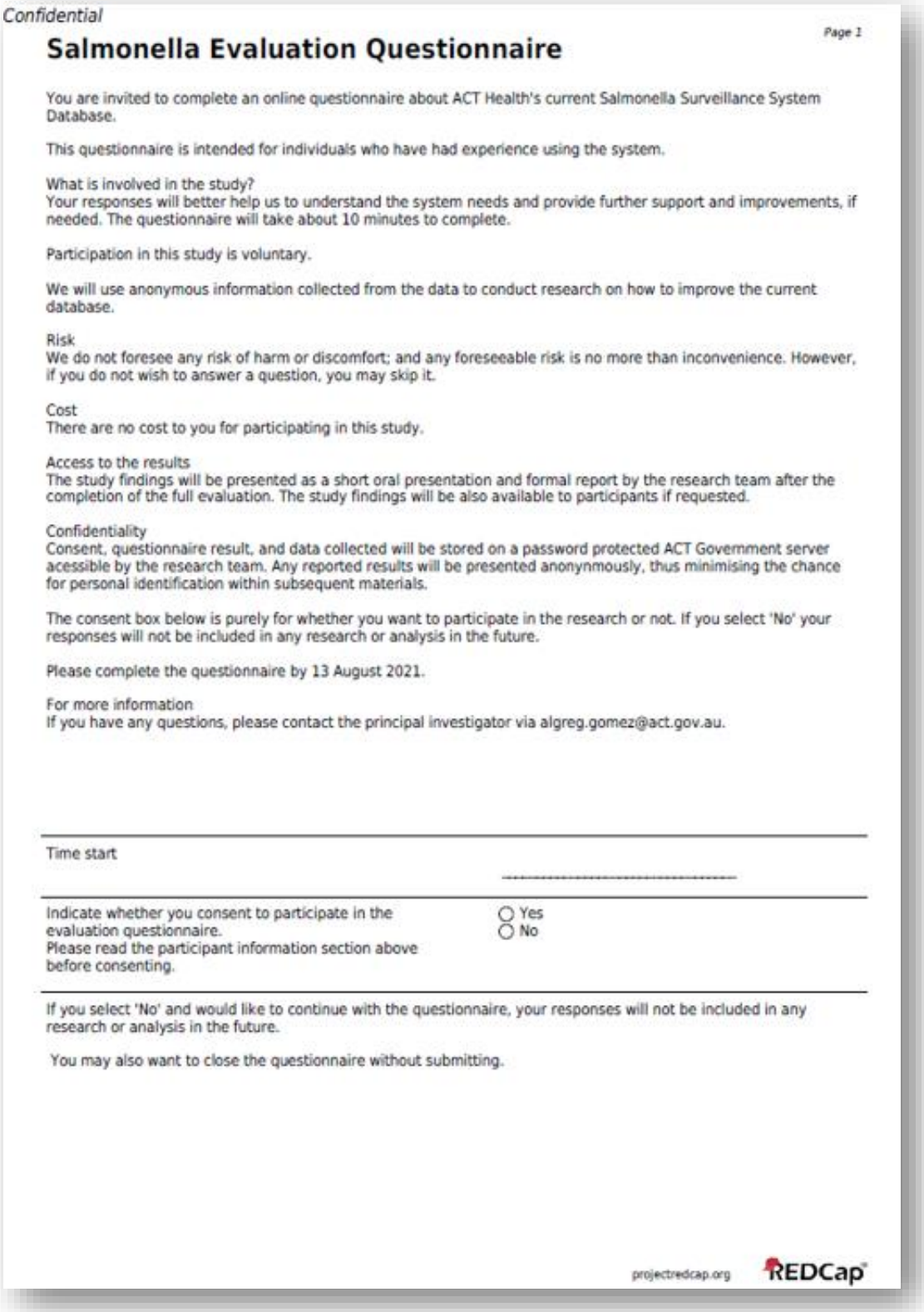
10.0 Appendices

Appendix 1: REDCap Pre-Implementation Evaluation Questionnaire



Confidential

Page 1

Salmonella Evaluation Questionnaire

You are invited to complete an online questionnaire about ACT Health's current Salmonella Surveillance System Database.

This questionnaire is intended for individuals who have had experience using the system.

What is involved in the study?
Your responses will better help us to understand the system needs and provide further support and improvements, if needed. The questionnaire will take about 10 minutes to complete.

Participation in this study is voluntary.

We will use anonymous information collected from the data to conduct research on how to improve the current database.

Risk
We do not foresee any risk of harm or discomfort; and any foreseeable risk is no more than inconvenience. However, if you do not wish to answer a question, you may skip it.

Cost
There are no cost to you for participating in this study.

Access to the results
The study findings will be presented as a short oral presentation and formal report by the research team after the completion of the full evaluation. The study findings will be also available to participants if requested.

Confidentiality
Consent, questionnaire result, and data collected will be stored on a password protected ACT Government server acessible by the research team. Any reported results will be presented anonynmously, thus minimising the chance for personal identification within subsequent materials.

The consent box below is purely for whether you want to participate in the research or not. If you select 'No' your responses will not be included in any research or analysis in the future.

Please complete the questionnaire by 13 August 2021.

For more information
If you have any questions, please contact the principal investigator via algreg.gomez@act.gov.au.

Time start

Indicate whether you consent to participate in the evaluation questionnaire.
Please read the participant information section above before consenting.

- ◯ Yes
- ◯ No

If you select 'No' and would like to continue with the questionnaire, your responses will not be included in any research or analysis in the future.

You may also want to close the questionnaire without submitting.

projectredcap.org REDCap

Participant's Details

First Name

Last Name

Email Address

What is your role?

- ○ Public Health Nurse
- ○ Public Health Officer
- ○ Public Health Physician
- ○ Epidemiologist
- ○ Administration/Data Entry
- ○ Manager
- ○ Other

Please describe:

Objective of the Surveillance System

What do you use the information from the current database for?

- ☐ Identify close-contacts for public health follow-up
- ☐ Research
- ☐ Reporting
- ☐ Detect outbreaks
- ☐ Clinical decision making
- ☐ Funding and operational planning
- ☐ Other (please specify)

Please describe:

The current database is able to collect and report data for local and national reporting requirements:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database is able to detect a person classified to have a high risk occupation:

Eg. aged-care worker, early childhood educator or staff, healthcare worker.

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database is able to detect local outbreaks:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database is able to inform multi-jurisdictional outbreak investigations:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Overall, the current database serve its purpose:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database allows me to fulfil my surveillance and public health follow-up duties:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database has led to the generation of reports, or publication of data in appropriate reports?

○ Yes
○ No

Please provide details:

Surveillance System Attributes: Simplicity

It is easy to notify a confirmed or suspected case:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Specification between different types of Salmonella can be easily captured by the current system:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

It is easy to complete all data fields for a confirmed or suspected case:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Surveillance System Attributes: Acceptability

I believe that notifications of confirmed cases of salmonellosis is important:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Within my role, I believe time spent on Salmonellosis surveillance is worth my time:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current requirements for confirmed case reporting are reasonable:
Taking into account the time taken to notify the case, process of notification and ease of notification.

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Surveillance System Attributes: Flexibility

The current database is able to adapt to changes in case definitions:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

IT support for the current database is easily accesible:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

If required, it is easy to make changes to the database to collect additional information:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database is able to accomodate multiple users in 'surge' scenarios, such as large outbreaks:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The current database can be managed effectively (still meets objectives) at reduced staff capacity:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Surveillance System Attributes: Data Quality

The data from the current database is of high quality (is accurate and contains no errors):

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Data is able to be extracted from the current database to be entered into the current Notiable Diseases Management System (NDMS):

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Data is able to be extracted from the current database to meet the National Notifiable Diseases Surveillance System (NNDSS) reporting requirements:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Are you aware of quality assurance processes within the system to ensure high quality data?

○ Yes ○ No ○ Prefer not say

If yes, please list the process that you are aware of:

Surveillance System Attributes: Timeliness

The surveillance system ensures public health follow-up of confirmed cases are conducted in a timely manner:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Notification of laboratory confirmed cases are notified in a timely manner

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Data from the surveillance system is made publicly available in a timely manner:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

The structure and process (receiving notifications, input of data, extract of data and analysis of data) of the surveillance system allows timely response to potential outbreaks:

○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

Surveillance System Attributes: Stability

Has there been any incidents in the last 3 years when the current database has not been available and required repair?

○ Yes ○ No ○ Prefer not say

Please specify:

Are there currently any risks that could destablise the operation of the surveillance system?

○ Yes ○ No ○ Prefer not say

Please specify:

Has there been any incidents in the last 3 years where a technical disruption in the notification process affected system functionality?

○ Yes ○ No ○ Prefer not say

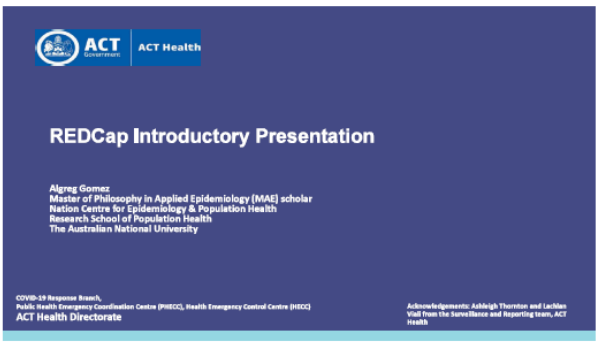
Please specify:

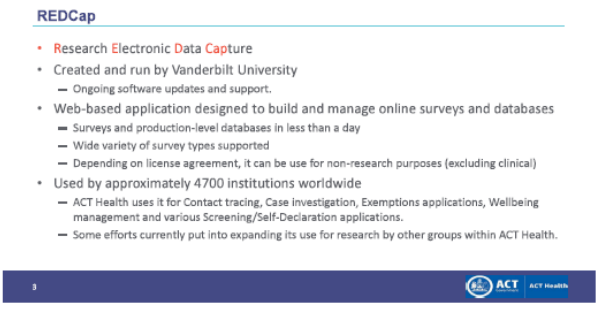
Time end

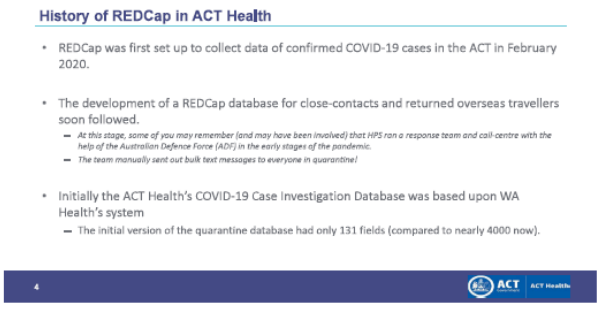
No further questions. Thank you for your assistance.

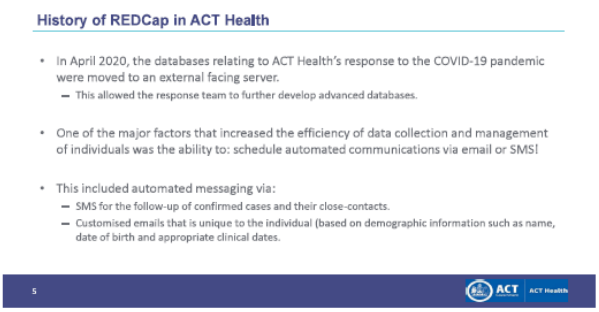
If you have further questions, please direct them to:
algreg.gomez@act.gov.au or algreg.gomez@anu.edu.au

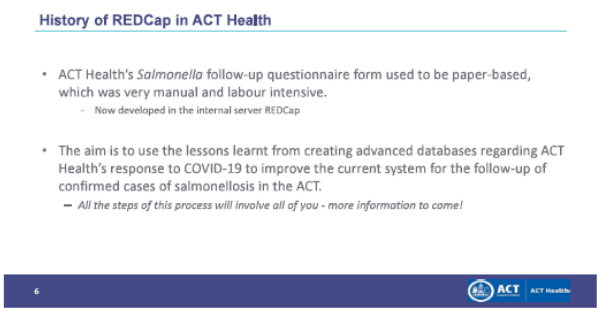
Appendix 2: Introductory face-to-face workshop conducted with the CDC, HPS, ACTHD on 29 April 2021.









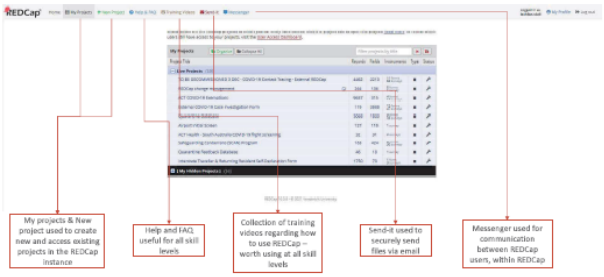


Logging in

Logging in

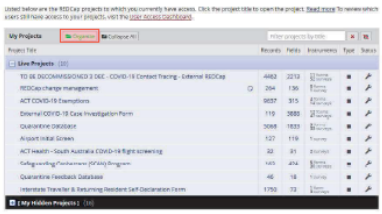
TIP: Ensure that you login into the appropriate 'REDCap Server' [i.e. internal vs. external server] with the correct credentials.

- Log-in credentials separate to ACT Health login information
  - Recommended that you use the same login information
  - Username: *"firstname.lastname"*
- 2-Factor Authentication in place
  - You will receive a code to verify your login that must be entered within two minutes
- You will be required to change your password periodically



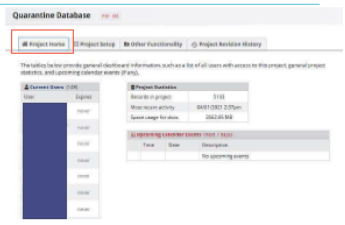
Projects

- Project dashboard will display all projects you have been given access to for your account
- You are able to hide projects and create folders to differentiate them using the organize button



Project Home

- Project home is used to display project information in the form of a dashboard
- Useful for both administrators and projects leads
- Provides predominantly operational-related information (including user lists, calendar events and number of records)



REDCap Sidebar

Sidebar

- Provides shortcuts to key parts of you project. You will save a lot of time if you are familiar with this sidebar!
- Project Home and Design
  - The project setup and designer are shortcuts to their respective pages and are very helpful during the setup phase of a project – mostly for project developers.
  - The dictionary and codebook are often used when analysing data, making bulk changes and creating reports.

Combi

Sidebar

- Data collection
  - Survey distribution tools provides access to the management of surveys that are sent out from existing projects, as well as a log of all past and scheduled survey invitations.
  - The record status dashboard displays the status of all instruments for records included within the project
  - You can add new and edit existing records using the corresponding button

Sidebar

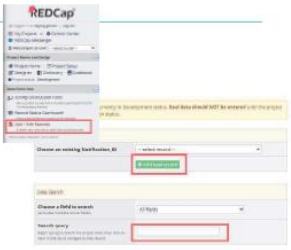
- Applications
  - Many of these applications have functionality that lies outside the scope of this presentation, but feel free to check them out as you go along.
  - The 'Data exports, reports, and stats' are very useful and will be covered in this presentation.
  - 'User rights' and 'DAG's' are covered in further advanced presentations.
  - Depending on your user rights, you may or may not see all the applications as shown.

Data Entry

Data Entry

- Add/Edit Records page, you may:
  - Open an existing record by selecting it from a list.
  - Type a key word or phrase, and open a record by selecting from the matches.
  - This page is also the only place where you can add a new record.

In many projects, adding a record simply means clicking a button. But if you see something different here, such as a place to type in a new record name or number, then follow the built-in prompts and instructional text to add a new record.



Data Entry

- REDCap assigns a sequential number to each new record and displays that at the top of the Record Home Page. Your project may call the record ID something different.
- REDCap can store almost any type of data, so it's used for many purposes. Always carefully read through any special instructions you see on your Record Home Page or elsewhere in REDCap.

Field Types

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Field Types

- The possible field types are shown to the right:
  - Text box: A small box where string data can be entered. Useful when short answers are likely to be provided
  - Notes box: A larger text box that is generally useful when longer answers are provided for a question

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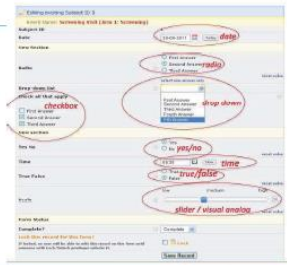
Field Types

- Multiple choice – Drop-down: A drop down list with choices will appear when selected. Only a single answer can be provided. Often useful when a large number of choices are available
- Multiple-choice – Radio buttons: Each choice is displayed with a small button next to it which can be selected. Only single answer possible. If more choices are provided then the form can become cluttered.



21

Field Types

- The possible field types are shown to the right:
  - Checkboxes: Small checkboxes with the choice description. Multiple answers can be selected
  - Yes – No: Auto-coded yes-no field. Will be automatically coded 1=Yes, 0=No.
  - True – False: Similar to Yes – No field except different wording
  - Signature: Field for drawing signature using mouse or finger on touch-screen device. Useful for consenting modules
  - File upload: allows user to upload one file per field. Useful for including notes recorded elsewhere so that anyone accessing record can view it.
  - Slider: A slider which can be used to gauge a response on a scale of 0-100. Often useful for more qualitative or subjective gauging of a response
  - Descriptive text: A field where no answer box or options are provided.

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Field Attributes

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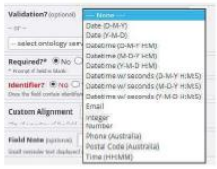
Field Validation Options

- These options ensure that fields are formatted for their appropriate purpose and are typically only possible when using a text box field type:
  - Date: Can be formatted in particular order. D = Day, M = Month, Y = Year. Default format is typically M-D-Y. Important to change this setting if based within Australia
  - Email: Ensures email address format given is valid. Does not cross-validate with email address source (i.e. bigpond) to ensure actual email exists
  - Phone: Ensures that a phone number is entered within the typical Australian phone format (e.g. 04XX XXX XXX)
  - Postal code: Only permits Australian postal code entries



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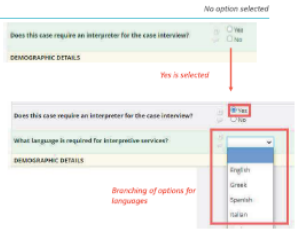
Field Validation Options

- REDCap automatically re-formats certain data. If you make a mistake, REDCap will display an alert.
- Validation is a way to ensure that data is saved in a consistent format, and most projects use this functionality.

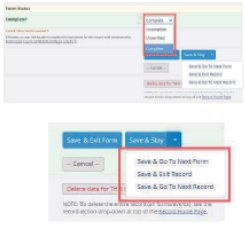
Branching Logic

- As you enter data, additional fields might appear.
- This feature is called branching logic or skip logic.
- It hides or reveals questions based on how other questions are answered. Simply follow the built-in prompts and read through the instrument' instructions to complete the form.
- Branching logic can really get complicated! But simple is always better.



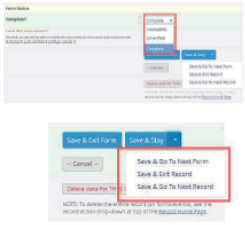
Save Early and Save Often!

- There is no auto-save in REDCap. So save early and save often.
- There are several save options at the bottom of the instrument and in a floating menu.
  - Save & Go to Next Form
  - Save & Exit Record
  - Save & Go To Next Record



Save Early and Save Often!

- Each option has slightly different functionality, so select whichever one applies for your particular situation.
- Again, you might see even more options here and your study procedures should provide guidance about which option is best for your data entry workflow.

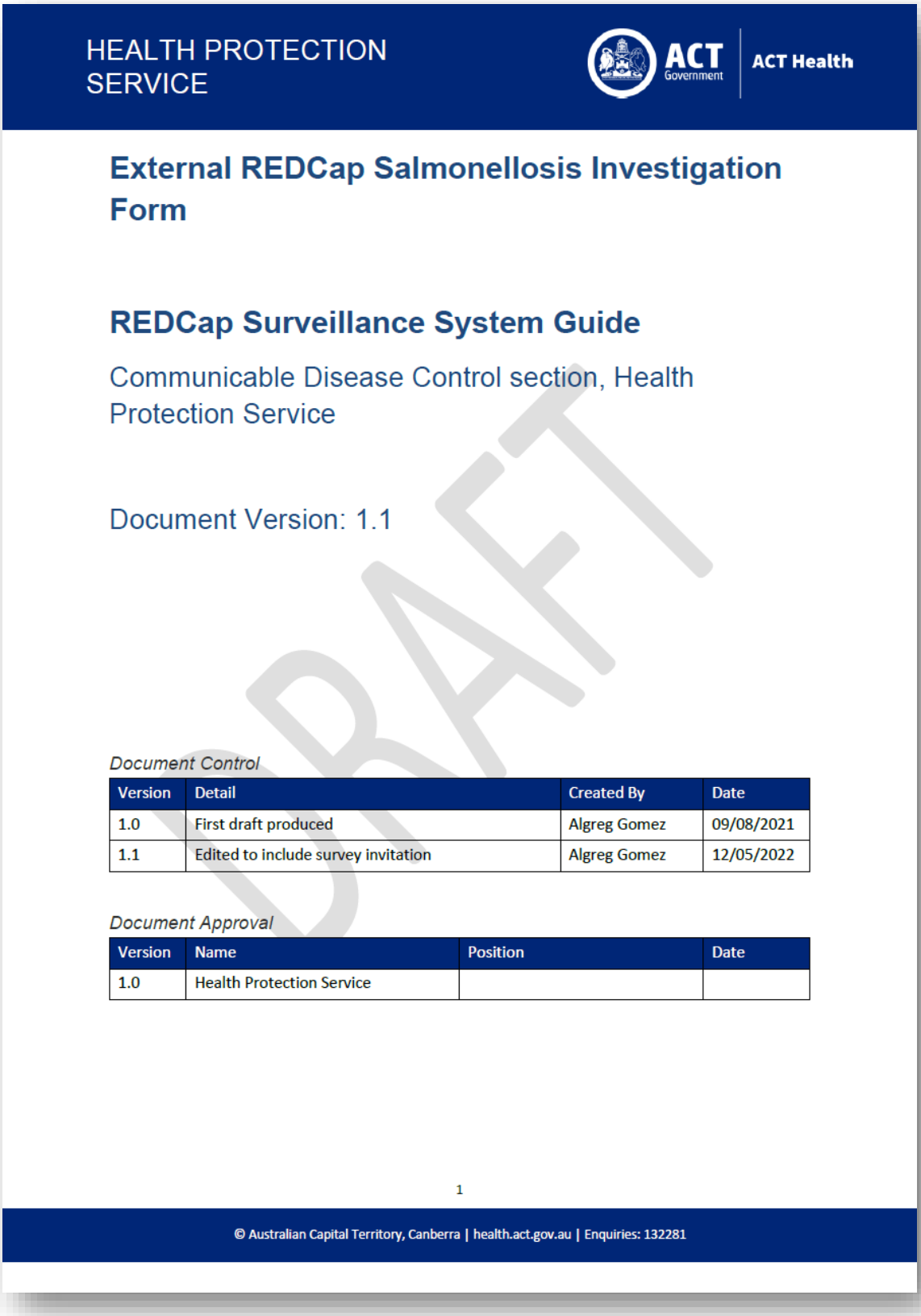


SUMMARY

Thank you!

Question Time!

Appendix 3: REDCap Salmonellosis Surveillance System Guide and Standard Operating Procedure (SOP), distributed May 2022



HEALTH PROTECTION SERVICE

ACT Government | ACT Health

External REDCap Salmonellosis Investigation Form

REDCap Surveillance System Guide

Communicable Disease Control section, Health Protection Service

Document Version: 1.1

DRAFT

Document Control

Version	Detail	Created By	Date
1.0	First draft produced	Algreg Gomez	09/08/2021
1.1	Edited to include survey invitation	Algreg Gomez	12/05/2022

Document Approval

Version	Name	Position	Date
1.0	Health Protection Service		

1

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Contents

1.0 Purpose

The standard operating procedure is intended for use by the Communicable Diseases Control (CDC) section of ACT Health to assist in the public health responses to laboratory confirmed salmonella notification of ACT residents.

This document provides guidance to officers with regard to appropriate data collection requirements in the External REDCap Salmonellosis Investigation form, including the use of REDCap reports, automated messaging and links to useful resources.

1.1 Data Items and Sources

- Laboratory/Pathology Receipt
- Software Systems:
  - REDCap: External Salmonellosis Investigation form
  - Notifiable Disease Management System (NDMS)

1.2 Procedure: Local Public Health Response

To be conducted in accordance with the *NSW Health Salmonellosis (excluding S. Typhi and Paratyphi Infections) Control Guideline*.

- Initial data entry to be completed by the Surveillance Officer within one (1) working day of notification.
- The patient to be notified of the illness within one (1) working day of receiving pathology receipt via automated notification (through REDCap; SMS or email).
- To attempt a phone interview for all salmonellosis cases with the *Salmonella* case investigation form within two (2) working days of notification and being entered into the External REDCap Salmonellosis Investigation form.
- To review completed shortened questionnaire within one (1) working of submission from the survey respondent (and at least within two (2) days of the notification date) by the OFN Epidemiologist to ensure all core data fields are completed.
  - This includes all core data fields to be added into NDMS.
  - Update the onset date, hospitalisation, emergency department visit and died NDMS fields.
  - Enter the likely place of acquisition (specific food source/premises or country/geographic region) in the *Suspected Source Details* NDMS field.

- Enter the outbreak reference in the *Outbreak* NDMS field (if applicable); and
- Enter any additional details in the *Comments* NDMS field.

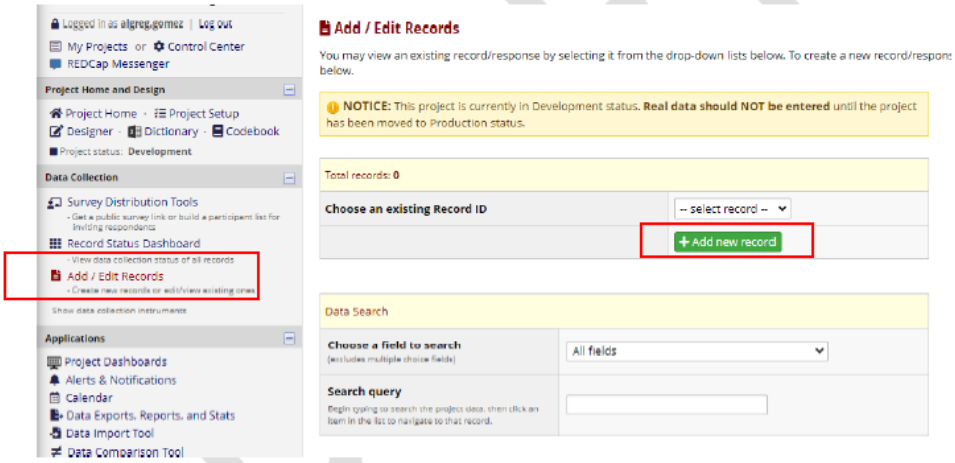
Note that all 'mandatory/core fields' added into the current NDMS will soon be migrated to SunQuest WorldCare System (new NDMS).

2.1 Internal Data Entry

2.1.1 Initial Case Details

This is a step-by-step instruction of how to enter a laboratory notification into the 'Initial Case Details' instruments.

Once a salmonellosis pathology notification is received, a surveillance officer will add a new person's record in REDCap as per below.



A new record will be created, with an automatic designated record number. Click the first circle next to 'Initial Case Details' to open the first instrument.

NEW Record ID **1**

Data Collection Instrument	Status
Initial Case Details	
Act Health Salmonella Questionnaire (survey)	
Epidemiological Details	
Phone Interview - Demographics	
Phone Interview - Case History	
Phone Interview - Environmental and Travel History	
Phone Interview - Food History	
Phone Interview - Summary	
Salmonella Hypothesis Generating Questionnaire	

Preview of the first instrument as shown below:

Initial Case Details

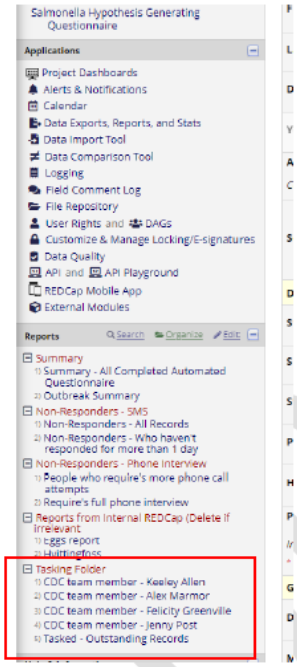
Adding new Record ID **1**

Record ID	1
PATHOLOGY DETAILS	
State ID:	
Initial Pathology Receipt	Upload file Upload the initial pathology received
Laboratory who sent the notification	○ ACT Pathology ○ Capital Pathology ○ Laverty Pathology ○ Australian Clinical Labs ○ Other reset
Specimen Collection Date	D-M-Y
Notification Received Date	Today D-M-Y
BASIC CONTACT INFORMATION	
First Name	First
Last Name	Last
Date of birth	D-M-Y
Year of Birth	View equation
Age at Notification (years) *Calculated using date of birth and notification date.*	View equation
Sex	○ Male ○ Female ○ X (Indeterminant/Non-binary) ○ Other (Not stated/Inadequately described) reset
DEMOGRAPHICS	
Street Address	

All fields in the 'Initial Case Details' instrument must be completed.
Note that there are no restrictions in mandatory fields except for 'Phone Number' as it is required for the automated messaging to be triggered. Ensure that the phone number is in international format for this field.

Ensure the tasking assignment is completed to be able to track the status of the record.

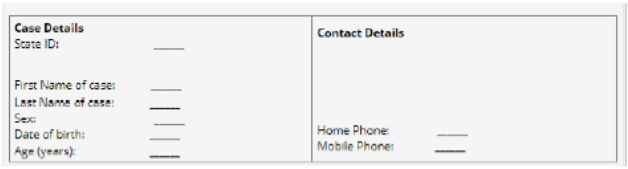
Note that when tasking or re-tasking a record, an automated alert (email) is sent to the CDC team member. The record will also be allocated the 'tasked' individual into the appropriate tasking report as shown below located in the sidebar.



2.1.2 Epidemiological Details

Epidemiological details instrument is unchanged to the previous version of the system.

The only new addition is field piping of the case details entered from the 'Initial Case Details' instrument as shown below:



3.1 Automated Alerts

3.1.1 Twilio

- Twilio, a third party add on/web service will aim to facilitate the automated SMS messaging, voice and call capability of REDCap. This is completed through a secure Application Programming Interface (API).
    - Twilio Regulatory Guidelines – Attached Here

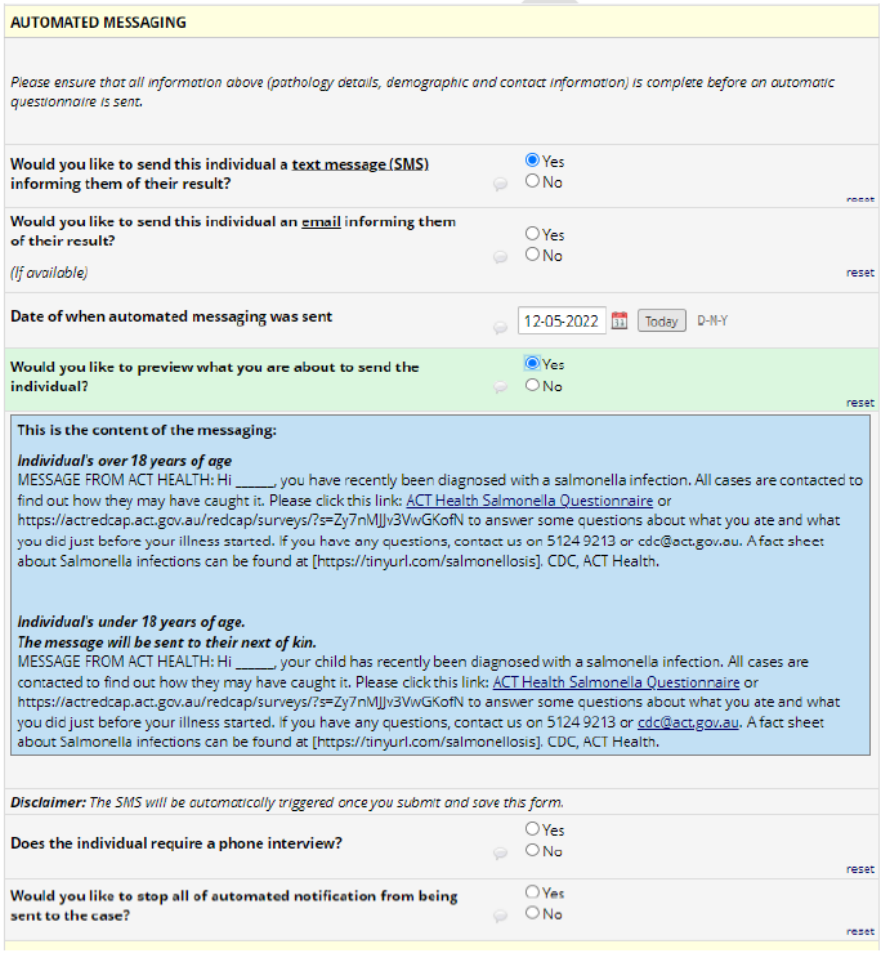
- Twilio will be used to send the text and survey link. The cases' data are stored in REDCap (names, email address and phone numbers) and are not hosted in the Twilio server. Brief overview of the process:
    - In REDCap, a member of the CDC team triggers an SMS message to be sent to the mobile number of the case (or their carer)
    - The case (or their carer) receives the SMS message via the Twilio service
    - The case opens the hyperlink to a modified salmonellosis questionnaire included the message
    - The respondent's browser opens from smart phone/digital device and they complete the questionnaire within the secure website (and read any public health messaging that is provided).
    - If the case does not complete the questionnaire within 48-hours, an alert will be sent to a CDC to interview the case over the phone according to current practice.
        - A team member from CDC will review the case questionnaire whether a further phone follow-up is needed if more information is required.
    - For cases with no mobile number, a CDC officer will be alerted to conduct a phone interview over the phone according to current practice (detailed proposed follow-up process is shown in Appendix A).
- The Twilio external add-on has been cleared and approved by the Governance Hub, DSD.
- The project developer(s) will set the module to its appropriate settings.
- System administrators will monitor the performance of the external add on.

3.1.2 Shortened Salmonella Questionnaire

Once the conditions are met, an automated SMS or email message will be sent to the recipient:

1. Would you like to send this individual a text message (SMS) informing them of their result? Yes
2. Date of when automated messaging was sent: enter the respective date
3. Click save the form

Based on their auto-calculated age, it will send them the message as highlighted below.



AUTOMATED MESSAGING

Please ensure that all information above (pathology details, demographic and contact information) is complete before an automatic questionnaire is sent.

Would you like to send this individual a text message (SMS) informing them of their result? ○ Yes ○ No reset

Would you like to send this individual an email informing them of their result? *(If available)* ○ Yes ○ No reset

Date of when automated messaging was sent 12-05-2022 Today D-M-Y

Would you like to preview what you are about to send the individual? ○ Yes ○ No reset

This is the content of the messaging:

Individual's over 18 years of age
MESSAGE FROM ACT HEALTH: Hi _____, you have recently been diagnosed with a salmonella infection. All cases are contacted to find out how they may have caught it. Please click this link: ACT Health Salmonella Questionnaire or https://actredcap.act.gov.au/redcap/surveys/?s=Zy7nMJJv3VwGKofN to answer some questions about what you ate and what you did just before your illness started. If you have any questions, contact us on 5124 9213 or cdc@act.gov.au. A fact sheet about Salmonella infections can be found at [https://tinyurl.com/salmonellosis]. CDC, ACT Health.

Individual's under 18 years of age.
The message will be sent to their next of kin.
MESSAGE FROM ACT HEALTH: Hi _____, your child has recently been diagnosed with a salmonella infection. All cases are contacted to find out how they may have caught it. Please click this link: ACT Health Salmonella Questionnaire or https://actredcap.act.gov.au/redcap/surveys/?s=Zy7nMJJv3VwGKofN to answer some questions about what you ate and what you did just before your illness started. If you have any questions, contact us on 5124 9213 or cdc@act.gov.au. A fact sheet about Salmonella infections can be found at [https://tinyurl.com/salmonellosis]. CDC, ACT Health.

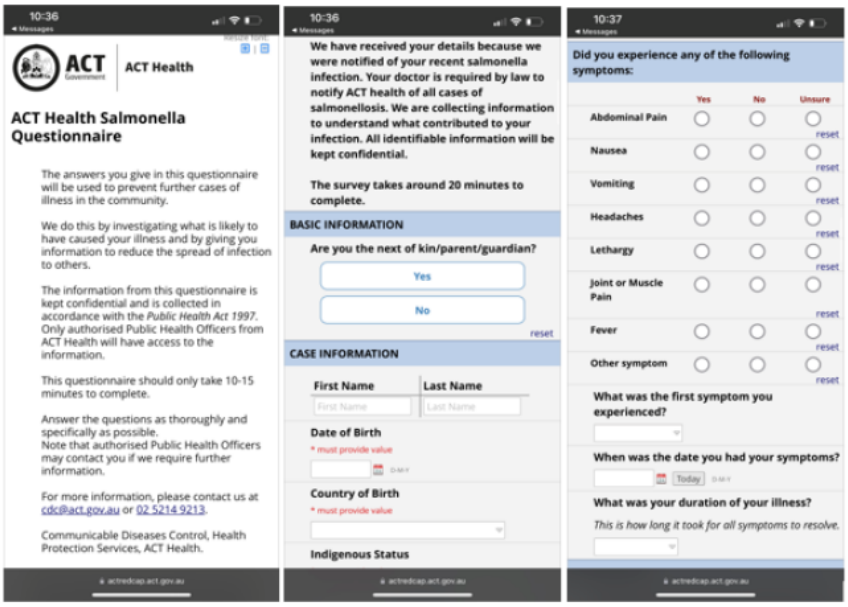
Disclaimer: *The SMS will be automatically triggered once you submit and save this form.*

Does the individual require a phone interview? ○ Yes ○ No reset

Would you like to stop all of automated notification from being sent to the case? ○ Yes ○ No reset

Once the form/instrument is saved, the alert will be scheduled 4-hours after the form was saved. This will allow a buffer time if automated notifications are incorrectly triggered.

Preview of the automated alert through a smart phone:

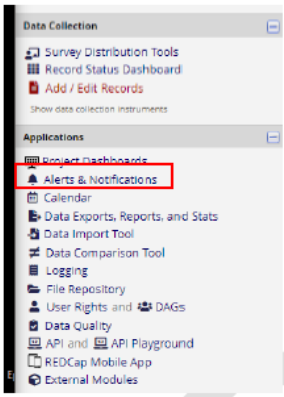


See Appendix 4 for the web view of the shortened salmonella questionnaire.

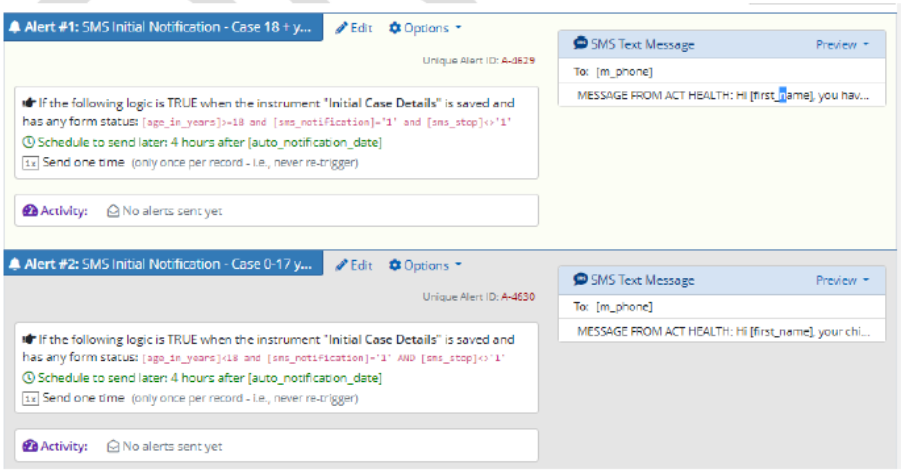
4.1 Survey Invitations

4.1.1 Alerts and Notifications

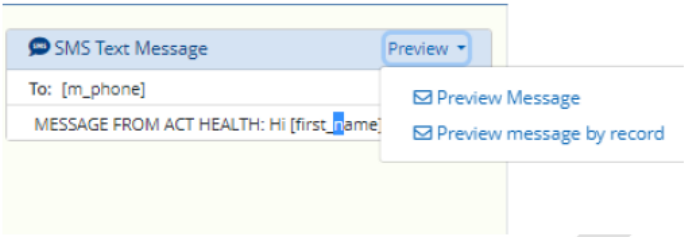
The Alerts & Notifications feature allows you to construct alerts and send customized notifications. These notifications may be sent to one or more recipients and can be triggered or scheduled when a form/survey is saved and/or based on conditional logic whenever data is saved or imported.



This is where you will see all of the alerts that are active and details such as the content of the message, scheduling, recipient preference and activity of whether the alert has been triggered or not.

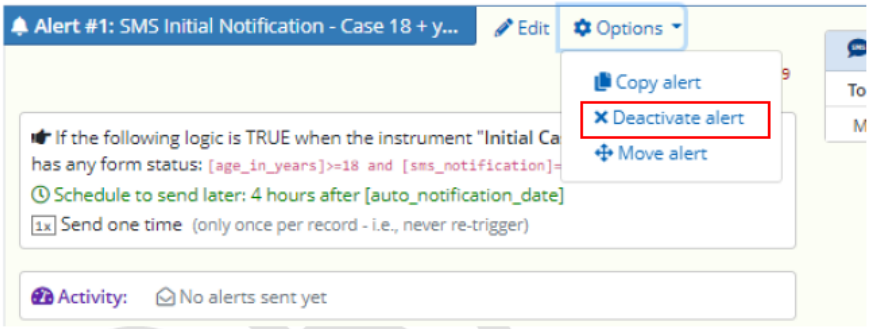


You may also preview the content of a particular alert, and do so with a particular record's information (if information piping is utilised) as shown below.



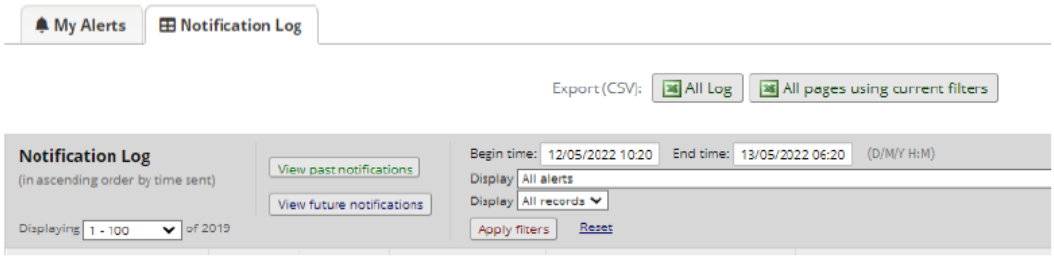
There is also the option of deactivating an alert via clicking the options tab next to the alert title.

Note: A deactivated alert can be re-activated.



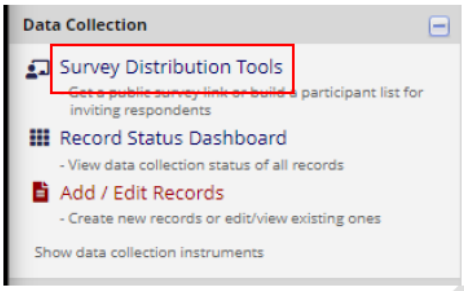
4.1.1.2 Notification Log

Notification log functions the same as the survey distribution outlined below (section 4.1.2).

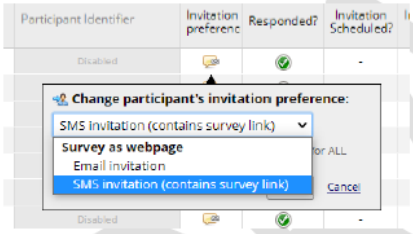


4.1.2 Survey Distribution Tools

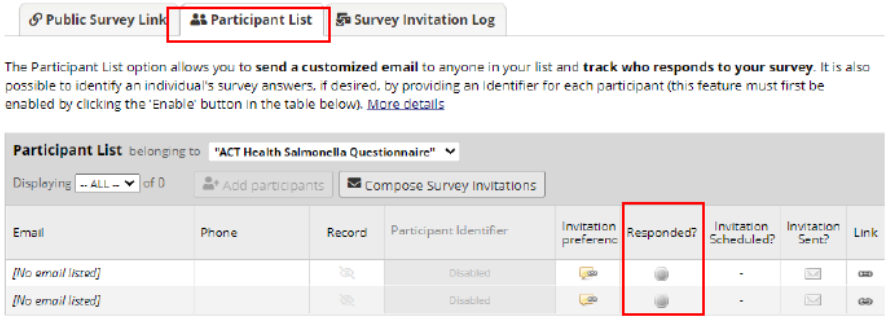
This subsection of the data collection tools is where you are able to review a participants preference of receiving a particular



Clicking participant list on the top of the browser as shown below, will display all alert invitation that may be scheduled and the participants preference of receiving the automated messaging (whether SMS or email).



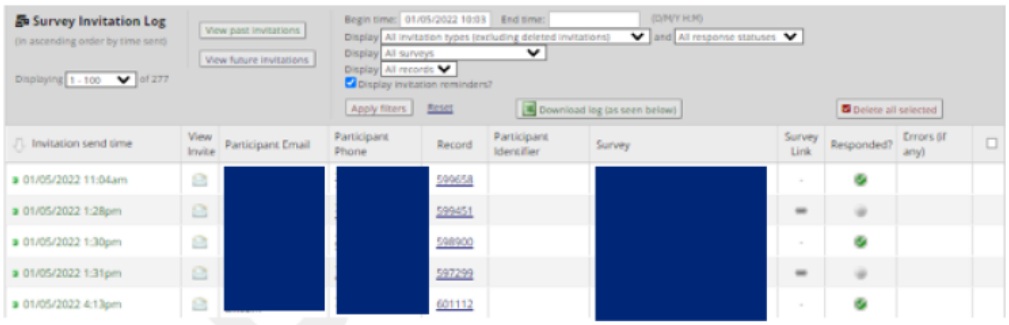
The column for "Responded?" will either be grey, yellow or green?
Grey = not responded, yellow = partially responded, green = completed survey



4.1.3 Survey Invitation Log

Survey invitation status can also be reviewed via the Survey Invitation Log. It will list all the survey invitations that have already been sent or have been scheduled to be sent to survey participants in this project.

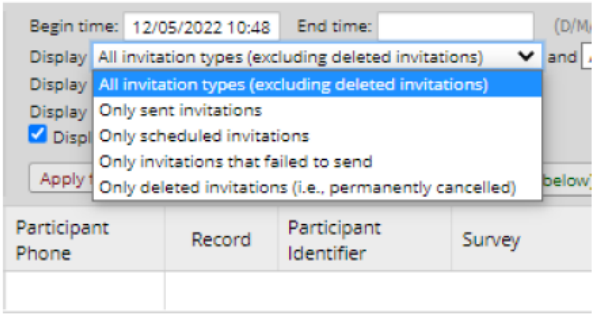
For each invitation it displays the participant email, particiapnt identified (if exists), survey name, and the date/time in which the invitation was (or will be) sent.



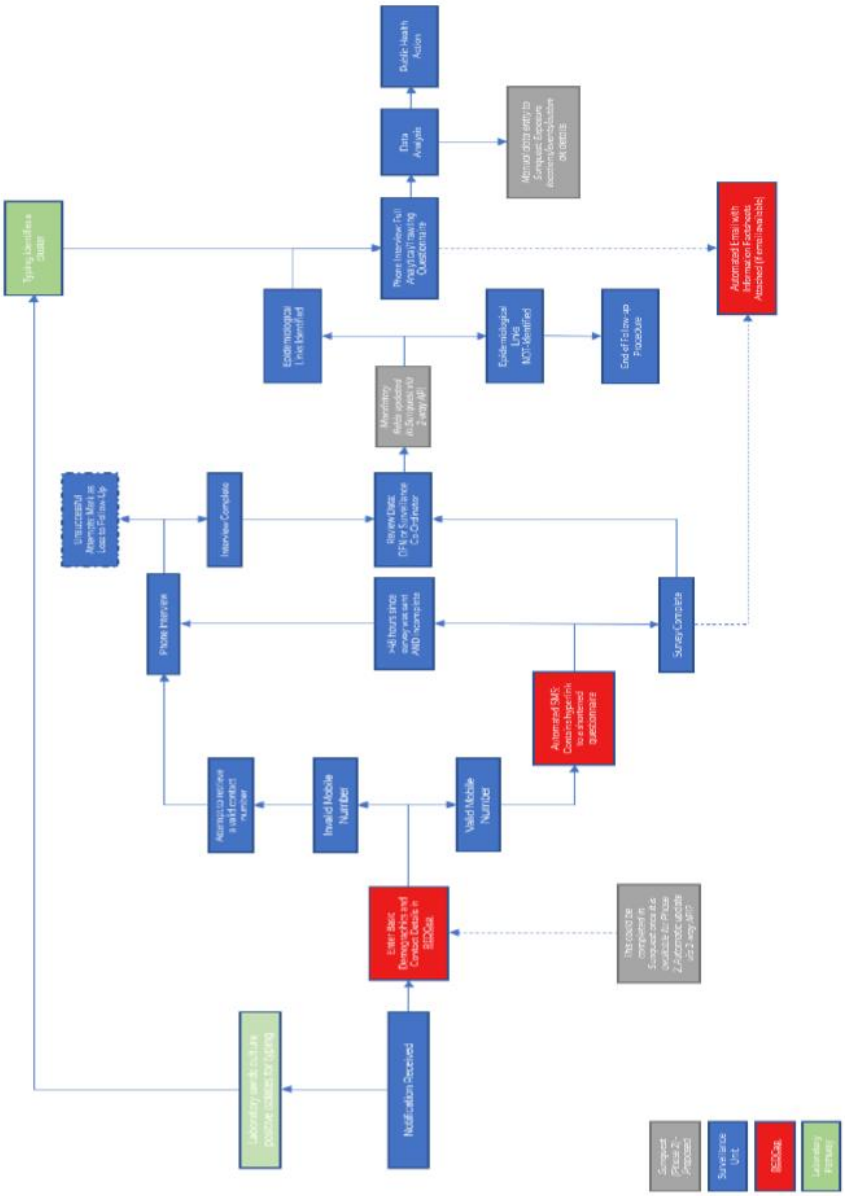
You may also download the log invitations in an excel file. This is useful when reviewing over 50 records at a time.

All auomated alerts may be reviewed by a particular invitation type.

This allows easier stratification of failed scheduled alerts.



Appendix 1: REDCap Information Flow



Appendix 2: Additional Resources

Note: ACT does not currently have the capacity to sequence or analyse isolates. The SOP: Requesting Isolate Whole Genome Sequencing and Analyses details how to request the sequencing and analysis of isolates by a reference laboratory.

Resources:

- Salmonella Fact Sheet - ACT Health
- Salmonellosis (excluding S. Typhi and Paratyphi Infection) Control Guidelines – NSW Health
- Salmonella Case Investigation Form - ACT Health
- Suspected foodborne outbreak SOP
- Requesting Isolate Whole Genome Sequencing and Analyses SOP

Appendix 3: Points of Contact

Contact personnel for any issues regarding any internal process for the collection, processing and analysis of data related to salmonellosis notifications in the ACT.

Role	Name	Contact Details
Digital Solutions Division (DSD)		
Surveillance Manager		
Surveillance Co-Ordinator		
Lead Project Co-Ordinator (MAE scholar)		
OzFoodNet Epidemiologist		

Appendix 4: Information sheet regarding the change of processes distributed to General Practitioners and respective clinical practices in the ACT, June 2022

ACT Government Health

Communicable Disease Control

Online patient questionnaire for salmonella surveillance

Information for GPs

Key Points

- **ACT health will commence initial public health follow up of salmonellosis cases by online survey**
- **An SMS link to a secure online questionnaire will be sent directly to cases after they have been informed of their diagnosis by their clinician**

Background

- Currently in the ACT, the Health Protection Service attempts to conduct a public health interview with all cases of salmonellosis to determine the likely source of their infection and identify any outbreaks.

Online salmonellosis case questionnaire

- ACT health will commence public health follow up by sending a secure online survey that can be completed people with salmonella infection who are notified to ACT health.
- After surveillance officers have confirmed that the patient with salmonellosis has been informed of their diagnosis, the patient will be sent an SMS link to a secure online questionnaire.
- The types of questions in the questionnaire include:
  - Travel history
  - Environmental exposures
  - Food exposures
- If the questionnaire is not completed, ACT Health will attempt to conduct a phone interview.

Resources

- Information to provide to patients about salmonella infection is available here: https://www.health.act.gov.au/sites/default/files/2020-11/Salmonella.pdf

Communicable Disease Control
ACT Health
June 2022

Phone: 02 5124 9213 | Email: cdc@act.gov.au
Communicable Disease Control | Health Protection Service | ACT Health Directorate | ACT Government
25 Mulley Street, Holder ACT 2611 | health.act.gov.au/hps

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Chapter V

Investigating the association between air pollution and asthma-syndrome-related emergency department and community health centre presentations in the Australian Capital Territory, 2015-2019

Table of Contents

List of Abbreviations

AAQ	Ambient Air Quality
ACT	Australian Capital Territory
ACTGAL	ACT Government Analytical Laboratory
ACTHD	ACT Health Directorate
AIHW	Australian Institute of Health and Welfare
AQG	Air Quality Guidelines
CDC	Communicable Disease Control (ACTHD)
CHECC	Clinical Health Emergency Coordination Centre
CHO	Chief Health Officer
CHS	Canberra Health Services
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
DoH	Department of Health (The Australian Government)
ED	Emergency Department
EPA	Environment Protection Authority
FEFP	Field Epidemiology Fellowship Program
HREC	Human Research Ethics Committee
ICD	International Classification of Diseases
NSW	New South Wales
NO_2	Nitrogen Dioxide
O_3	Oxygen
PACF	Partial Autocorrelation Function
PCR	Polymerase chain reaction
PHREDSS	Public Health Rapid Emergency Disease and Syndromic Surveillance system
PHO	Public Health Officer
PPM	Parts Per Million
PM	Particulate Matter
SO_2	Sulfur Dioxide
WiC	Walk-in-Clinic
WHO	World Health Organization
WPRO	Western Pacific Regional Office

1.0 Prologue

1.1 Study Rationale

There are many reasons why studies on respiratory illnesses and air quality are relevant. They can first aid in our understanding of the connection between respiratory health and air pollution. Public health strategies and measures that can lower the risk of respiratory diseases can be informed by this understanding. Additionally, research studies can assist us in locating places with particularly low air quality so that we can focus actions there. Finally, research studies can aid in our understanding of the interactions between various environmental factors and respiratory health, which can aid in the development of more efficient strategies for lowering air pollution and enhancing public health. By examining how air quality influences asthma and other negative health outcomes, we can better comprehend the complex interactions between lifestyle, health outcomes, and both. My supervisors and I identified this research study as an important topic. We believe that environmental health studies such as these, particularly in a local context, can have a significant impact on the health of individuals and communities. I was interested in expanding my technical knowledge in this area, and this provided me an opportunity to work with a different section within the ACT Health Directorate (ACTHD).

1.2 My Role

I served as the lead investigator for this project. I conducted a literature review, created the study protocol and obtained ethics approval. Additionally, I organised and cleaned all the provided datasets. I extracted the relevant datasets from multiple data sources and screened for missing data as needed. This project was not related to my usual operational work, so it presented new challenges that I was eager to take on. It was my first project that used research methods in environmental epidemiology. I gained an understanding of the unique challenges of using large environmental health datasets and applied analytical techniques to address the many biases that such data possess. I developed coding scripts through STATA 16 and R program.

This project was my last piece of work that I conducted through my MAE candidature. With many deadlines approaching, including my placement as a Field Epidemiology Fellow at the World Health Organization (WHO) Western Pacific Regional Offices (WPRO) in Manila, Philippines, I had to be efficient with my time and focus on the important aspects of this study. I had to adjust my approach to the study multiple times

to meet the thesis deadline. Despite the challenges, I was able to develop and complete the project successfully.

1.3 Lessons Learnt

I gained many lessons from this project, which was my first experience using environmental health data. Environmental health data can provide us with valuable insights into the health of our environment and the potential risks posed to human health. By analysing this data, we can learn about the sources of environmental contamination, the effects of pollution on human health, and the effectiveness of environmental protection measures. Additionally, we can use environmental health data to identify areas of concern and develop strategies to reduce environmental risks. Such data and respective analysis can also be used to inform public policy decisions and help guide decision-making in the development of new technologies. Finally, environmental health data can be used to inform public health campaigns and help raise awareness of environmental issues. By utilising this data, we can gain a better understanding of the environment and its impact on human health and develop strategies to protect our environment and improve public health.

This research project provided an opportunity to broaden my skills and understanding of environmental epidemiology, as well as to develop relationships with the Environmental Chemistry team. I was able to learn and utilise different technical skills when dealing with large environmental datasets, such as data cleaning, data analysis, data visualisation, and statistical modelling. Additionally, this project allowed me to work with data that was not related to the routine operational duties within the COVID-19 Response Branch, which enabled me to gain a deeper understanding of the environmental health field.

By the time of my candidacy, I had gained understanding of various statistical analysis programs. I applied the knowledge I had gained from other major projects to ensure that I could effectively analyse the data for this project. I used the information from **Chapter II** to understand how the data was collected and stored so that it could be interpreted correctly. Additionally, I was able to reuse codes I had written for previous analyses.

Finally, I demonstrated my competency in writing an advanced draft of a manuscript for research publication by taking advantage of the opportunity presented by this major project. The pressure to write succinctly and straight to the point was alleviated by the support I received from my academic and field supervisors, who provided guidance on my writing style specific to this topic.

1.4 Public health implications of this work

I was able to analyse the effects of air quality indicators such as particulate matter on emergency department presentations in the ACT. The findings of this analysis build on previous literature that describes the effects of air pollution on human health. It is unique as there has not been any published report on this topic within the local context of Canberra. This research project was also useful in providing a report back to the Environmental Chemistry team on the completeness of their data and improve their data collection processes. Investigating air quality indicators and health outcomes is an important public health issue. Air pollution poses a major environmental health hazard and can cause a variety of adverse health outcomes, including respiratory and cardiovascular diseases, cancers, and premature death. I believe that this work will inform current and future policies and strategies by the ACT Government.

1.5 Acknowledgements

I would like to thank Ian Fox, Swarup Chatterjee and the broader Environmental Chemistry team for their guidance over this research project. I would like to acknowledge my supervisors; Timothy Sloan-Gardner, Rebecca Hundy and Dr Matthew Kelly in supporting this project through the many challenges whilst being deployed out to the Field Epidemiology Fellowship Program (FEFP) at WPRO WHO.

1.6 Master of Philosophy in Applied Epidemiology core activity requirement

- Design and conduct an epidemiology project,
- Preparation of an advanced draft of a paper for publication in a national or international peer-reviewed journal,
- Target literature review.

The remainder of this chapter is presented as an advanced draft of a research manuscript.

Investigating the association between air pollution and asthma-syndrome-related emergency department presentations in the Australian Capital Territory, 2015-2019

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2.0 Abstract

2.1 Background

Asthma and allergic diseases are two of the most common chronic illnesses worldwide, and air pollution has been identified as a major contributing factor. This report aims to examine the levels of air quality indicators and asthma-syndrome-related emergency department (ED) and community-centre presentations in Canberra, Australian Capital Territory (ACT).

2.2 Methods

We extracted data on air quality indicators from three different Canberra monitoring sites (Florey, Civic and Monash) between January 2015 to December 2019. We compared these indicators to the WHO's global air quality guidelines (AQG) 2021. We used a multivariate Poisson regression model to estimate an incidence rate ratio (IRR) for asthma-syndrome health related outcomes (ASHRO).

2.3 Results

All three air quality monitoring sites were above the 2021 AQG that states a yearly upper limit of 5 μg/m^3. At the Florey site, the 2021 AQG 24-hour mean for $PM_{2.5}$ of 15 μg/m^3 was exceeded a median of 32 days per year. It was not exceeded by any other air quality monitoring site. At the Civic site, the 24-hour mean for PM_{10} of 45 μg/m^3 was exceeded with a median of 1 day per year with the Monash or Florey station recording a median of zero days. There were no other indicators that exceeded the 2021 AQG across the study period. In the multivariate Poisson regression model, NO_2 was an indicator was associated with the largest IRR of 1.844. O_3 was the only indicator that portrayed a decrease (0.51 IRR) in the incidence rate of an ASHRO.

2.4 Conclusions

This study found that increases in $PM_{2.5}$, PM_{10}, CO, and NO_2 were associated with an increase in ASHRO in the ACT, between 2015-2019. In contrast, an increase in O^3 was associated with a decrease in ASHRO. The multivariate model shows that when all the air pollution measures are considered together, none are significantly associated with the outcome. While NO_2 showed a potential increase and O_3 a potential decrease in asthma-related events, the wide 95% confidence intervals emphasize substantial uncertainty. In our multivariate analysis, no statistically significant indicators were identified.

Key words: air quality, air pollution, asthma syndrome, particulate matter, emergency department, environmental epidemiology

3.0 Background

Pollution is a severe environmental problem that can be harmful to human health both indoors and outdoors. Mould, dust, smoke, and chemicals are responsible for indoor air pollution, whereas emissions from industries, cars, and other sources are to blame for outdoor air pollution (1). According to studies, heart disease, respiratory conditions, and other health issues can be triggered by these contaminants (1,2). Two of the most prevalent chronic illnesses in the world are asthma and allergy diseases, and air pollution has been identified as a significant risk factor in both conditions (2). A chronic inflammatory condition of the airways known as asthma can cause wheezing, coughing, chest tightness, and breathing difficulties (3). Air pollution can exacerbate asthma symptoms and allergy diseases and raise the likelihood of acquiring asthma, according to studies (3).

In Canberra, Australian Capital Territory (ACT), air pollution is treated as a major environmental issue (4). Home to over 450,000 people, the city is surrounded by mountains and bushland, creating an environment which has less regular air pollution than other Australian jurisdictions (5). While Canberra enjoys mostly lower levels of air pollution, the city's unique geography contributes to its air quality dynamics. Since many people use wood-burning stoves to heat their houses in Canberra, wood burning is a substantial source of air pollution (6). The Australian government has taken measures to lessen air pollution in Canberra (7). This includes tightening vehicle emissions requirements, offering financial incentives to encourage individuals to convert to cleaner fuels and enacting rules to cut industrial emissions. Initiatives to limit wood burning have also been developed, such as subsidies for homeowners to move to cleaner heating systems (6,7). However, depending on the season and the weather, Canberra still experiences varying amounts of air pollution. Summertime air pollution levels are higher in Canberra because of the higher temperatures and reduced wind (8,9).

Characteristics of Australia's bushfires have been significantly impacted by climate change (9,10). Bushfire frequency and intensity have increased due to rising temperatures and shifting rainfall patterns, resulting in more frequent and severe fire seasons. The availability of fuel for fires has increased because of warmer temperatures, making it harder to put out fires (10,11). The 2019–2020 bushfire season in Canberra was one of the worst in the area's history, resulting in the burning

of almost 5.4 million hectares of land around the surrounding region of New South Wales (NSW) (12). For weeks, smoke from the flames covered the city, seriously polluting the air and leading to health issues like respiratory problems and eye irritation (10,12). The most immediate effect of the bushfire smoke was an increase in respiratory illnesses (12). The smoke contained a range of pollutants, including fine particles, carbon monoxide, and ozone, which can irritate the lungs and cause breathing difficulties (12). The long-term effects of the bushfire smoke are still being studied, but evidence from other settings indicates that there will be an increase in chronic illnesses such as cancer and cardiovascular disease from these pollutants (12,13,14). The bushfire smoke also had a significant impact on mental health. For many Australians, the smoke exacerbated pre-existing mental health issues and caused anxiety and sadness (12).

The most commonly studied air pollutants are ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) (15). Ozone is a secondary pollutant formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight. Pollutants like nitrogen dioxide are released from combustion sources like cars and power plants. Sulfur dioxide is a pollutant emitted from combustion sources such as power plants and industrial processes (15). Another type of air contaminants that are most frequently researched include Particulate Matter (PM) specifically, $PM_{2.5}$ and PM_{10}, which are particles with an aerodynamic diameter of equal or less than 2.5 and 10 micrometre respectively (15). PM is a type of air pollution that consists of tiny particles suspended in the air. It is composed of a variety of components, including dust, smoke, soot, and other pollutants. PM has been linked to a variety of health problems, including respiratory and cardiovascular diseases (2,7). Recent studies have demonstrated that long-term exposure to PM increases the risk of respiratory and cardiovascular diseases, including asthma, chronic obstructive pulmonary disease (COPD), and heart attacks, as well as premature death. Additionally, short-term exposure to PM has been associated with an increased risk of hospital admissions and emergency department (ED) visits for respiratory and cardiovascular conditions (16,17). According to research conducted in the China and a multicity study in Europe, hospital admissions for respiratory and cardiovascular diseases rose by 1.2% for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ and by 6.4% for a 12.4 $\mu g/m^3$ increase in $PM_{2.5}$, respectively (18,19). These results raise serious concerns since they point to a possible link between exposure to PM and a higher risk of hospitalisation and ED visits, particularly for vulnerable groups including the elderly and people with

established respiratory and cardiovascular diseases. This report aims to describe the air quality indicators and their associations with hospitalisations and health centre presentations between 2015 and 2019 in Canberra, ACT.

4.0 Methods

4.1 Target Population and Setting

We selected the population and setting of Canberra, ACT, Australia based on the availability of air quality monitoring data. Canberra is the capital city of Australia and has an estimated population of 456,652 people (5). The air quality monitoring data in Canberra provides a comprehensive overview of the air quality in the city, including information on levels of ozone, nitrogen dioxide, carbon monoxide, and PM. This data is collected from a network of monitoring stations located throughout the city and is updated daily. We chose a study period of 2015-2019 (inclusive), based on the availability of complete air monitoring data and emergency data for the region. The period was chosen to ensure that we had access to the most comprehensive and up-to-date information available, allowing us to make the most accurate and reliable conclusions possible. The data can be used to identify areas of poor air quality, inform decisions about air pollution control measures, and assess the effectiveness of existing air pollution control measures. Additionally, the data is available to the public and can be used to inform citizens about the air quality in their area (19).

4.2 Study Design

We conducted an observational epidemiological study to investigate the relationship between air quality indicators and health outcomes. Data on air quality indicators were extracted and analysed to describe the variation and trends over a 5-year period (2015-2019 inclusive).

4.3 Data Sources

In the ACT, air quality indicators are monitored by the Environmental Chemistry team, ACT Government Analytical Laboratory (ACTGAL). Air pollutant data in Canberra is collected by the ACT Government's Environment Protection Authority (EPA) (20). The EPA operates a network of air quality monitoring stations across the ACT, which measure levels of air pollutants such as ozone, nitrogen dioxide, carbon monoxide, and particulate matter. The EPA is established under the *Environment Protection Act 1997* (the Act) (21).

Air pollutant data in Canberra is collected through continuous monitoring, where instruments measure the concentration of pollutants and transmit the data to a central

monitoring station for analysis. Air pollutant data collected from the Florey station were used in this study, as it had the least amount of missing data for $PM_{2.5}$ and PM_{10} compared to the Monash and Civic air quality monitoring station (Table 1). This data can be accessed through the ACT Government website, which provides real-time air quality information for the region: https://www.data.act.gov.au (22). The website also provides historical data, which can be used to track changes in air quality over time. Data on health outcomes are collected from public hospitals (The Canberra Hospital and Calvary Public Hospital) and Canberra Health Services (CHS) Walk-in-Clinics (WiC) in Canberra. The hospitals and WiC facilities service the areas where air quality measurements were taken throughout the study period.

4.4 Exposure data

We obtained hourly measurements of $PM_{2.5}$, $PM_{10,}$ ozone (O_3), nitrogen dioxide (NO_2), and carbon monoxide (CO). We calculated 24-hour means and yearly averages for each set of hourly and 8-hour air quality indicator. We compared these indicators to the WHO's global air quality guidelines (AQG) 2021 (23). The WHO recommends that countries set national air quality standards based on certain 24-hour average indicators, with PM_{10} and $PM_{2.5}$ limits of 45 and 15 μg/m^3 respectively, ozone limits of 60 μg/m^3, nitrogen dioxide limits of 25 μg/m^3 and carbon monoxide limits of 4 mg/m^3.

4.5 Outcome measures

We defined the primary outcome measure to be asthma-related emergency department or WiC presentations in Canberra public hospitals and clinics. Asthma syndromes were coded based on WHO's International Classification of Diseases (ICD-10) diagnoses codes and clinical impressions are collected for WiC across the ACT. Asthma syndromes and other syndromes were contained within an internal dashboard managed by ACT Health Directorate (ACTHD). The dashboard is used by the Communicable Disease Control (CDC) section of Health Protection Services (HPS) to identify trends and spikes in emergency department and community (WiC) presentations for a range of pre-defined syndromes. The syndromes have been pre-defined by CDC with representatives from NSW Health's Public Health Rapid Emergency Disease and Syndromic Surveillance System (PHREDSS).

This study used available de-identified and aggregated data to describe health outcomes. Air quality indicators were extracted and analysed to assess variation and trends between 2015-2019, excluding the period when SARS-CoV-2 infections were

introduced in Canberra, Australia (March 2020 onwards) which may impact the outcome variable as a confounder. This data will be referred to as asthma-syndrome health related outcome (ASHRO) as the primary health outcome in all the figures and tables in the results.

4.6 Statistical Analysis

We analysed a de-identified list of data using R, version 4.1.0, statistical software (R Foundation for Statistical Computing, Vienna, Austria) (24). Categorical data were presented as frequency and proportions. Continuous variables were described using mean, standard deviation (SD), median, range and interquartile range (IQR). In observational epidemiological studies, researchers must treat missing data to ensure accurate results. In this study, we used listwise deletion which involves removing any observations with missing data. Missing data of all air quality variables is reported in Appendix 1.

We used Pearson's bivariate Correlation to assess the data and investigate the correlation between air quality indicators and daily ASHRO. The results were considered statistically significant where was *p* is less than 0.05. We conducted a time-series analyses to visualise the daily 24-hour average of each air quality indicator (exposure data) over time. We conducted univariable analysis to determine the association between single air pollutant variable and asthma-syndrome presentations. We included all the variables with *p* less than 0.25 in the final multiple Poisson regression model to estimate an incidence rate ratio (IRR) and check the independent effect of each factor.

Ethical Consideration

The ACT Health Human Research Ethics Committee (HREC) reviewed and approved the ethical aspects of this research under the ACT Reference 2022.LRE.00190.

5.0 Results

The average yearly mean concentrations of $PM_{2.5}$ over the study period were 8.75 $\mu g/m^3$ at the Florey site, 7.5 $\mu g/m^3$ at the Civic site and 8.99 $\mu g/m^3$ at the Monash site (Table 1). In every year assessed, all three air quality monitoring sites were above the 2021 AQG that states a yearly upper limit of 5 $\mu g/m^3$. At the Florey site, the 2021 AQG 24-hour mean for $PM_{2.5}$ of 15 $\mu g/m^3$ was exceeded a median of 32 days per year (range of 24-59). It was not exceeded by any other air quality monitoring site. At the Civic site, the 24-hour mean for PM_{10} of 45 $\mu g/m^3$ was exceeded with a median of 1 day per year (range of 0-29) with the Monash or Florey station recording a median of zero days.

Table 1: Summary of particulate matter measure across the three fixed air quality monitoring site stations (Florey, Civic and Monash) in Canberra, ACT, 2014-2019.

Parameters	Year	Air Quality Monitoring Sites 24-Hour Mean (% missing)		
		Florey	**Civic**	**Monash**
$PM_{2.5}$ ($\mu g/m^3$)	2015	6.65 (6.5)	6.26 (42.9)	8.52 (37.8)
	2016	7.11 (3.6)	5.52 (6.6)	7.24 (2.6)
	2017	7.43 (4.5)	5.95 (7.6)	7.77 (1.7)
	2018	7.29 (3)	6.49 (1.55)	6.96 (1.4)
	2019	15.24 (1.5)	12.68 (3.7)	14.28 (1.2)
	Overall	8.75 (3.8)	7.5 (12.5)	8.99 (9)
PM_{10} ($\mu g/m^3$)	2015	10.58 (3.5)	11.09 (1.6)	9.96 (1.9)
	2016	10.05 (2)	10.76 (0.5)	9.76 (0.5)
	2017	9.79 (2)	10.03 (13.5)	9.74 (13.5)
	2018	12.08 (3.5)	13.48 (1.8)	11.79 (0.6)
	2019	23.61 (0.6)	23.06 (2.3)	18.98 (0.8)
	Overall	13.23 (2.3)	13.74 (3.9)	12.05 (1)

PM = Particulate Matter

Table 1 shows that the air pollutant data collected from the Florey station had the least amount of missing data for $PM_{2.5}$ and PM_{10} compared to the Monash and Civic air quality monitoring station. The descriptive and analytical tables and figures will use data from Florey air quality station from here after.

There were no other indicators that exceeded the 2021 AQG across the study period (Table 2). The highest combined asthma-syndrome presentations from ED and community WiCs in Canberra were in recorded in 2016 with the lowest combined presentation recorded in 2019. An average of 4 presentations were recorded across the study period (Table 2). The two hospitals existed and reported ED presentations throughout the entire study period.

Table 2: Summary of asthma-syndrome presentations and air pollutant measures⁺ between 2015-2019 in Florey monitoring station, Canberra, ACT

Parameters	Year	Range		Mean	SD
		Minimum	Maximum		
***ASHRO**	2015	0	13	4	2
	2016	0	31	5	3
	2017	0	17	5	2
	2018	0	16	4	3
	2019	0	4	3	3
	Overall	0	31	4	3
$PM_{2.5}$ ($\mu g/m^3$)	2015	0.33	25.22	6.65	5.23
	2016	0.18	27.24	7.11	4.47
	2017	0.15	27.24	7.43	5.20
	2018	0.35	31.04	7.29	4.90
	2019	0.30	319.56	15.24	32.63
	Overall	0.15	319.56	8.75	15.67
PM_{10} ($\mu g/m^3$)	2015	0.12	68.50	10.58	6.52
	2016	0.91	28.84	10.05	5.55
	2017	0.81	29.23	9.79	5.56

	2018	1.49	159.50	12.08	11.49
	2019	1.79	379.71	23.61	40.96
	Overall	0.12	379.71	13.23	20.27
Ozone (ppm)	2015	0	0.02	0.010	0.01
	2016	0	0.03	0.015	0.01
	2017	0.01	0.04	0.019	0.01
	2018	0	0.03	0.020	0.01
	2019	0	0.05	0.021	0.01
	Overall	0	0.05	0.021	0.01
NO_2 (ppm)	2015	0	0.02	0.01	00
	2016	0	0.01	0.01	0
	2017	0	0.02	0.01	0
	2018	0	0.02	0.01	0
	2019	0	0.01	0.01	0
	Overall	0	0.02	0.01	0
CO (ppm)	2015	0.06	0.06	0.27	0.23
	2016	0.01	0.01	0.23	0.18
	2017	0	0	0.23	0.23
	2018	0	0	0.24	0.17
	2019	0.03	0.03	0.28	0.33
	Overall	0	0.06	0.25	0.24

PM = Particulate Matter, SD = standard deviation, $\mu g/m^3$ = micrograms per cubic meter, mg/m^3 = milligram per cubic meter, PPM = parts per million. ASHRO = asthma-syndrome health related outcome

$^+$ Mean values are 24-hour averages for air quality indicators and monthly means for the health outcome indicator.

* The range for asthma-syndrome presentations are presentations per month across all facilities combined. ED presentation values are rounded to the nearest whole value.

Table 3 shows the Pearson's correlation between asthma-syndrome presentations and daily air pollutants from the Florey Air Quality Monitoring Station from 2015-2019. The results show that there is a positive correlation

between asthma-syndrome presentations and $PM_{2.5}$ (r=0.113), PM_{10} (r=0.098), CO (r=0.103), and NO_2 (r=0.055). There is a negative correlation between asthma-syndrome presentations and O_3 (r=-0.023).

The correlations suggest weak positive associations between asthma-syndrome presentations and most air pollutants measured at the Florey Air Quality Monitoring Station.

Table 3: Pearson's correlation between asthma-syndrome presentations and daily air pollutants, Florey Air Quality Monitoring Station, 2015-2019

Measure	Asthma-syndrome Presentations	$PM_{2.5}$	PM_{10}	O_3	CO	NO_2
ASHRO	1.000					
$PM_{2.5}$	0.11	1.000				
PM_{10}	0.10	0.90*	1.000			
O_3	-0.02	0.18*	0.22*	1.000		
CO	0.10	0.73*	0.61*	-0.27*	1.000	
NO_2	0.06	0.28*	0.22*	-0.05*	0.68*	1.000

*Statistically significant (p <0.05). ASHRO = Asthma-syndrome health related outcome

Figure 1 to 3 outlines the 24-hour means for all the daily air pollutant concentration in the Florey air quality monitoring station between 2015-2019. The red vertical line indicates the major bushfire event that occurred in the 2019-20 bushfire season.

Figure 1: Calculated 24-hour means of $PM_{2.5}$ and PM_{10} measurements between 2015-2019, Florey station, Canberra, ACT

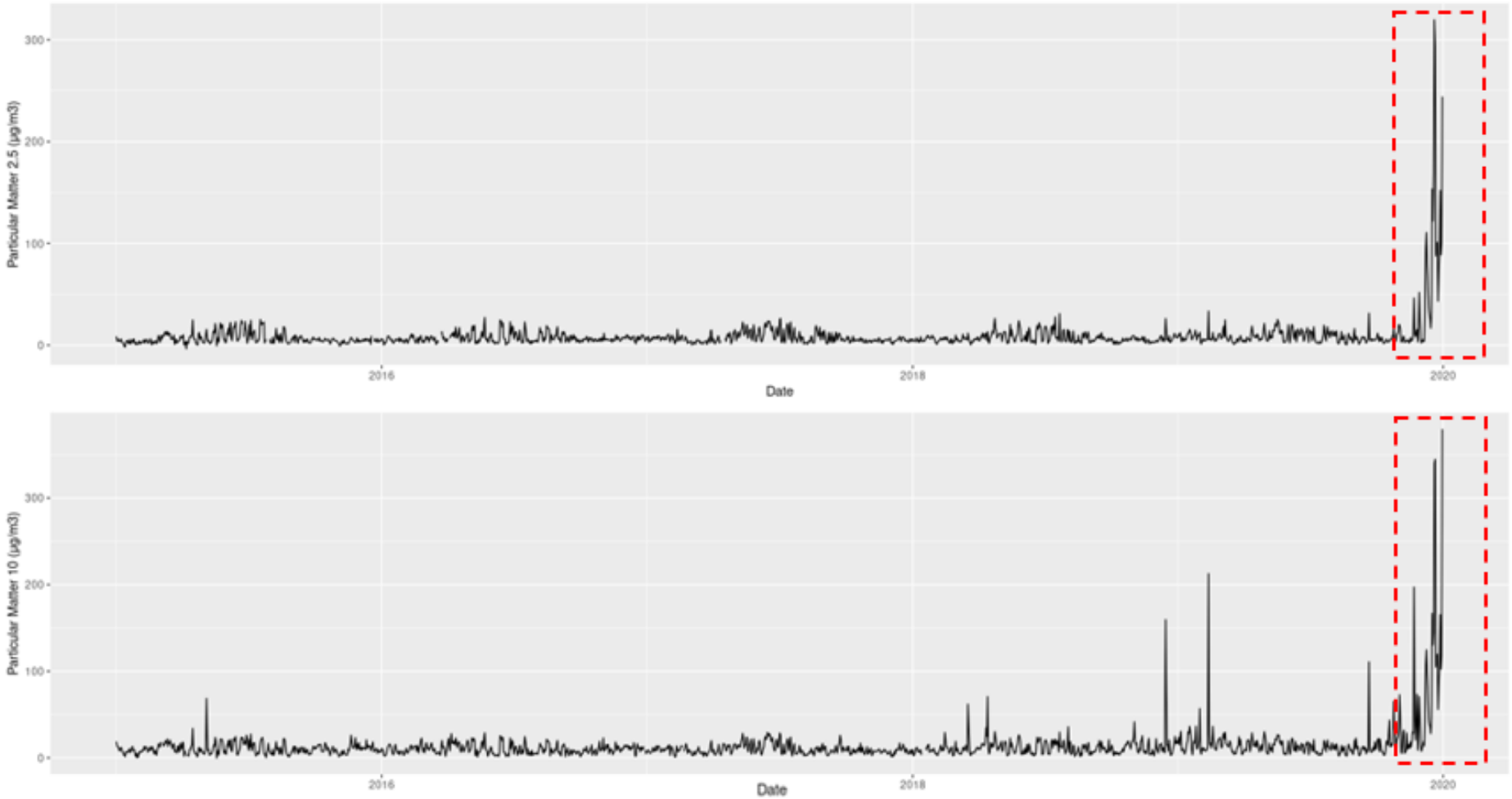


Figure 2: Calculated 24-hour means of nitrogen dioxide and carbon monoxide measurements between 2015-2019, Florey station, Canberra, ACT

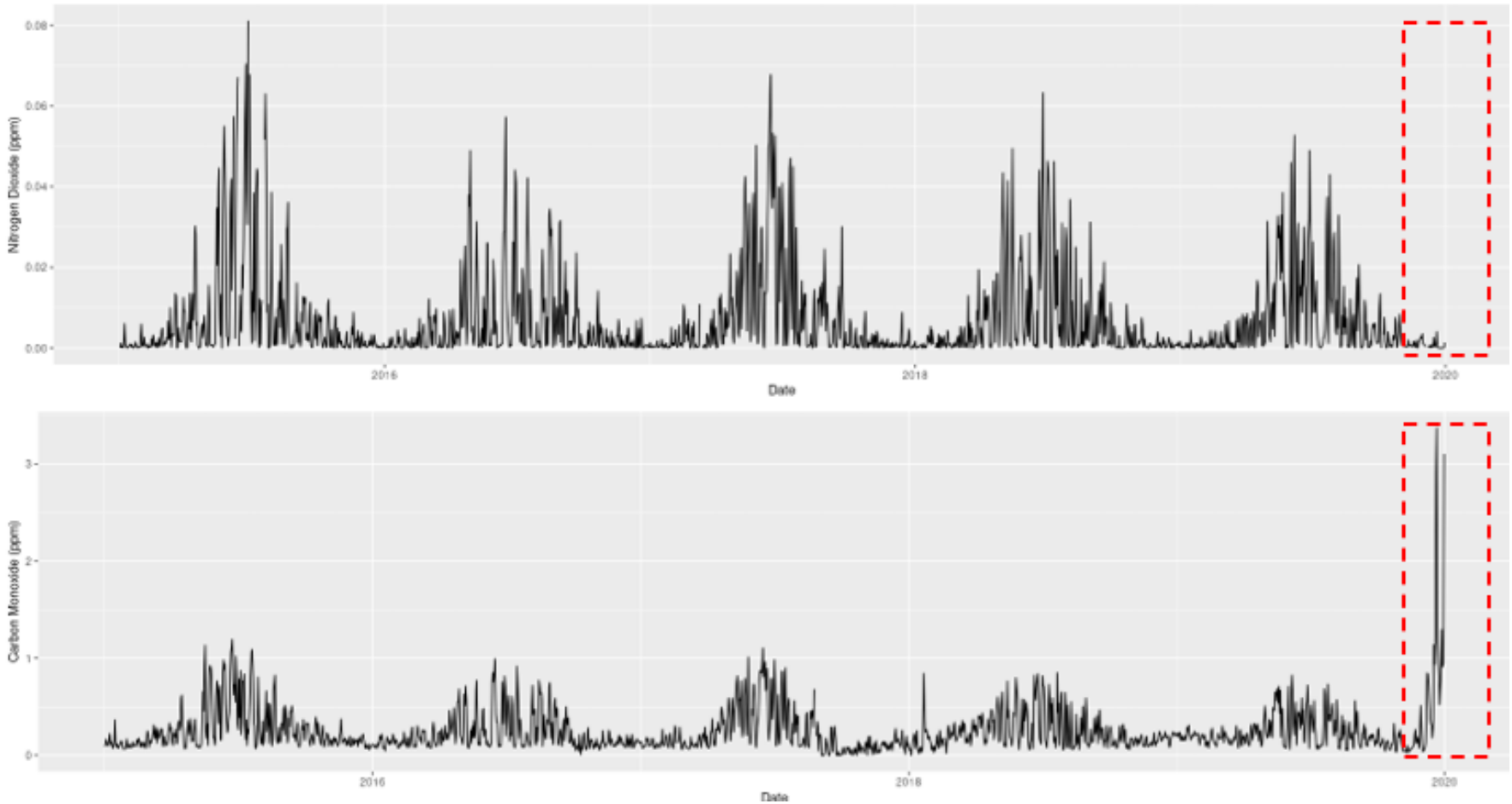
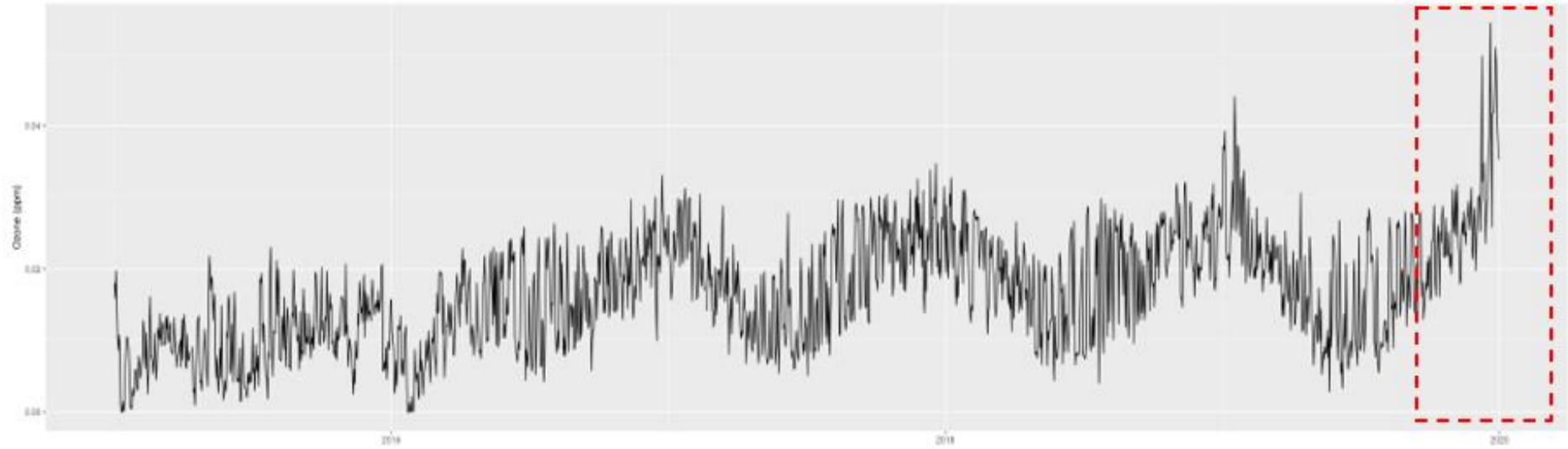


Figure 3: Calculated 24-hour means of ozone measurements between 2015-2019, Florey station, Canberra, ACT



Univariate and Multivariate Analysis

We used univariate Poisson regression to model the association between each of the single predictor variable of daily measures ($PM_{2.5}$, PM_{10}, CO, O_3 and NO_2) and an outcome variable (ASHRO). In univariate models an increase in ASHRO was associated with increases in four air quality measures – $PM_{2.5}$, PM_{10}, CO, and NO_2 – whereas an increase in O_3 was associated with a decrease in ASHRO. The results of the models showed that there was a statistically significant association between all predictors.

Table 4: Univariate and Multivariate Poisson Regression models to determine the association between air pollutants and asthma-syndrome presentations between 2015-2019 in Canberra, ACT

Parameter	Univariate Model		Multivariate Model		
	Coefficient	95% Conf. Interval	Coefficient	IRR	95% Conf. Interval
$PM_{2.5}$	0.003*	0.002-0.004	0.002	1.003	1-1.007
PM_{10}	0.002*	0.002-0.003	0	1	1-1.002
CO	0.242*	0.160-0.324	0.094	1.031	0.837-1.27
O_3	-1.602*	-4.436-1.232	-0.673	0.51	0.001-2.049
NO_2	9.578*	3.264-15.892	1.886	1.844	0-28320.06

*Statistically significant (p <0.05). IRR = Incident Rate Ratio.

In the multivariate model, NO_2 was an indicator that was the portrayed the largest Incident Rate Ratio (IRR) of 1.844 (95%CI: 0-28320.06). This suggest that for every unit of NO_2 concentration, the expected count of asthma-related presentations increased by a factor of 1.844 (Table 4). O_3 was the only indicator that portrayed a decrease in the incidence rate with an IRR of 0.51 (95%CI: 0.001-2.049). This indicates that for each unit increase of O_3 concentration, the expected count of asthma-related presentations decreased by a factor of 0.51. Although, the point estimates of IRR indicated an increase in asthma-related events with increased NO_2 and a decreased with increased O_3 concentration, there are wide 95% confidence intervals reflecting substantial uncertainty. The multivariate model did not reveal any indicator that were statistically significant.

6.0 Discussion

To the best of our knowledge, this is the first study that has examined the association of air pollutants and ASHRO emergency department and community centre presentations in the ACT. This study found that increases in $PM_{2.5}$, PM_{10}, CO, and NO_2 were associated with an increase in ASHRO presentations in the ACT, between 2015-2019. In contrast, an increase in O^3 was associated with a decrease in ASHRO presentations. The multivariate model shows that when all the air pollution measures are considered together, none are significantly associated with the outcome. While NO_2 showed a potential increase and O_3 a potential decrease in asthma-related events, the wide 95% confidence intervals emphasize substantial uncertainty. In our multivariate analysis, no statistically significant indicators were identified. Levels of air pollution indicators were at the highest during December 2019 as shown in Figure 1-3. This is due to the major bushfire event that impacted the east coast of Australia between December 2019 and February 2020 (12,13,14).

Main findings

All three air quality monitoring sites were above the 2021 AQG that states a yearly upper limit of 5 μg/m^3 for $PM_{2.5}$. Air pollutant data collected from the Florey station were used in this study, as it had the least amount of missing data (for $PM_{2.5}$ and PM_{10}) compared to the Monash and Civic air quality monitoring stations (Table 1). Florey air quality monitoring station was selected as the primary site for further analysis and was also the most impacted by air pollution based on the average yearly mean $PM_{2.5}$ of 8.7 μg/m^3 and the median number of days with 24-hour median $PM_{2.5}$ above 15 μg/m^3 (n=32), both of which were higher than the other two stations (Table 1). These results indicated that air pollution levels in this area are high and could pose a risk to public health.

Bushfires and smoke in Canberra from December 2019 to February 2020 had a significant impact on air quality indicators, such as $PM_{2.5}$, PM_{10}, CO_2 and O_3 (Figure 1 to 3) (3). The 24-hour means of these indicators increased considerably prior to readings earlier than 2020. The smoke also reduced visibility and caused respiratory irritation, potentially leading to an increase in ASHRO presentations (12,14). Low wind speeds and high temperatures during this period further exacerbated the effects of the smoke on air quality (12). In contrast, ASHRO presentation was the lowest in 2019 compared to other years in the study period. Poor air quality can have delayed effects

on emergency department presentations. The low presentations in our study may have been due to lag effects of poor air quality on asthma and respiratory related illness. A report by the Australian Institute of Health and Welfare (AIHW) outline that the highest increase of asthma presentation was seen in week starting 12 January 2020, which was outside our study period (3,12). A study by Rahman et al (2022) showed that a 10 $\mu g/m^3$ increase in $PM_{2.5}$ is associated with a 0.84% increase in emergency department visit for respiratory diseases four days later (25). This suggests that the effects of air pollution can be delayed, and that ED visits may not necessarily reflect the current air quality (26).

The results of the univariate model showed that there was a statistically significant association between all predictors of $PM_{2.5}$, PM_{10}, CO, and NO_2 with an increase in ASHRO presentations, while an increase is O_3 is associated with a decrease in such presentations (Table 4). However, the confidence intervals for these associations were large, indicating that the results should be interpreted with caution. The wide confidence intervals suggest a considerable range of uncertainty around the estimated associations, indicating the possibility of various unaccounted factors, measurement errors or natural variability that could influence the observed relationships between air pollutants and the outcome measure of AHSRO presentations. The multivariate model examined the relationship between air pollutants and asthma-related presentations. NO_2 was the indicator with the highest IRR, suggesting that for every unit of NO_2, there was an associated 1.844 increase in the incidence of an asthma-related presentation. O_3 was the only indicator that portrayed a decrease (0.51 IRR) in the incidence of an asthma-syndrome presentation. However, none of the indicators were found to be statistically significant. This means that the results of the model did not show a clear relationship between air pollutants and asthma-related presentations. To address the issue of air pollution and its potential link to asthma-related presentations, it is recommended that further research be conducted to better understand the relationship between air pollutants and asthma-related presentations.

Air pollution has been linked to a range of adverse health outcomes, including increased risk of mortality, cardiovascular and respiratory diseases, and adverse birth outcomes. A systematic review of the literature published in 2020 found that long-term exposure to air pollution was associated with an increased risk of mortality from

all causes, cardiovascular diseases, and respiratory diseases (27). The review also found that exposure to air pollution was associated with an increased risk of preterm birth, low birth weight, and stillbirth (27,28). These findings suggest that air pollution has a significant impact on human health, and that reducing air pollution levels could have a positive effect on public health (28, 29).

Limitation of the study

Our study had some limitations. First, because it was a retrospective study, inclusion was contingent upon accurate diagnosis coding. Coding mistakes may have resulted in the incorrect inclusion or exclusion of patients. Second, some individuals with asthma may choose to self-treat at home with an inhaled bronchodilator or oral steroid rather than seeking ED therapy for an asthma attack. Only if symptoms persist or worsen would they visit the ED for treatment. Additionally, previous studies have showed that people with respiratory conditions were significantly more likely to wear a mask or P2 respirator during fires, be given antibiotics, or be prescribed oral corticosteroids. These results include people over 65 years of age who reported fewer visits to health facilities than those under 65 years and were more likely to report avoiding outdoor air (30). Adults with asthma may feel both physical and psychological symptoms, including anxiety or a dread of visiting the emergency room because of a possible exposure to other illnesses or allergens (12,31). Physical symptoms include breathing problems, chest tightness, and coughing (2,3). Lack of mobility, advanced age, financial resources, and knowledge of the warning signs and symptoms of an asthma attack can also cause delays in treatment, which can have negative effects (3,32). The accuracy and scope of retrospective research studies using air quality data might be compromised by several restrictions. Inability to capture the full range of air quality issues, such as long-term exposure to pollutants or the effects of climate change, and lack of a complete picture of air quality due to not including all sources of pollution or other environmental factors are a few of them (33).

Finally, this study did not gather information on factors that have been linked to asthma episodes, including virus epidemics, pollen spores, fungus spores, and barometric pressure. As a result, the pollination season largely determines the link between air pollution concentrations and the frequency of asthma attacks (34,35). However, further research should examine the potential subtle relationship between

these factors and asthma exacerbation rate at an individual level. Smoke and bushfire effects can be difficult to accurately evaluate without data on the presence and concentration of aeroallergens (12,36). Without this information, it would be challenging to discover potential causes of asthma episodes, create efficient treatments and preventative measures, and guarantee accurate asthma diagnosis and treatment (36,37).

Recommendations/future studies

Future studies should investigate how aeroallergens affect various populations, including children, the elderly, and individuals with pre-existing diseases, in terms of their health outcomes (38). The possible health impacts of aeroallergens, which are airborne particles that can make people allergic, have drawn more attention in recent years (34,39,40). Aeroallergens can come from mould, dust mites, pollen, and pet dander, among other things. The potential for aeroallergens to interact with other environmental factors, such as air pollution, and alter health outcomes should also be investigated in further research (34,38,41). Future studies should also concentrate on the efficacy of interventions like air filtration systems, allergen-proof bedding, immunotherapy, public awareness campaigns, air quality regulations, and policies to reduce sources of aeroallergens, to decrease aeroallergen exposure and reduce the incidence of negative health outcomes (42,43,44).

Conclusion

This study found that increases in $PM_{2.5}$, PM_{10}, CO, and NO_2 were associated with an increase in asthma-syndrome presentations in the ACT, between 2015-2019. In our multivariate analysis, no statistically significant indicators were identified. By utilising environmental health data, we can identify areas of concern and develop strategies to reduce environmental risks. Additionally, environmental health data can be used to inform public health campaigns and raise awareness of environmental issues. Through this data, we can gain a better understanding of the environment and its impact on human health, allowing us to develop effective strategies to protect our environment and improve public health. However, due to the multi-factorial nature of asthma-syndromes and respiratory related illness, it is important to consider other lifestyle and environmental factors in future studies.

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The views expressed in this paper are those of the authors, and do not necessarily reflect the opinions of any external agencies. The authors have conducted independent research and analysis to form their conclusions, which may not be shared by any other entities.

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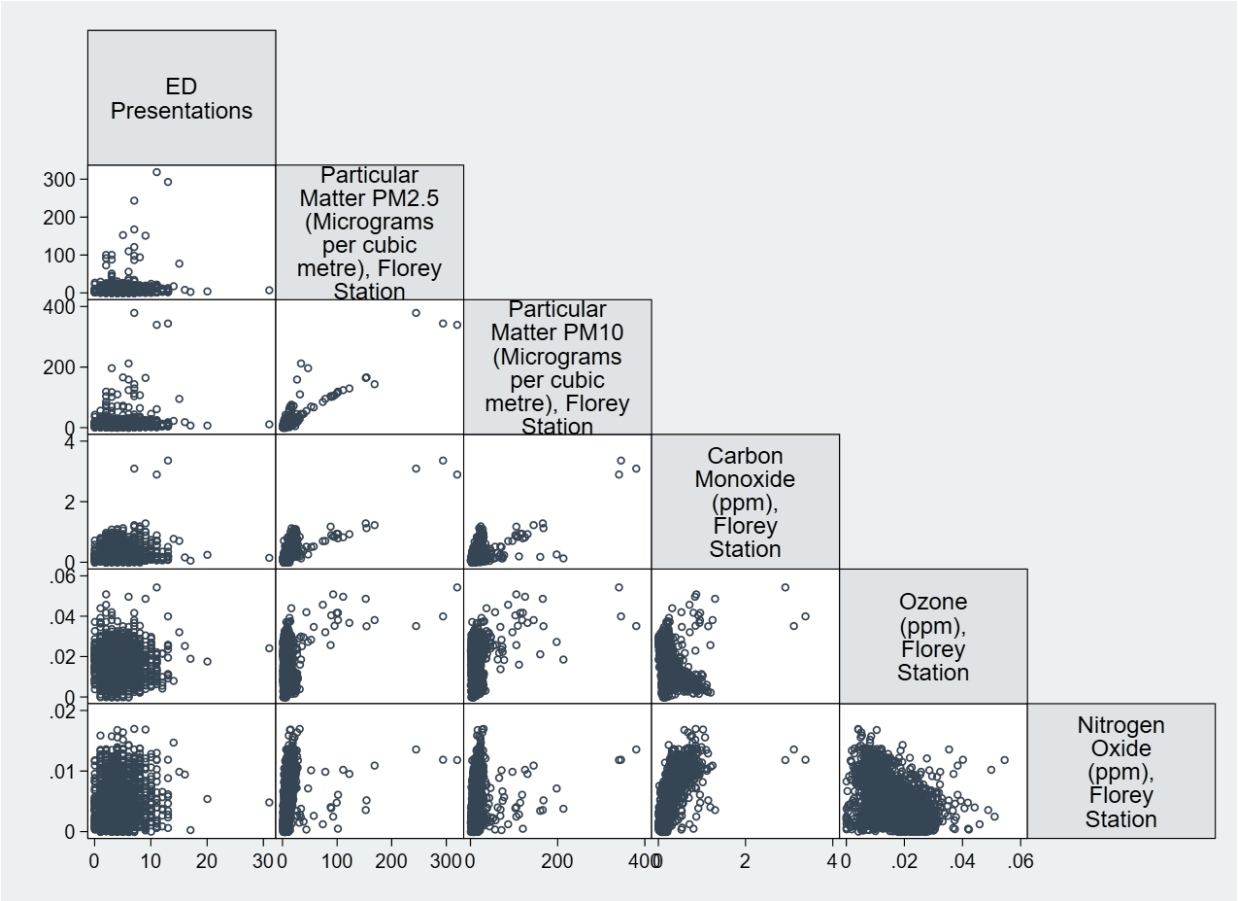
8.0 Appendices

Appendix 1: Missing daily data for ozone, nitrogen oxide and carbon monoxide across the three fixed air quality monitoring site stations (Florey, Civic and Monash) in Canberra, ACT, 2014-2019.

Parameters	Year	Air Quality Monitoring Sites % Missing		
		Florey	Civic	Monash
Ozone (ppm)	2015	5.8	11	7.2
	2016	4.2	4.2	4.8
	2017	4.5	4.2	4.5
	2018	4.8	4.8	4.2
	2019	4.7	4.2	4.2
	Overall	4.8	5.7	5
NO^2 (ppm)	2015	8.5	100	5.2
	2016	5.3	100	4.4
	2017	6.4	100	4.4
	2018	6.7	100	4.5
	2019	7.6	100	5.2
	Overall	6.9	100	4.8
CO (ppm)	2015	5.1	100	5.2
	2016	4.5	100	4.2
	2017	5.3	100	4.6
	2018	5.3	100	7.5
	2019	4.7	100	28.2
	Overall	5	100	9.94

Appendix 2: Scatterplot matrices for asthma-syndrome related presentations, $PM_{2.5}$, PM_{10}, Carbon Monoxide (CO), Ozone (O_3) and Nitrogen Dioxide (NO_2) between 2015-2019 in Canberra, ACT



Explanatory note: *Scatterplot matrices are a useful tool for visualizing relationships between multiple variables. For emergency department presentations and daily pollutant data, scatterplot matrices can be used to identify correlations between different variables. This can help to identify potential causes of emergency department presentations, or to identify correlations between different pollutants. The main advantage of scatterplot matrices is that they can quickly and easily visualize relationships between multiple variables.*

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Chapter VI

Master of Philosophy in Applied Epidemiology Teaching Experience

Table of Contents

List of Abbreviations

ACTGAL	Australian Capital Territory Government Analytical Laboratory
ANU	The Australian National University
ART	Acute Response Team
CHARM	Canberra Health Annual Research Meeting
CDC	Communicable Disease Control section
COVID-19	Coronavirus Disease 2019
FEFP	Field Epidemiology Fellowship Programme
HECC	Health Emergency Control Centre
HPS	Health Protection Service
LFF	Lessons From the Field
MAE	Master of Philosophy (Applied Epidemiology)
NINDSS	National Interoperable Notifiable Diseases Surveillance System
NNDSS	National Notifiable Diseases Surveillance System
PHECC	Public Health Emergency Coordination Centre
PHU	Public Health Unit
RACF	Residential Aged Care Facility
REDCap	Research Electronic Data Capture
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SOP	Standard Operating Procedure
WHO	World Health Organization
WPRO	Western Pacific Regional Offices

1.0 Teaching Activities

1.1 Prologue

A requirement of the Master of Philosophy in Applied Epidemiology (MAE) program is to teach field epidemiology. Teaching public health concepts and peer-to-peer learning are important skills to develop for public health professionals and field epidemiologists. These are usually conducted in two teaching components through a presentation on a 'Lessons from the field' (LFF) topic and a case study to first year MAE scholars. The LFF involves the delivery of a problem-solving exercise that we have encountered in our projects to a nominated group of peers in our MAE cohort. The lesson is usually composed of tasks that the other MAE's complete in their own time (and should take about 2-3 hours). This is followed a few weeks later by a teleconference where a virtual lesson is presented, and the aspects and results of the tasks are discussed. We were separated into groups of seven to each deliver our own and be involved in each of the case studies.

Another component of the core requirement of teaching activities was to conduct a teaching session for first year MAE scholars. Our MAE cohort worked within self-allocated groups of 4-5 students to prepare a teaching session on one topic that we felt would be beneficial to the MAE2022 cohort. I worked with an enthusiastic and efficient group of individuals throughout this exercise. I was also able to teach public health concepts by delivering a presentation on my experiences as Field Epidemiology Fellowship Program (FEFP) fellow with the Western Pacific Regional Office (WPRO), World Health Organization (WHO) which is covered in **Chapter VII Section 1.0** of this bound volume.

This chapter outlines my contribution to these activities, and collaboration with others in the cohort to achieve the teaching competency. There are several sections in this chapter that introduce the topic, learning objectives and lessons learned from these activities.

Master of Philosophy in Applied Epidemiology core requirements

- Teach topics in field epidemiology
    - Prepare at least one “Lessons from the field (LFF)”
    - Prepare and conduct a teaching session for first year MAE scholars

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- My LFF group: Aiden Yuen, Anna Rafferty, Aruna Phabmixay, Jane McAllister, Connie Slater, Haley JC Dyke, and Erin Flynn
- My MAE Teaching Session group: Hayley JC Dyke, Zoe Joo, and Yasmin Lisson.

2.0 Lessons From the Field (LFF)

2.1 Background

Every year, MAE scholars are asked to develop and deliver a problem-solving exercise to a nominated group of peers of their cohort. The facilitating scholar is required to create supporting documents (study exercise sheet and instructions) for the exercise and presentation materials that was to be provided to other MAEs in their own cohort. The exercise was to be completed by the other scholars in their own time. The allocated time for each LFF session was around 2-3 hours (no more than half a day's work for scholars to complete), which was followed by a one-hour teleconference where the facilitating scholar led the discussion and worked through the case study/exercise.

2.2 My role and lessons learned

For this LFF, I presented an introduction to creating a survey using Research Electronic Data Capture (REDCap). REDCap is a data management platform that has various utilities and is readily available across different organisations. I chose this topic after developing multiple automated surveys for ACT Health outlined in my surveillance project (**Chapter IV**) and other experiences outlined in this chapter. The case study that I developed was set in the context of an outbreak investigation, to ensure that the context was relevant to the participants and was based on the real-life experiences described in Section 5.0 below. A conscious decision was made to ensure that the learning objectives followed a SMART (specific, measurable, achievable, relevant, and time-bound) structure.

The learning objectives of the activity were:

- To be able to identify the key components of designing a data collection tool by the end of the teaching session
- To be able to identify key strengths and limitations of REDCap by the end of the teaching session
- To understand the principles of public facing and data forms by the end of the teaching session

Preparing for the teaching session offered an opportunity to develop an appropriate case study to a nominated group of peers along with a structured lesson plan. As part of the preparation, I prepared and delivered a questionnaire through REDCap to gauge how experienced the audience was regarding their knowledge of data collection system(s) (specifically, REDCap system). I was able to intentionally cater the session to ensure that the basic application was covered prior to explaining the advance functions of the system. I found that setting clear timeframes and learning objectives for the session was helpful in ensuring that all the participants understand the different sections of the exercise.

I developed an activity sheet that outlined the basic capabilities of REDCap (Appendix 1), accompanied by an online exercise through REDCap itself (Appendix 2). This was followed by a tutorial session explaining the intricacies of the system. To provide more value, I developed an activity sheet that could also be used as a system guide. This system guide was also designed to be distributed to the broader team of the Data and Reporting team from the COVID-19 Response Branch. The document aimed to introduce REDCap and its use as a surveillance and data capture system to new employees of the Data and Reporting team. The activity sheet also had useful tips and outlined common advantages and disadvantages of REDCap, which were based on the experiences I encountered throughout my candidature (which may not easily be found on the web). The tutorial presentation had questions that aimed to consolidate the information provided in the study sheet (Appendix 3). After the presentation, the learnings, and answers from the LFF was collated and distributed to the cohort. A brief evaluation of the LFF was also conducted at the end of the lesson.

2.3 Feedback from follow-up survey: LFF

A brief electronic survey using REDCap was sent to gather feedback on my LFF. A five-point scale was used to gather information on how well the session went, including if the objectives were met and if the content was useful (or not). All seven participants responded to the survey. All respondents (100%, 7/7) found that the session met its objectives. All respondents (100%, 7/7) found the content *'very'* useful.

In the following question, I asked for which component of my LFF session was found most useful. The options provided were;

- Content of the pre-exercise document,
- Completing the REDCap exercise,

- Demonstration of REDCap capabilities,
- Demonstration of learning how to set up an automated alert or,
- All of the above.

The majority of respondents (71%, 5/7) chose '*All of the above'* with the remainder indicating that the demonstration of how to set up an automated alert was the most useful section.

In free text fields, I also asked for points of improvements for both the activity sheet and the LFF presentation.

> **Respondent One**: *"No improvement needed, was a great introduction"* regarding the activity sheet and secondly, *"The walk through of REDCap would have been better as static slides for reference, rather than a live visual"* regarding the LFF presentation.
>
> **Respondent Two:** *"Activity sheet was great, loved the interactive use of REDCap to present the activity. Maybe extra info on how to extract the data would be useful".* For improvements for the LFF presentation, they outlined that there was none required; *"None, thought it was great".*

Finally, I requested for the respondents to write down further comments about their overall experiences regarding my LFF.

> **Respondent Three:** *"Really useful and informative. I wish I'd known about REDCap when I did the questionnaire for my surveillance evaluation"*
>
> **Respondent Four:** *"Brilliant LFF. Loved that you built this whole LFF in REDCap!!"*
>
> **Respondent Five:** *"I'm liking the mixture of the review of the activity and the practical demonstration, it really solidifies what we were talking about."*

Overall, I was pleased with the content of the LFF, how it was presented and most importantly, how it was perceived. As described above, I was very grateful for the lessons learned from developing and presenting my LFF to such engaged audience.

Acknowledgements

I would like to acknowledge my presentation group, who presented invaluable lessons learnt through their own LFF sessions. I would like to acknowledge my LFF group; Aiden Yuen, Anna Rafferty, Aruna Phabmixay, Jane McAllister, Connie Slater, Haley JC Dyke, and Erin Flynn, as all the sessions that were presented in my group were relevant and useful.

3.0 Peer-to-peer teaching to first-year MAE scholars

3.1 Background

The MAE2021 cohort was divided into self-allocated groups of 4-5 students to prepare a teaching session on a topic we felt would be beneficial to first year students. These teaching sessions to first year students (MAE2022) are aimed at delivering a topic that may not be addressed in formal course block teaching activities. My group was composed of Hayley JC Dyke, Zoe Joo, Yasmin Lisson and myself. This teaching group was different to the LFF group aforementioned in Section 2.0.

Our topic of choice was to deliver a presentation on notifiable diseases and conditions in Australia. We all felt that this was a topic that could have been better explained and could have provided a better platform for new scholars who have had very little public health experience in Australia. The teaching session to first year MAE students occurred during their last day of first course block, 4 March 2022. This session was a part of the second-year subject *POPH8914 Issues in Applied Epidemiology*.

The learning objectives of the activity were:

- Understand how notifiable diseases and conditions are reported to the National Interoperable Notifiable Diseases Surveillance System (NINDSS)
- Be able to describe how surveillance data informs public health action
- Be able to identify some important public health responses to surveillance signals
- Understand differences in COVID-19 responses compared to other notifiable disease responses

Table 1. Structure of the teaching session on notifiable conditions in Australia to the first year MAE scholars on 4 March 2021.

Section	Presenter	Content
1.0	Hayley	Background
1.1	Zoe	Overview of NINDSS How notifiable conditions are reported in Australia? Pros and cons of NINDSS
1.2	Yasmin	NINDSS Dashboard
2.0	Hayley	Interpreting Surveillance Data
2.1	Hayley and Algreg	Case Study: Legionellosis
2.2	Yasmin and Zoe	Case Study: Syphilis
2.3	All	Case Study Group Discussion: Legionellosis and Syphilis
3.1	Algreg	Case Study: COVID-19
3.2	Algreg	Case Study Group Discussion: COVID-19
3.3	Algreg	Open Discussion: COVID-19 differences and similarities
4.0	Hayley	Conclusion

3.2 My role and lessons learned

Our group presented materials to first year MAE scholars that may not be addressed formally in the traditional course block teaching units. We aimed to have an online teaching session that was both informative and interactive. We included interactive polls, two separate case study discussions and one large open group discussion (Table 1).

The session began with background information on notifiable conditions in Australia, which was followed by an overview of the National Notifiable Diseases Surveillance

System (NNDSS) which has recently been replaced by the National Interoperable Notifiable Diseases Surveillance System (NINDSS). We then explained the key sections of the NINDSS dashboard. The two small group discussions were focused on a case study on legionellosis and syphilis. The large group discussion was on COVID-19 exposures in high-risk settings. My main role was to develop a case study regarding an acute response to multiple SARS-CoV-2 infections in a Residential Aged-Care Facility (RACF). This was found to be an important topic, as it was deemed relevant to most of the first-year scholars involved (or who will be involved) in a local government area (LGA) or public health unit (PHU) setting.

Through this teaching activity, I developed a deeper appreciation for work that was needed to prepare and develop a structured lesson plan. I was fortunate that my teaching colleagues were studious when working as a group. It meant that there was adequate progress when coming together during our teaching planning sessions. This activity was one of most rewarding group projects that I have worked in.

3.3 Feedback from follow-up survey: teaching first year cohort

The evaluation feedback that was sent to the participants provided an insight of what our group did well, and what could have been improved (Appendix 5). The majority (70%, 14/20) of the first-year group selected “strongly agree” to the statement the session met its learning objectives, with the remainder (30%, 6/20) indicating they “agreed” with the statement. Secondly, our evaluation asked whether they found our session useful in this stage of their MAE journey. Again, the majority (90%, 18/20) indicated that they either “strongly agreed” or “agreed” with the aforementioned statement.

In a free text field, our group asked two important questions:

1. What are some of the important takeaways from this session?

> **Respondent One:** *“Interpreting surveillance data and using it to determine actions”.*
>
> **Respondent Two:** *“You learn by sharing knowledge”.*
>
> **Respondent Three:** *“Info on NNDSS, going through concrete case studies”.*

2. I would improve this session for next time by:

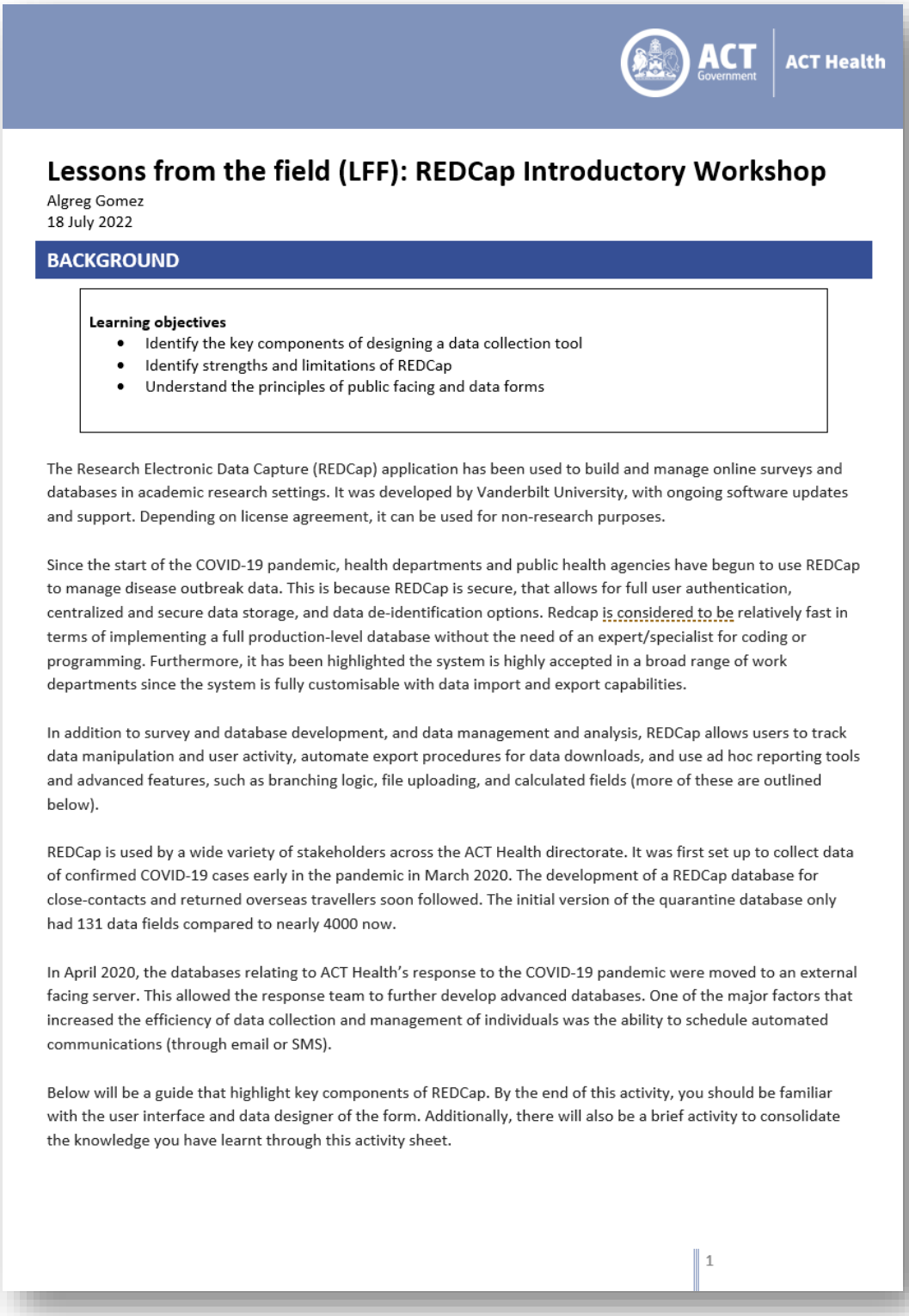
> **Respondent Four:** *"Great session, very interactive".*
>
> **Respondent Five:** *"Nothing really I can think of. Was very well run".*
>
> **Respondent Six:** *"No particular suggestions! Maybe more time with the handouts to read as I didn't get to them until just before the session".*

Acknowledgements

This teaching session was developed equally by Hayley Dyke, Yasmin Lisson, Zoe Joo and myself. I would like to acknowledge the Outbreak Preparedness and Response team of the COVID-19 Response Branch, ACTHD. They provided support and advice regarding the standard operating procedures (SOP) that provided the basis of my allocated section of the presentation. I would like to acknowledge Pallavi Venkatesh, Jodie Huet, Sue Reid and Mric Gomez from the Case Investigation team for their support.

Appendices

Appendix 1: LFF - Activity Sheet Handout



ACT Government | ACT Health

Lessons from the field (LFF): REDCap Introductory Workshop

Algreg Gomez
18 July 2022

BACKGROUND

Learning objectives

- Identify the key components of designing a data collection tool
- Identify strengths and limitations of REDCap
- Understand the principles of public facing and data forms

The Research Electronic Data Capture (REDCap) application has been used to build and manage online surveys and databases in academic research settings. It was developed by Vanderbilt University, with ongoing software updates and support. Depending on license agreement, it can be used for non-research purposes.

Since the start of the COVID-19 pandemic, health departments and public health agencies have begun to use REDCap to manage disease outbreak data. This is because REDCap is secure, that allows for full user authentication, centralized and secure data storage, and data de-identification options. Redcap is considered to be relatively fast in terms of implementing a full production-level database without the need of an expert/specialist for coding or programming. Furthermore, it has been highlighted the system is highly accepted in a broad range of work departments since the system is fully customisable with data import and export capabilities.

In addition to survey and database development, and data management and analysis, REDCap allows users to track data manipulation and user activity, automate export procedures for data downloads, and use ad hoc reporting tools and advanced features, such as branching logic, file uploading, and calculated fields (more of these are outlined below).

REDCap is used by a wide variety of stakeholders across the ACT Health directorate. It was first set up to collect data of confirmed COVID-19 cases early in the pandemic in March 2020. The development of a REDCap database for close-contacts and returned overseas travellers soon followed. The initial version of the quarantine database only had 131 data fields compared to nearly 4000 now.

In April 2020, the databases relating to ACT Health's response to the COVID-19 pandemic were moved to an external facing server. This allowed the response team to further develop advanced databases. One of the major factors that increased the efficiency of data collection and management of individuals was the ability to schedule automated communications (through email or SMS).

Below will be a guide that highlight key components of REDCap. By the end of this activity, you should be familiar with the user interface and data designer of the form. Additionally, there will also be a brief activity to consolidate the knowledge you have learnt through this activity sheet.

1

Figure 1: RSPH REDCap Log-in Front Page

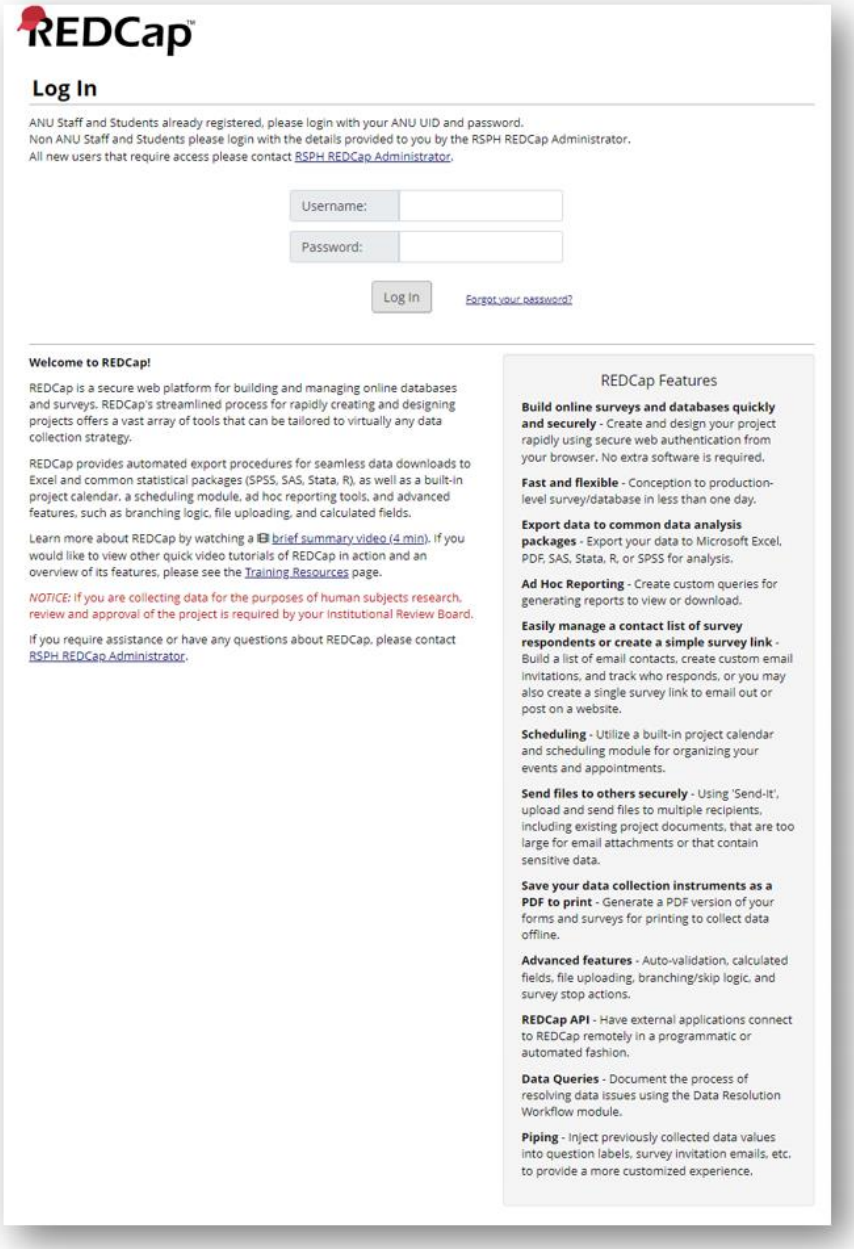
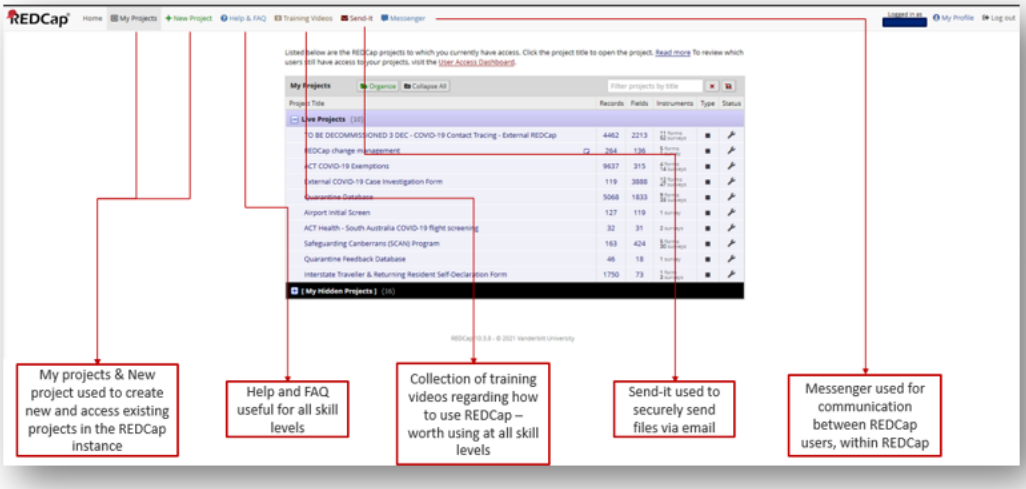


Figure 2: REDCap Project Dashboard in a web browser view.



Disclaimer: If you are familiar or comfortable with the intricacies of REDCap, please proceed to **Section 5: Exercise and Activity**.

SECTION 1: BASIC APPLICATION

How to log-in

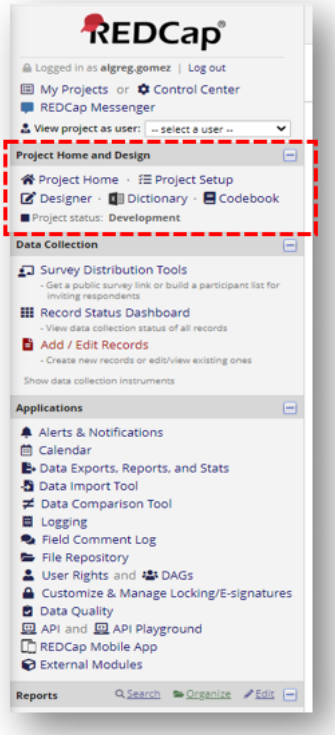
- Log-in credentials may or may not be separate to your ANU log-in.
  - If you do not have one already, simply request a REDCap account to mae.nceph@anu.edu.au.
  - A staff from NCEPH will create and manage your REDCap account for you.
- There will be a 2-factor authentication in place.
- As a system user, you will be required to change your password periodically and this will be automatically flagged by the system.
- The system be accessed by both desktop, smart device (phone, tablet, and applicable for both android and iOS).
  Once you have logged in, the project dashboard will display all the databases you have been given access to (Figure 2).

Tip: you can hide projects and create folders to differentiate them using the 'Organize' button.

REDCap Sidebar

- The sidebar can be found on the left-hand side of the interface.
- It provides shortcuts to key parts of your database.
  Tip: You will save a lot of time, if you are familiar with this section.
    - The **Project Home and Design** (highlighted red), will be the focus of this LFF.
        - The project setup and designer are shortcuts to their respective pages and are very helpful during the setup phase of a project – mostly used by system developers.
        - The dictionary and code are often used when analysing data, making bulk changes and creating reports.

Figure 3: Project Home and Design in the Sidebar section

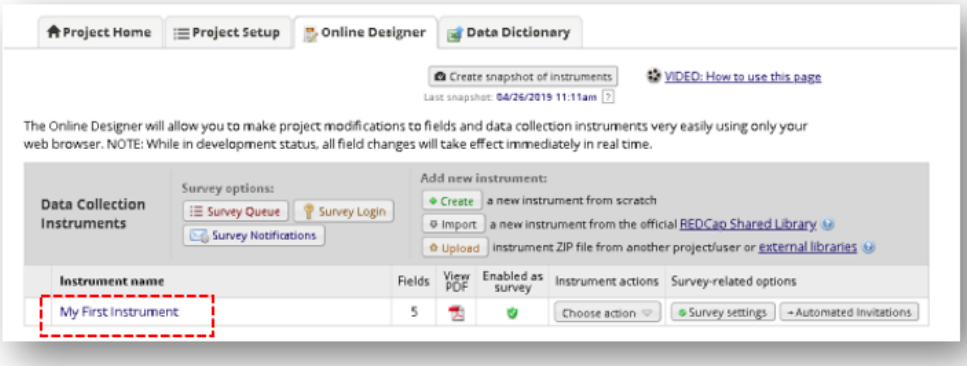


PART 2: DESIGNING DATA TOOLS (PART 1)

Online Designer

The Online Designer is one of the primary tool in which you can create and edit your data entry form, also known as an Instrument. Below is a standard instrument when creating an empty project without the use of data dictionary template.

Figure 4: Online Designer view mode



Note that you may rename and customise this instrument by clicking the instrument name as highlighted.

To simply add a new field, click the "Add Field" button and select the appropriate field attributes.

Data Dictionary

The other mode in creating a data entry instrument is through the Data Dictionary.

The Data Dictionary mode is a specifically formatted .csv spreadsheet. It contains the metadata used to construct data collection instruments and fields. It is ideal for large or repetitive projects, in some instances whereby one may need to make large–scale changes to your forms that would be difficult or tedious to perform with the Online Designer.

Each column of the spreadsheet maps to a property in the designer – which makes it intuitive to work with (figure 5).

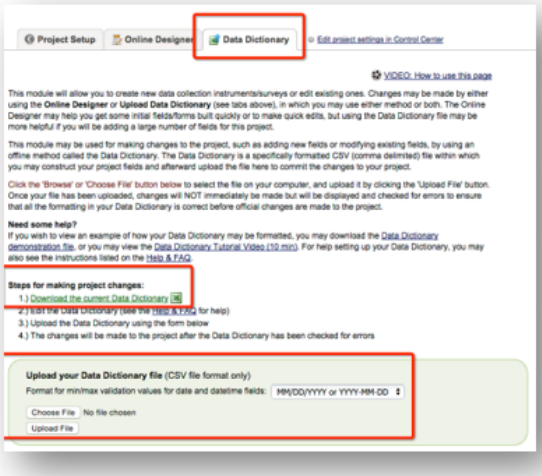
Figure 5: Sample of data dictionary output in a CSV

	A	B	C	D	E	F	G
1	Variable / Field Name	Form Name	Section Header	Field Type	Field Label	Choices, Calculations, OR Slider Labels	Field Note
2	study_id	my_first_instrument		text	Study ID		
3	date_enrolled	my_first_instrume	Consent Information	text	Date subject signed consent		YYYY-MM-DD
4	patient_document	my_first_instrument		file	Upload the patient's consent form		
5	first_name	my_first_instrume	Contact Information	text	First Name		
6	last_name	my_first_instrument		text	Last Name		
7	address	my_first_instrument		notes	Street, City, State, ZIP		
8	telephone_1	my_first_instrument		text	Phone number		Include Area Code
9	email	my_first_instrument		text	E-mail		
10	dob	my_first_instrument		text	Date of birth		
11	age	my_first_instrument		calc	Age (years)	rounddown(datediff([dob],'today','y'))	
12	ethnicity	my_first_instrument		radio	Ethnicity	0, Hispanic or Latino | 1, NOT Hispanic or Latino | 2, Unknown / Not	
13	race	my_first_instrument		dropdowr	Race	0, American Indian/Alaska Native | 1, Asian | 2, Native Hawaiian or	
14	sex	my_first_instrument		radio	Gender	0, Female | 1, Male	
15	given_birth	my_first_instrument		yesno	Has the patient given birth before?		
16	num_children	my_first_instrument		text	How many times has the patient given birth?		
17	gym	my_first_instrume	Please provide the patien	checkbox	Gym (Weight Training)	0, Monday | 1, Tuesday | 2, Wednesday | 3, Thursday | 4, Friday	
18	aerobics	my_first_instrument		checkbox	Aerobics	0, Monday | 1, Tuesday | 2, Wednesday | 3, Thursday | 4, Friday	
19	eat	my_first_instrument		checkbox	Eat Out (Dinner/Lunch)	0, Monday | 1, Tuesday | 2, Wednesday | 3, Thursday | 4, Friday	
20	drink	my_first_instrument		checkbox	Drink (Alcoholic Beverages)	0, Monday | 1, Tuesday | 2, Wednesday | 3, Thursday | 4, Friday	
21	specify_mood	my_first_instrume	Other information	slider	Specify the patient's mood	Very sad | Indifferent | Very happy	
22	meds	my_first_instrument		checkbox	Is patient taking any of the following	1, Lexapro | 2, Celexa | 3, Prozac | 4, Paxil | 5, Zoloft	
23	height	my_first_instrument		text	Height (cm)		
24	weight	my_first_instrument		text	Weight (kilograms)		
25	bmi	my_first_instrument		calc	BMI	round(([weight]*10000)/(([height])^(2)),1)	
26	comments	my_first_instrume	General Comments	notes	Comments		

The Data Dictionary is helpful when you require to create similar field types numerous times on the same (or different) instrument, or edit field attributes or branching logic.

Large–scale changes made easier through the Data Dictionary may include copying many fields (rows) into another form. For instance, if you wanted to copy rows 3 through 13 into another instrument, you would simply highlight rows 3 through 13 in Excel (the entire rows), copy, paste into the appropriate position (ensuring you did not paste over any other rows), and change the Form Name (column B) to "Contact Info" for the newly pasted rows

Figure 6: Key set up and sections of the Data Dictionary interface



PART 3: DESIGNING DATA TOOLS (PART 2)

There are multiple fields types you may choose from. Below are field types and attributes that you may come across (as shown in Figure 7).

Field Types

1. **Text Box:** A small box where string* data can be entered. Useful when short answers are likely to be provided.
   *A string data type is variable that holds a sequence of one or more alphanumeric characteristics.

2. **Notes Box:** A larger text box that is generally useful when longer answers are provided for a question.

3. **Multiple Choice**

   a. **Drop-drown list**: A drop down list with choices will appear when selected. Only a single answer can be provided. Often useful when a large number of choices are available.

   b. **Radio Buttons**: Each choice is displayed with a small button next to it which can be selected. Only single answer possible.
   Tip: limit the choices provided, as the form can become cluttered.

   c. **Checkboxes**: Small checkboxes with the choice description. This is where multiple answers can be selected.

4. **Yes/No:** Auto-coded field, and will be automatically coded 1=Yes, 0=No.

5. **True/False:** Similar to yes – no field except different wording.

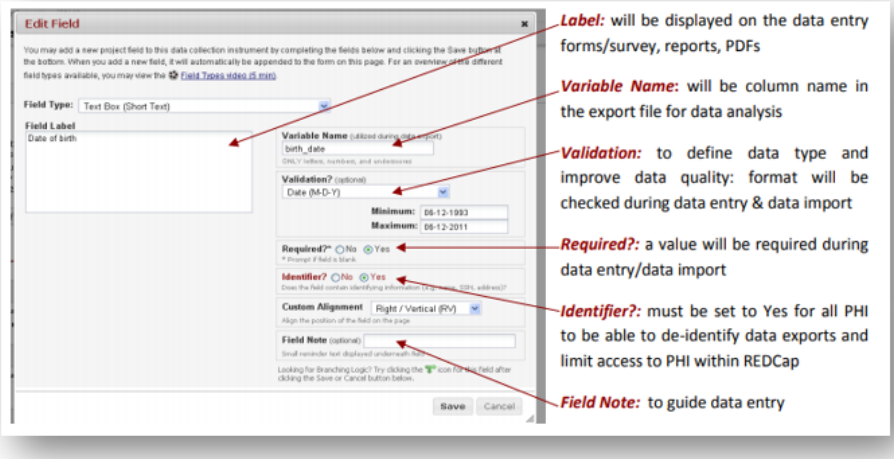
6. **Slider:** A slider field which can be used to gauge a response on a scale of 0-100.
   Tip: Often useful for more qualitative or subjective gauging of a response.

7. **Descriptive Text:** A field where no answer box or options are provided.

8. **Advanced field types:**
   a. **Dynamic SQL Query:** dropdown hooked up to another project.
   b. **File upload:** ability to attach documents to a field.
   c. **Matrix field:** multiple field types into the same set of responses.

   There is also the option to "add a new section" to the same instrument.

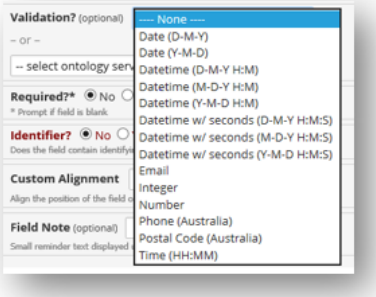
Figure 7: REDCap field attributes



Field Data Validation

These options ensure that fields are formatted for their appropriate purpose and are typically only possible when using a text box field type:

Figure 8: Validation Types



1. Integer
   This validation type can include negative and positive integers.

2. Letters only

3. Number:
   Numbers can include decimal values.

4. Email:
   REDCap has the ability to validate where a free text field is with an "@" symbol with an email domain ending with (".com" or ".edu"). A limitation to this is that there is also the possibility of REDCap now recognising a new or uncommon domain.

5. Date:
   There are three different formats you can specify for date are Day-Month-Year, Month-Day-Year, and Year-Month-Day. There is also a "Today" icon that can be clicked, to automatically fill in the current date.

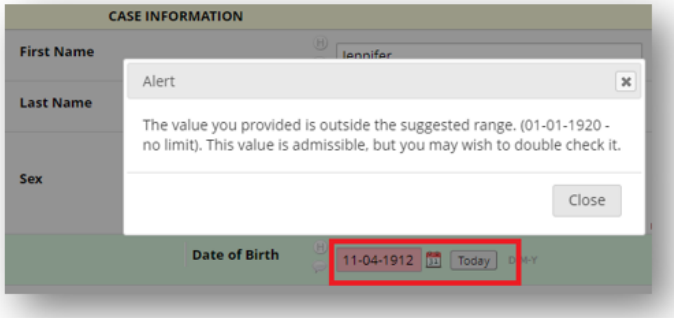
6. Time:
   This validates type can accept Hour:Minute format. As above with date/datetime field, there is a "Now" icon that can be used for data entry.

7. Datetime: as above.

Tip: you can specify minimum and maximum values for any numeric/data types.

Note: REDCap automatically re-formats certain data. If you make a mistake, REDCap will display an alert. Validation is a way to ensure that data is saved in a consistent format, and most projects use this functionality.

Figure 9: Field validation error alert



PART 4: BRANCHING LOGIC

If you would like for certain questions to appear only under certain conditions, you may employ the REDCap technique "branching logic" or "skip logic" to do so.

Branching Logic: may be employed when fields/questions need to be hidden for data entry under certain conditions. For instance, you may want to hide the question "How many donuts did you eat?" until a "Yes" answer is checked for a previous question, "Did you eat any donuts?"

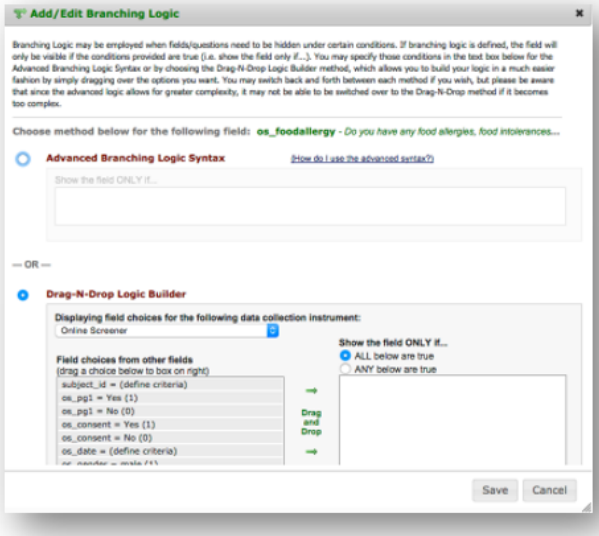
Logic can be used in branching, calculated fields, conditional logic for automated survey invitations, alerts, data quality rules, the survey queue, advanced filters for reports, and project dashboards. The format for the logic will depend on where you are using it in the project, the type of field, and how the project is set up (classic, longitudinal, repeating instruments).

Branching logic can get really complicated – but simple is always better!

You can use a "Drag-N-Drop', or advanced syntax as shown below (Figure 10).

The "Drag-N-Drop" is as simply as it describes. You may drag and drop particular fields in the logic builder and apply conditions.

Figure 10: Add/Edit Branching Logic Overview



Using "Advanced Branching Logic Syntax" adds further potential in developing complex logic.

Adding variable to a logic is easy! You will need to add the variable name in the projected in square brackets [], for example [variable_example].

You will require a value that constitutes to the variable that you're interested in (as above), and this will depend for whether the field value is 'string' or a pure number. A 'string' is any combination of text and numbers, such as multiple-choice code in a radio or checkbox field or an unvalidated text field.

You may use mathematical operations (=, <, >, <=, >=, <>) and combine statements within a logic.

Field Name: Suburb
Field Choices: 1, Mouse City
2, Caramel Town
99, Other

Example number 1:
If you want subsequent questions to appear ONLY IF "Mouse City" is selected, you may use the following branching logic: ***[Suburb]="1"***

Example 2:
If you want subsequent questions to appear ONLY IF "Mouse City" is selected OR "Other" AND must contain a value (also interpreted as, the field cannot be blank), you may use the following branching logic:
[Suburb]="1" OR [Suburb]="99" AND [Suburb]<>""

PART 5: EXERCISE

Below is a case study that will consolidate the information provided above.

You are an epidemiologist working with the ACT Health Directorate performing your weekly routine surveillance on salmonella. The Disease Surveillance section that you are working with have noticed an increase in number of individuals with salmonellosis in the recent days. Upon several routine case interviews, a common food business (Mouse City Bakery) was highlighted and have been flagged by recent case interviews. The bakery is well known for its custard pies and wide range of donuts that has been a common food item from the case interviews.

Two days have passed since the first salmonella notification to the Disease Surveillance section that may have been related to this one particular bakery. A social media post has been circulated and it has highlighted that there are groups of people reporting that they have felt ill after the consumption of donuts. This has triggered a wave of phone calls to the Disease Surveillance section reporting food poisoning complaints.

The OzFoodNet epidemiologist has asked you to create a data capture system to collect information from those reporting food poisoning complaints. The Microsoft Excel Spreadsheet that was being used had numerous limitations. This data capture system must be able to be used by the public health staff conducting the hypothesis generating questionnaire and be flexible to include specific questions aimed at the types of foods eaten at Mouse City Bakery.

Your REDCap activity sheet is found through a REDCap form here: Lessons from the Field: REDCap Activity Sheet
You may also scan the QR code below to complete the activity sheet.

You may click 'submit' once the questionnaire has been completed and the content of your submission as well as the correct answers will be sent to your email.

If the hyperlink above does not work, please don't hesitate to contact me at algreg.gomez@anu.edu.au.

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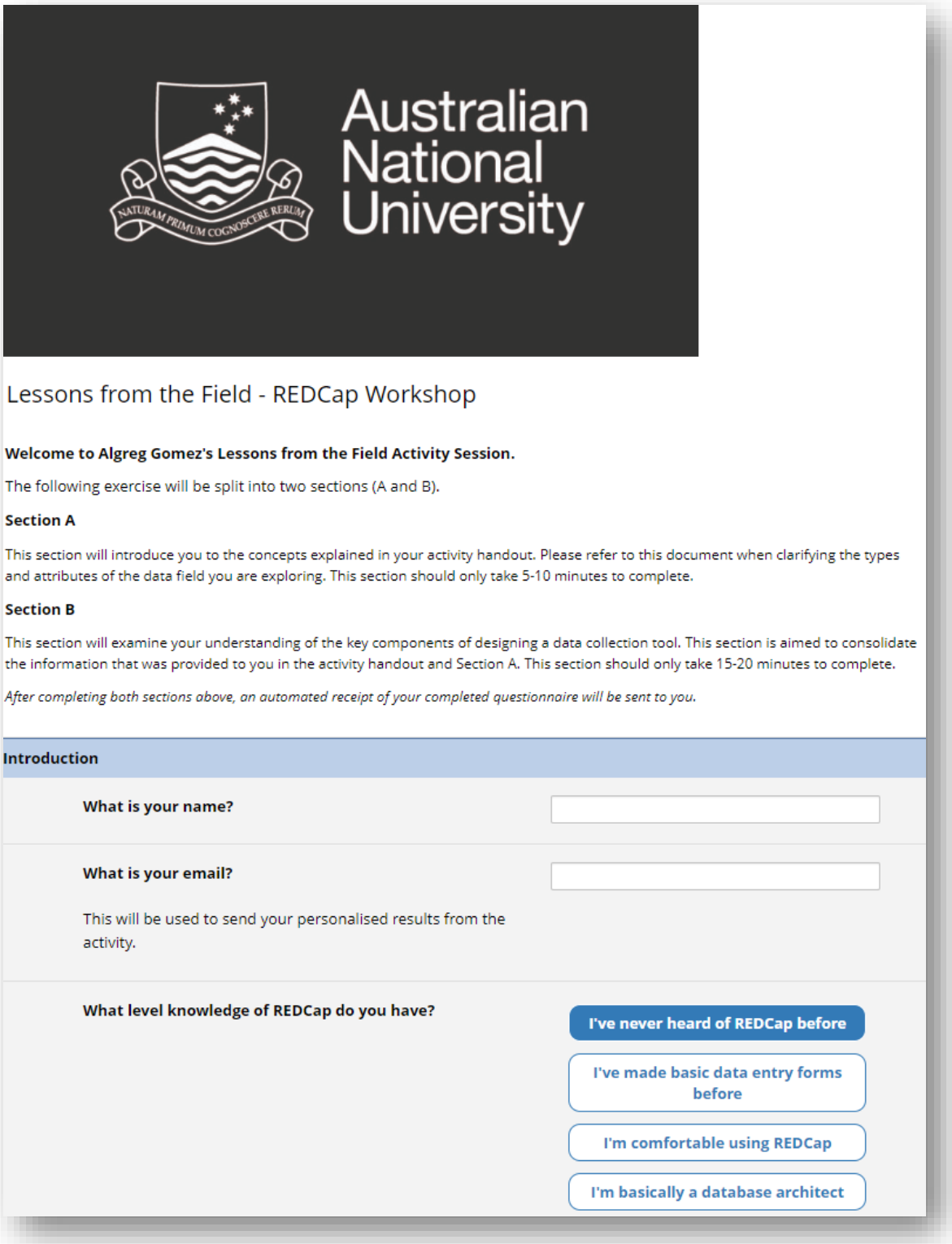
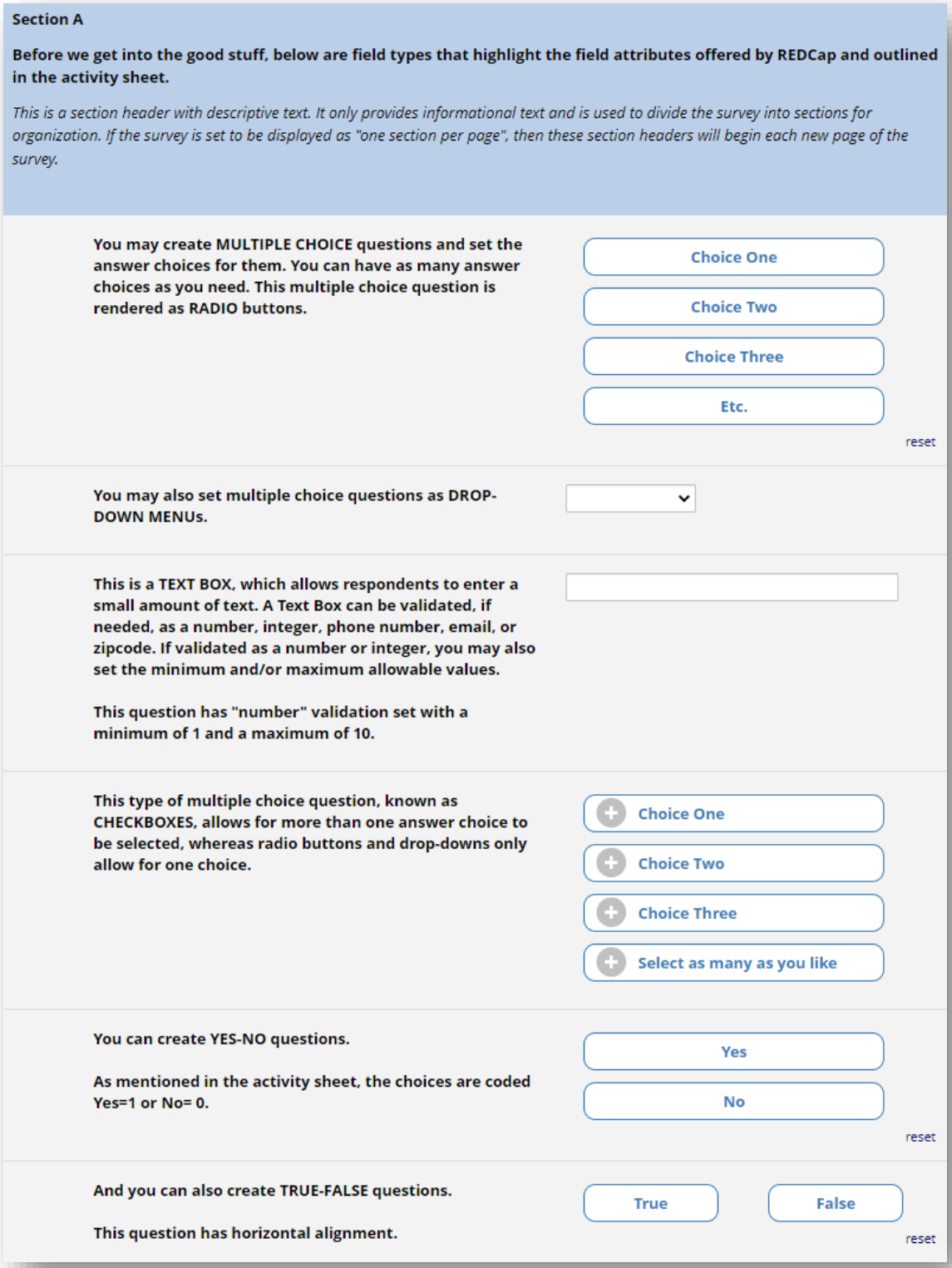
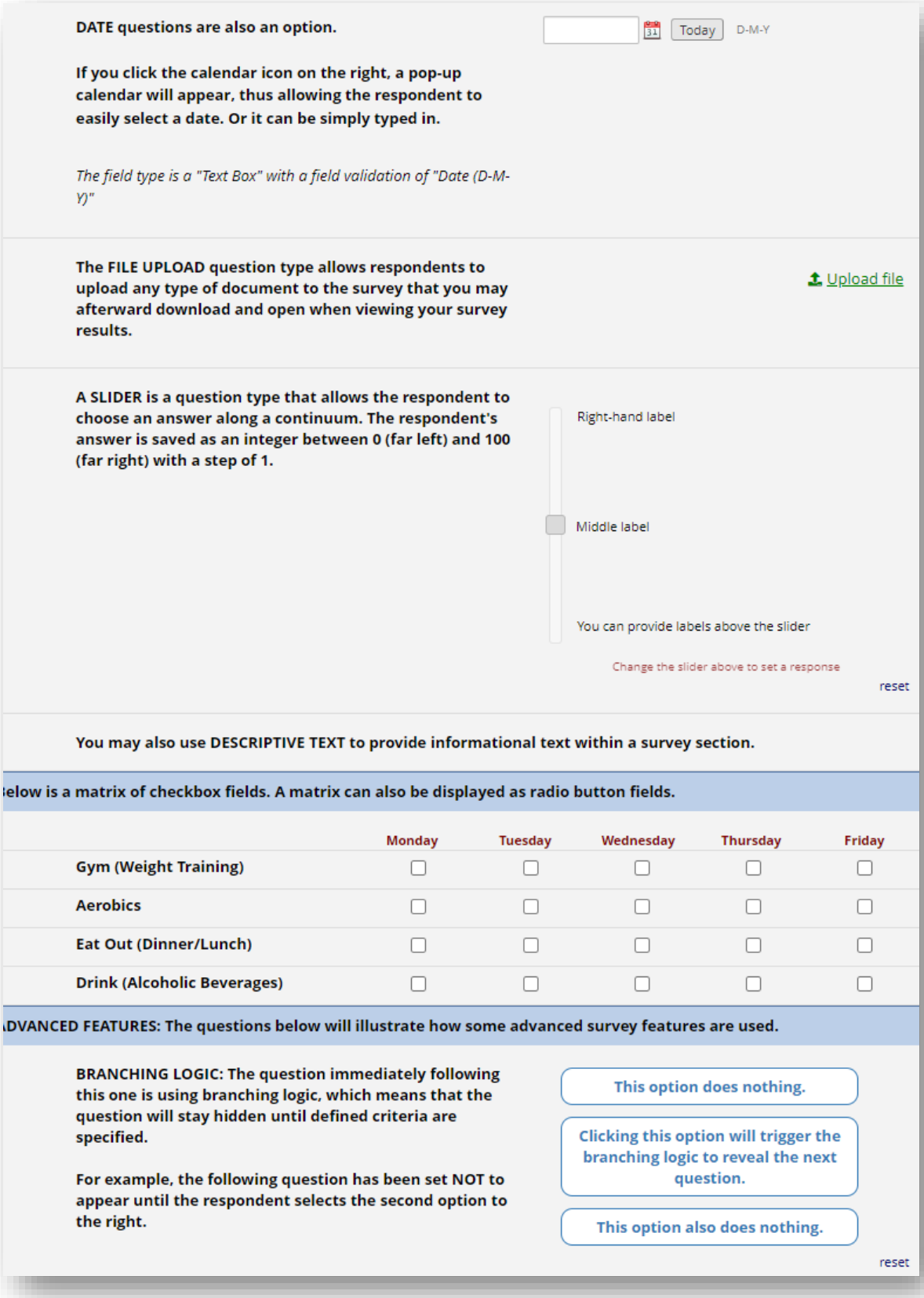
PA Harris, R Taylor, BL Minor, V Elliott, M Fernandez, L O'Neal, L McLeod, G Delacqua, F Delacqua, J Kirby, SN Duda, REDCap Consortium, The REDCap consortium: Building an international community of software partners, J Biomed Inform. 2019 May, doi: 10.1016/j.jbi.2019.103208

Appendix 2: LFF - REDCap Interactive Workshop [Internet Web Browser View]




Section A
Before we get into the good stuff, below are field types that highlight the field attributes offered by REDCap and outlined in the activity sheet.
This is a section header with descriptive text. It only provides informational text and is used to divide the survey into sections for organization. If the survey is set to be displayed as "one section per page", then these section headers will begin each new page of the survey.
You may create MULTIPLE CHOICE questions and set the answer choices for them. You can have as many answer choices as you need. This multiple choice question is rendered as RADIO buttons.
Choice One
Choice Two
Choice Three
Etc.
reset
You may also set multiple choice questions as DROP-DOWN MENUs.
This is a TEXT BOX, which allows respondents to enter a small amount of text. A Text Box can be validated, if needed, as a number, integer, phone number, email, or zipcode. If validated as a number or integer, you may also set the minimum and/or maximum allowable values.
This question has "number" validation set with a minimum of 1 and a maximum of 10.
This type of multiple choice question, known as CHECKBOXES, allows for more than one answer choice to be selected, whereas radio buttons and drop-downs only allow for one choice.
Choice One
Choice Two
Choice Three
Select as many as you like
You can create YES-NO questions.
As mentioned in the activity sheet, the choices are coded Yes=1 or No= 0.
Yes
No
reset
And you can also create TRUE-FALSE questions.
This question has horizontal alignment.
True
False
reset


DATE questions are also an option.
Today
D-M-Y
If you click the calendar icon on the right, a pop-up calendar will appear, thus allowing the respondent to easily select a date. Or it can be simply typed in.
The field type is a "Text Box" with a field validation of "Date (D-M-Y)"
The FILE UPLOAD question type allows respondents to upload any type of document to the survey that you may afterward download and open when viewing your survey results.
Upload file
A SLIDER is a question type that allows the respondent to choose an answer along a continuum. The respondent's answer is saved as an integer between 0 (far left) and 100 (far right) with a step of 1.
Right-hand label
Middle label
You can provide labels above the slider
Change the slider above to set a response
reset
You may also use DESCRIPTIVE TEXT to provide informational text within a survey section.
elow is a matrix of checkbox fields. A matrix can also be displayed as radio button fields.
Monday
Tuesday
Wednesday
Thursday
Friday
Gym (Weight Training)
Aerobics
Eat Out (Dinner/Lunch)
Drink (Alcoholic Beverages)
DVANCED FEATURES: The questions below will illustrate how some advanced survey features are used.
BRANCHING LOGIC: The question immediately following this one is using branching logic, which means that the question will stay hidden until defined criteria are specified.
For example, the following question has been set NOT to appear until the respondent selects the second option to the right.
This option does nothing.
Clicking this option will trigger the branching logic to reveal the next question.
This option also does nothing.
reset

Section B: Consolodating your knowledge

Below is a case study that will consolidate the information provided above.

You are an epidemiologist working with the ACT Health Directorate performing your weekly routine surveillance on salmonella. The Disease Surveillance section that you are working with have noticed an increase in number of individuals with salmonellosis in the recent days. Upon several routine case interviews, a common food business (Mouse City Bakery) was highlighted and have been flagged by recent case interviews. The bakery is well known for its custard pies and wide range of donuts that has been a common food item from the case interviews.

Two days have passed since the first salmonella notification to the Disease Surveillance section that may have been related to this one particular bakery. A social media post has been circulated and it has highlighted that there are a number of groups of people reporting that they have felt ill after the consumption of donuts. This has triggered a wave of phone calls to the Disease Surveillance section reporting food poisoning complaint.

The OzFoodNet epidemiologist has asked you to create a data capture system to collect information from those reporting food poisoning complaints. The Microsoft Excel Spreadsheet that was being used had numerous limitations. This data capture system must be able to be used by the public health staff conducting the hypothesis generating questionnaire and be flexible that can include specific questions aimed at the types of foods eaten at Mouse City Bakery.

Question 1: List five common advantages of using an online questionnaire for an outbreak investigation:

Expand

Question 2: List five common disadvantages of using an online questionnaire for an outbreak investigation:

Expand

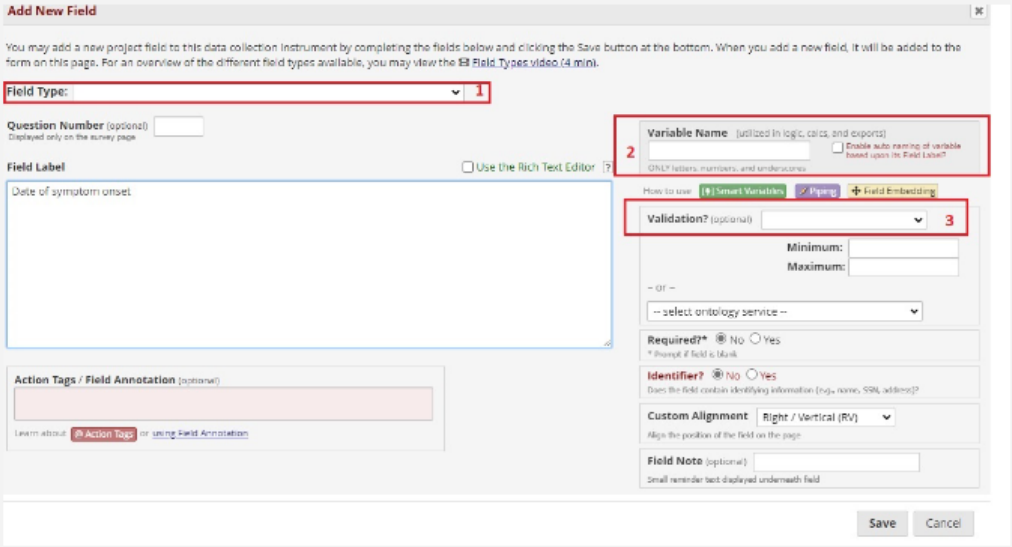
Question 3: Write down the appropriate demographic fields that should be collected in this data capture system for the outbreak?
Note: outline at least 3 identifiers.

Expand

Question 4: For the image below, complete the questions below:

Figure 1: Creating a new field

Note: you may use the introductory workshop activity sheet as a guide.



4.1 Select the most appropriate Field Type: _____

4.2 Enter an appropriate Variable Name: _____

4.3 What is the most appropriate validation: _____

Question 5: You have created the variable below regarding if an individual ate the venue or not:

Field name: [venue_eaten]

Choices: Yes or No (1=Yes, 0=No, 2=Cannot remember)

Expand

Write the appropriate branching logic so that the hypothetical questions after [venue_eaten] only appear if the respondent has NOT ticked "No"?

Question 5: You have created the variable below regarding if an individual ate the venue or not:

Field name: [venue_eaten]

Choices: Yes or No (1=Yes, 0=No, 2=Cannot remember)

Write the appropriate branching logic so that the hypothethical questions after [venue_eaten] only appear if the respondent has NOT ticked "No"?

Expand

Question 6: You have realised that there are group of variables that requires changes.

For large scale changes, what would be the most appropriate way of updating your database?

- Online Designer
- Data Dictionary
- Too difficult, I'd rather contact the system administrator

reset

Question 7: You are planning to ask questions (hint: plural) **regarding the specific type of symptoms that individual experienced whilst being ill.**

What field choice would be the most appropriate?

- Individual Yes/No Fields
- Text Box
- Multiple Choice
- Matrix Fields of Yes/No
- True/False

reset

End of Section B

Ensure that you have the correct details in the email field.

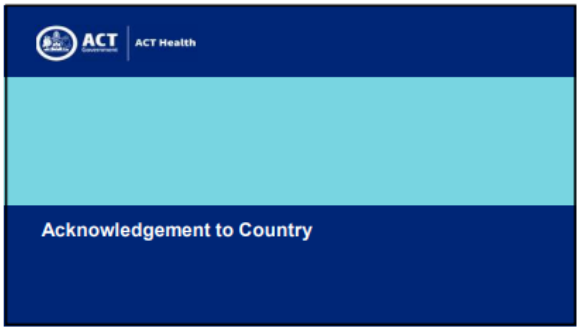
Please ensure that you have placed an answer for all questions in Section B, and click submit below.

Section C is the evaluation questionnaire that will be distributed after Algreg's presentation on Monday 18 July 2022.

Submit

Appendix 3: LFF - Tutorial Presentation Slides, 18 July 2022

1



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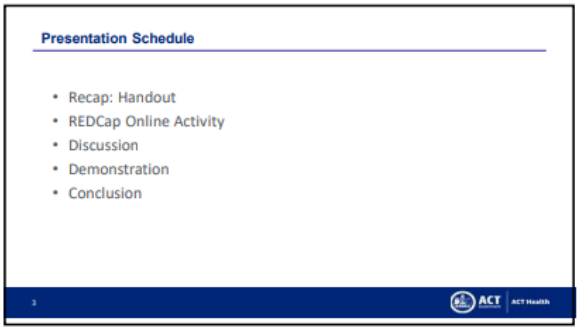

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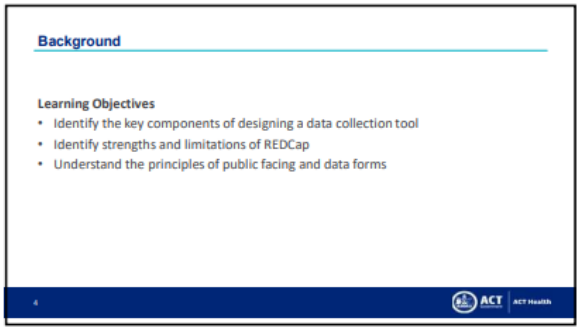

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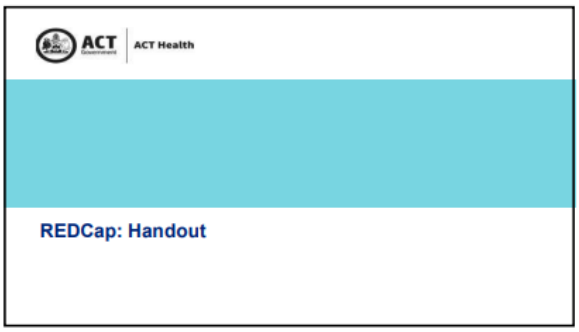

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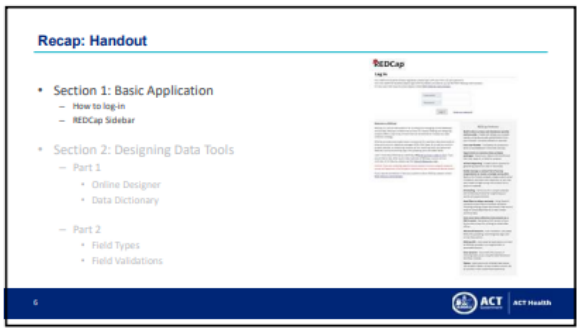

6

Recap: Handout

- Section 1: Basic Application
  - How to log-in
  - REDCap Sidebar
- Section 2: Designing Data Tools
  - Part 1
    - Online Designer
    - Data Dictionary
  - Part 2
    - Field Types
    - Field Validations

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Recap: Handout

- Section 3: Branching Logic
  - Advanced Branching Logic Syntax
  - 'Drag-N-Drop' Logic Builder
- Section 4: Exercise
  - REDCap Activity
    - Section A: Examples
    - Section B: Consolidating your knowledge

8

8

Recap: Online Activity

- Section 3: Branching Logic
  - Advanced Branching Logic Syntax
  - 'Drag-N-Drop' Logic Builder
- Section 4: Exercise
  - REDCap Activity
    - Section A: Examples
    - Section B: Consolidating your knowledge

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Recap: Online Activity

- Section 4: Exercise

  Question 1: List 5 common advantages of using an online questionnaire for an outbreak investigation

  Question 2: List 5 common disadvantages of using an online questionnaire for an outbreak investigation

  Question 3: Write down the appropriate demographic fields that should be collected in this data capture system for the outbreak?

10

10

Recap: Online Activity

- Section 4: Exercise

  Question 1: List 5 common advantages of using an online questionnaire for an outbreak investigation

  Question 2: List 5 common disadvantages of using an online questionnaire for an outbreak investigation

  Question 3: Write down the appropriate demographic fields that should be collected in this data capture system for the outbreak?

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Recap: Online Activity

- Section 4: Exercise

  Question 1: List 5 common advantages of using an online questionnaire for an outbreak investigation

  Question 2: List 5 common disadvantages of using an online questionnaire for an outbreak investigation

  Question 3: Write down the appropriate demographic fields that should be collected in this data capture system for the outbreak?

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Recap: Online Activity

- Section 4: Exercise

  Question 4.1: Select the most appropriate field type:

  Question 4.2: Enter an appropriate Variable Name
  - Variable name must describe the information you are trying to capture
  - Can be easily decoded when analysing data
  - Variable name shouldn't contain more than 20 characters in length, and are without any spaces or special characters.

  Question 4.3: What is the most appropriate field validation?

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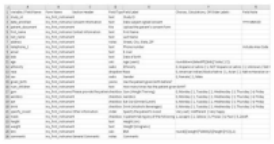
Recap: Online Activity

- Section 4: Exercise

  Question 5:
  Option 1: [venue_eaten]<>"0"
  Option 2: [venue_eaten]="1" or [venue_eaten]="2"
  Option 3: [venue_eaten]>"0"

  Question 6:
  For large changes to your database, the data dictionary is more appropriate rather than changing individual variables manually through the online designer.

  Question 7:
  The Matrix Fields allow for the same set questions coded in the same fashion to be placed in a uniform matrix. This is ideal for multiple yes/no questions such as the presence (or lack of) specific symptoms.



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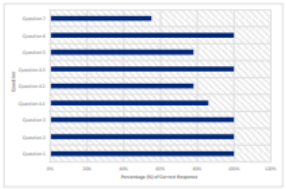
Recap: Online Activity

- Well done!
- High quality of responses were received!



15

ACT Government | ACT Health

Discussion

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Discussion

- Open Discussion
- What did you find useful?
- What would you do differently?
- You should have received an automated link for an evaluation for this presentation.
- It should only take 5-minutes to complete!

17

Discussion

- Open Discussion
- What did you find useful?
- What would you do differently?
- You should have received an automated link for an evaluation for this presentation.
- It should only take 5-minutes to complete!

18

ACT Health

Demonstration

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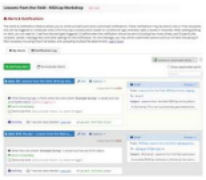
Demonstration

Creation of this online workshop activity through REDCap

- Designer view
- Reports
- Survey Distribution
- Alerts and Notifications



ACT Health

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Thank you!

For any further questions or if you would like help with REDCap database/case survey set-up, please don't hesitate in contacting me at algreg.gomez@anu.edu.au

ACT Health

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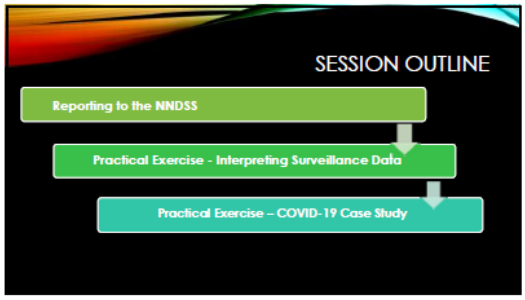
Appendix 4: Teaching Session - Presentation Slides

Topic: Surveillance of Notifiable conditions in Australia to first year MAE scholars, presented on 4 March 2021.

1

2



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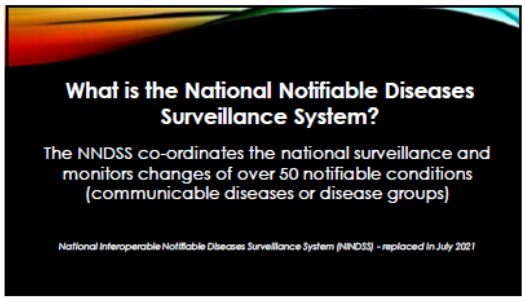

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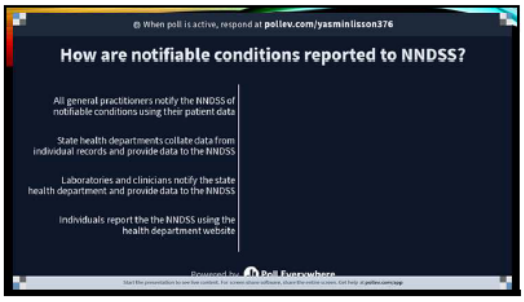

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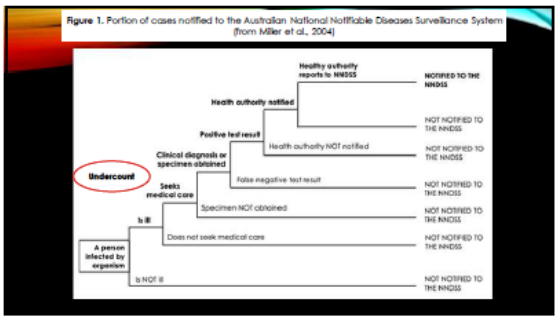
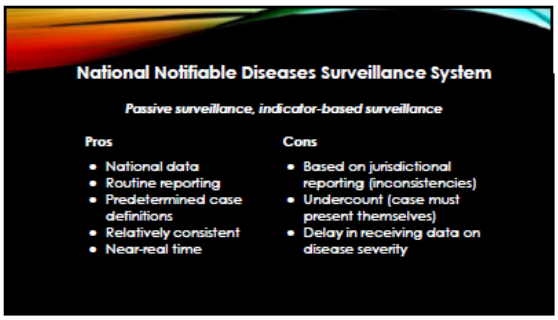


Figure 1. Portion of cases notified to the Australian National Notifiable Diseases Surveillance System (from Miller et al., 2004)
Healthy authority reports to NNDSS
NOTIFIED TO THE NNDSS
Health authority notified
NOT NOTIFIED TO THE NNDSS
Positive test result
Health authority NOT notified
NOT NOTIFIED TO THE NNDSS
Clinical diagnosis or specimen obtained
Undercount
Seeks medical care
False negative test result
NOT NOTIFIED TO THE NNDSS
Specimen NOT obtained
NOT NOTIFIED TO THE NNDSS
Is ill
Does not seek medical care
NOT NOTIFIED TO THE NNDSS
A person infected by organism
Is NOT ill
NOT NOTIFIED TO THE NNDSS

7


National Notifiable Diseases Surveillance System
Passive surveillance, indicator-based surveillance
Pros
National data
Routine reporting
Predetermined case definitions
Relatively consistent
Near-real time
Cons
Based on jurisdictional reporting (inconsistencies)
Undercount (case must present themselves)
Delay in receiving data on disease severity

8

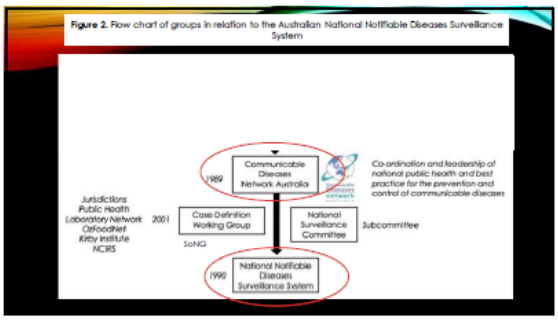


Figure 2. Flow chart of groups in relation to the Australian National Notifiable Diseases Surveillance System
Communicable Diseases Network Australia
1989
Co-ordination and leadership of national public health and best practice for the prevention and control of communicable diseases
Jurisdictions
Public Health Laboratory Network
Ozfoodnet
Kirby Institute
NCIRS
2001
Case Definition Working Group
SoNG
National Surveillance Committee
Subcommittee
1990
National Notifiable Diseases Surveillance System

9

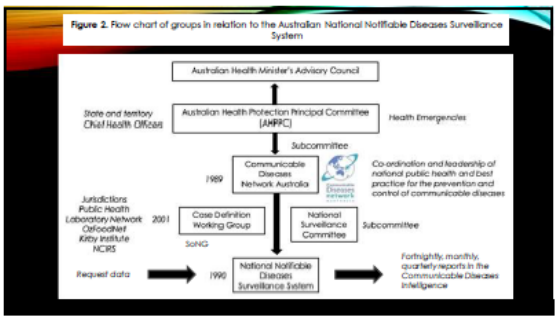
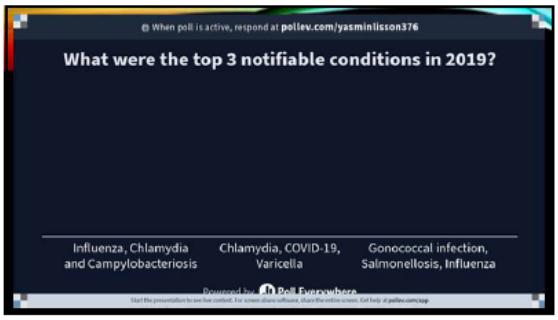


Figure 2. Flow chart of groups in relation to the Australian National Notifiable Diseases Surveillance System
Australian Health Minister's Advisory Council
State and territory Chief Health Officers
Australian Health Protection Principal Committee (AHPPC)
Health Emergencies
Subcommittee
Communicable Diseases Network Australia
1989
Co-ordination and leadership of national public health and best practice for the prevention and control of communicable diseases
Jurisdictions
Public Health Laboratory Network
Ozfoodnet
Kirby Institute
NCIRS
2001
Case Definition Working Group
SoNG
National Surveillance Committee
Subcommittee
Request data
1990
National Notifiable Diseases Surveillance System
Fortnightly, monthly, quarterly reports in the Communicable Diseases Intelligence

10


When poll is active, respond at pollev.com/yasminlisson376
What were the top 3 notifiable conditions in 2019?
Influenza, Chlamydia and Campylobacteriosis
Chlamydia, COVID-19, Varicella
Gonococcal infection, Salmonellosis, Influenza
Powered by Poll Everywhere

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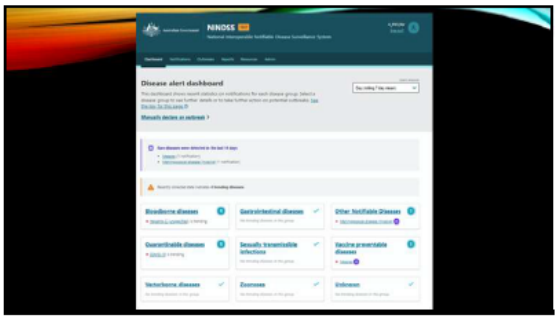
NINDSS
Disease alert dashboard

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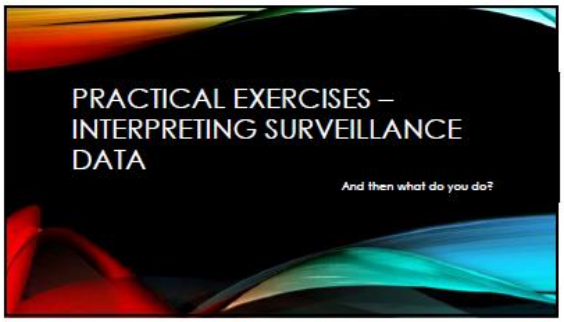

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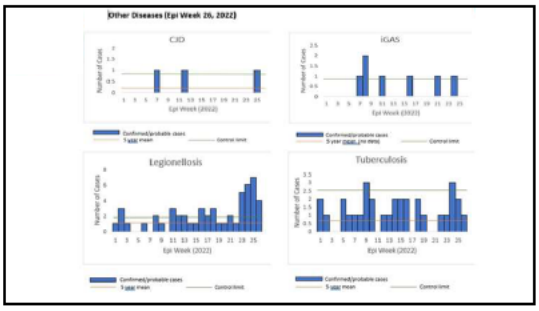
PART 1: REVIEWING THE SURVEILLANCE DATA

You are an epidemiologist working at a state government public health unit. You join your team in the conference room for your regular surveillance report review meeting.

Your supervisor draws your attention to two pages in the report.

Open the Handouts pdf on Wattle, and look at handouts A and B

19



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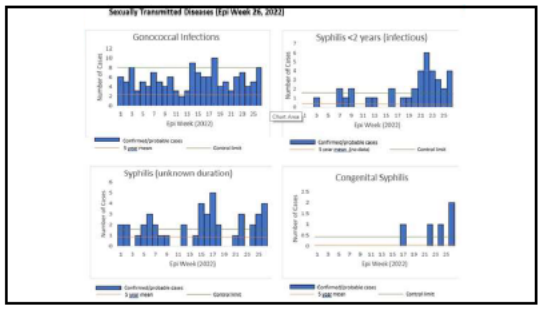

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PART 2: INTERPRET DATA AND PLAN SOME ACTIONS

Now you have identified two potential diseases flagging in your surveillance report, you need to consider what this might mean and some key actions.

Two groups will discuss legionellosis, two groups will discuss syphilis. **(10 mins)**

Hints:

- have a look at the Series of National Guidelines for each (google!)

- actions might include asking for more details about the data for your disease, planning how to get more information about cases, or coordinating certain actions

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PART 2: INTERPRET DATA AND PLAN SOME ACTIONS

Legionellosis groups – what do you need/are going to do?

Syphilis groups – what do you need/are going to do?

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PART 3: REVIEWING COVID-19 DATA

This week's surveillance meeting is a special combined meeting with the COVID-19 surveillance and response unit.

Your supervisor has notified you that there have been multiple notifications of COVID-19 cases in a Residential Aged-Care Facility (RACF).

Review the information provided in **Handout E** in your breakout rooms, and make a comment on your findings and provide suggestions for the next steps forward **(10 mins)**

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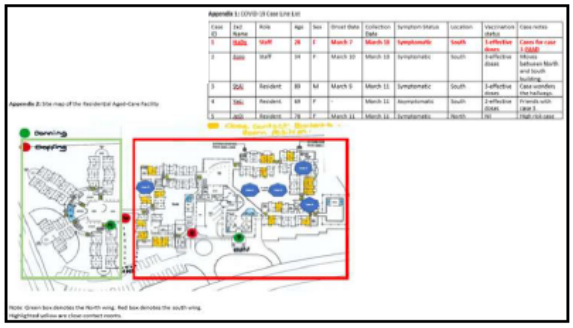

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COVID-19 IN A HIGH RISK SETTING- RESPONSES

Differences?

Similarities?

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FINAL THOUGHTS?

Please fill in our quick 2 minute evaluation SurveyMonkey:

https://www.surveymonkey.com/r/RTLNJ59

Don't worry, we'll put it in the chat!

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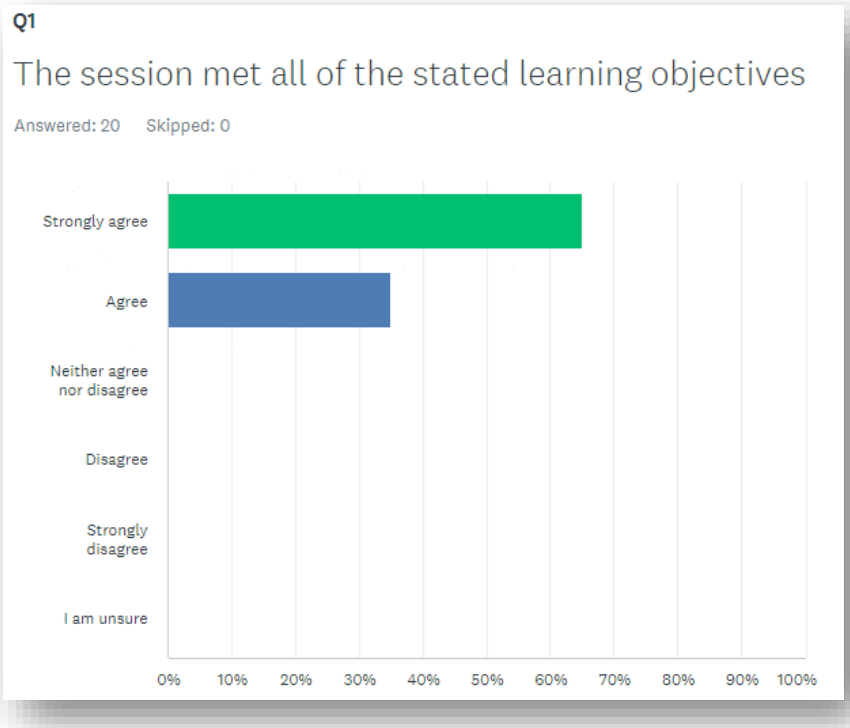
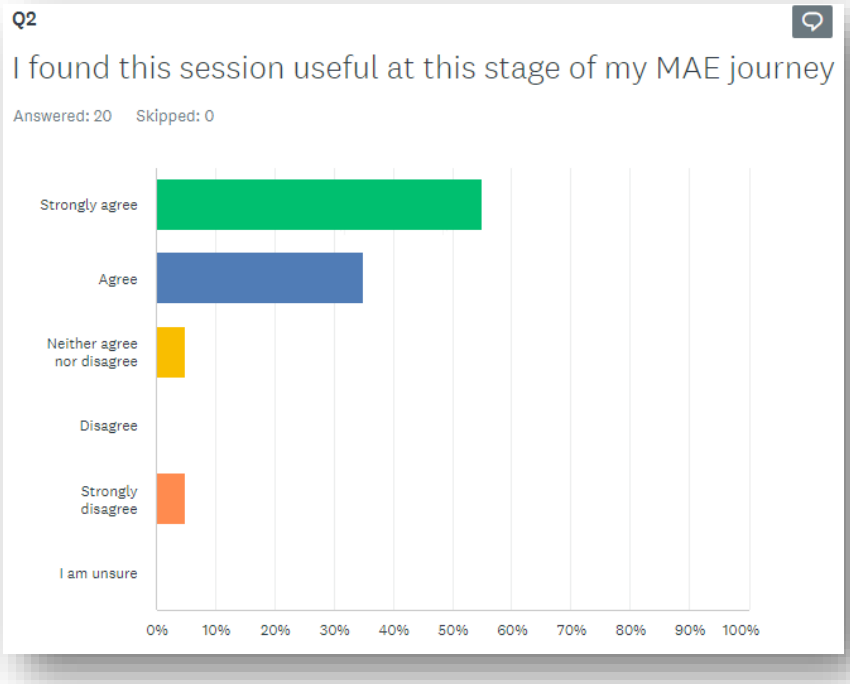
Appendix 5: Teaching Session - Evaluation Results





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Chapter VII

Summary of Other Public Health Activities and Experiences

Table of Contents

1.0 Field Epidemiology Fellowship at World Health Organization (WHO) Western Pacific Regional Offices (WPRO)

1.1 Background

On March 2022, the opportunity to participate in the Field Epidemiology Fellowship Program (FEFP) through the World Health Organization (WHO) Western Pacific Regional Offices' (WPRO). This was offered to eligible applicants that have completed their; ANU field work training, gained approval from their field and academic supervisors, and have demonstrated that the applicant was well on-track with their MAE milestones. After a highly competitive process, I was chosen as one of two successful applicants that was successful in being offered an opportunity to undertake a 7-week placement with WPRO in Manila, Philippines. This opportunity was also recognised through an MAE newsletter distributed by the National Centre for Epidemiology and Population Health (NCEPH), ANU (Appendix 1).

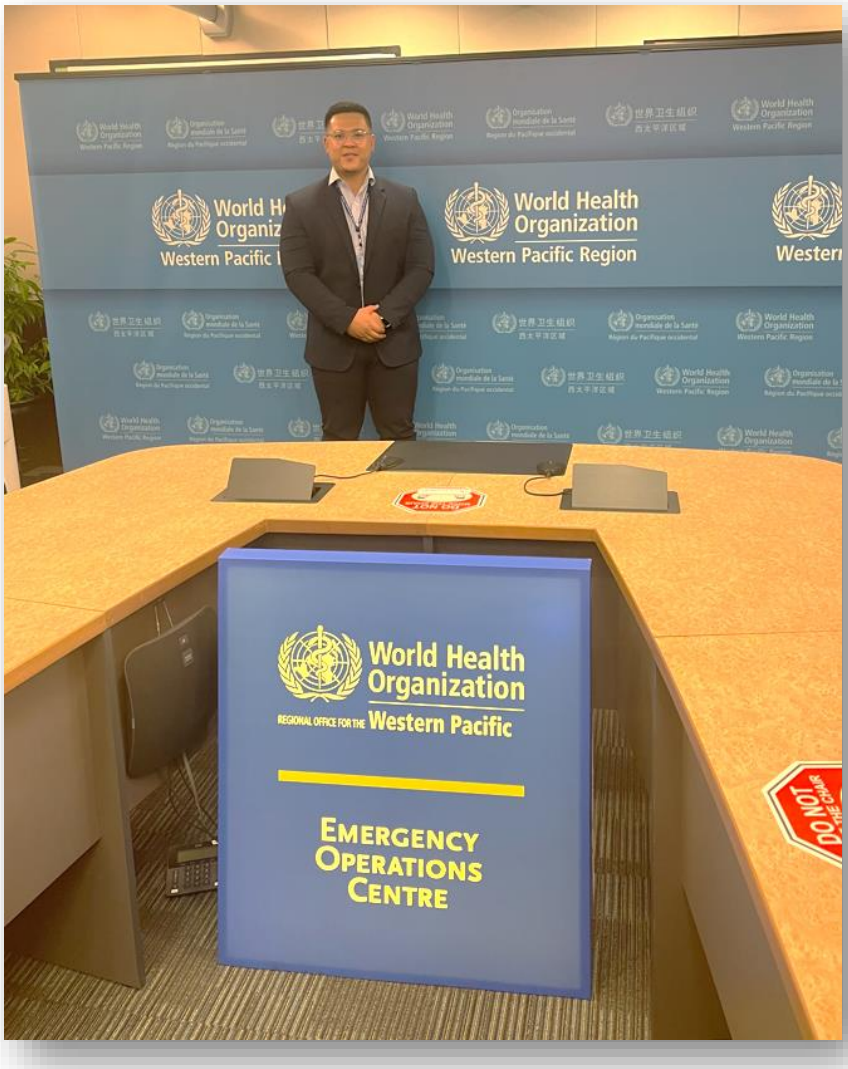
1.2 My role and lessons learned

During my time as an FEFP fellow from 14 August to 1 October 2022, I had the privilege to join and be supported by the members of Health Emergency Information and Risk Assessment (HIM) team of the WHO Health Emergencies (WHE) Programme. A briefing was conducted by each of the senior staff of the WHE, including Dr Babatunde Olowokure and Dr Tamano Matsui; whom was at the time of my placement, the Regional Emergencies Director (RED) and a Programme Area Manager (PAM) respectively. Prior to my placement, it was highlighted that an all-hazards approach was undertaken throughout all the operational tasks and requirements conducted with the HIM team. The HIM team played an important role in supporting the implementation of the International Health Regulations (2005) also known as 'the IHR', through the Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies (APSED III) and the Western Pacific Regional Framework for Action for Disaster Risk Management for Health.

In my first week, I was able to contribute to the WHO WPRO Food Safety (FOS) team for a workshop titled "Operationalizing Health Emergency and Disaster Risk Management" which was presented in Cairo, Egypt alongside colleagues from the WHO Eastern Mediterranean Regional Office (EMRO). This was a great learning experience, which occurred early on in my fellowship at WPRO. I was also able to

appreciate the respective structures and systems in place that are involved in the collection of the appropriate public health data. This further developed my understanding of the data that the HIM team collects (and manages) to inform risk assessments for major health events. I was involved in participating in routine regional meetings for the COVID-19 and Monkeypox outbreaks (Image 1). I would contribute by preparing presentation slides that would provide update on the multi-country Monkeypox situation in the Western Pacific.

Image 1: Emergency Operations Centre (EOC), Regional Office for the Western Pacific, WHO



In addition to the ongoing “on-the-field learning”, I was also invited to attend multiple scientific conferences and international meetings that involved the WHE. I was able to attend; The Global Outbreak Alert and Response Network (GOARN) partner

meeting, Fifteenth Biregional Meeting of National Influenza Centres, Second Meeting of the Western Pacific Region Emerging Molecular Pathogen Characterization Technologies (EMPaCT) Surveillance Network, Second Biregional Advocacy Meeting on Risk Mitigation in Traditional Food Markets and, Polio Outbreak Simulation Exercise which involved four member states (including Australia). I acknowledge that not all fellows have the chance to be invited or be involved in a range of international meetings and scientific conferences. I was privileged that I was offered this opportunity and was able to take and share the many lessons learnt from these conferences. This opportunity was in addition to the diverse objectives that must be met by all persons who undertake the WHO WPRO FEFP.

The first objective of the fellowship was to identify public health threat signals using various disease surveillance platforms. This objective was met by utilising Event-Based Surveillance (EBS) and Indicator-Based Surveillance (IBS) systems. Epidemic Intelligence Open Source (EIOS) was one of the main web-based surveillance system that was used to support the early detection of public health signals for the region. The EIOS initiative has one main goal, and that is to save lives and minimize the impact of emerging health threats. It was noted that this is done through supporting the quality and timely detection of potential threats. In addition to using EIOS, official and unofficial information from web sources, Ministries of Health (MoH) websites, local news agencies and social media were screened for other relevant signals. I was able to work with the HIM team to contact WHO country offices (WCO) and National Focal Points (NFP) to verify information on outbreaks and public health threats in the western pacific region. I was responsible for public health events such as an earthquake event in Papua New Guinea, flooding events in Malaysia, Acute-Gastroenteritis (AGE) outbreak in the Philippines and Super Typhoon “Noru” in the Philippines.

The second objective of the fellowship programme was to understand and demonstrate the process of risk assessment using surveillance data. I was able to contribute to the daily, weekly, and biweekly routine reports on key disease outbreaks and public health threats in the region. Specifically, I prepared a daily regional surveillance report that was distributed to internal and external WHO WPRO stakeholders, which uses signals from routine EBS and IBS screening from the HIM team. The daily report also included COVID-19 data produced by the Information and Planning team (I&P) of the Incident Management Support Team (IMST). I was also

responsible for the preparation and distribution of weekly Avian Influenza (AI), biweekly dengue and seasonal influenza reports. This was in addition to managing signals and respective events that were either presented during daily morning meetings or WHE division-wide meetings. I was also involved in the IMST to respond to the multi-country monkeypox outbreak. One of my main projects was to develop a presentation on the decline of case numbers in the European region using a hypothesis-driven approach. This project informed my final objective as described below.

Image 2: Front Garden and Assembly Hall with the Member States' flags, Regional Office for the Western Pacific, WHO

The third objective of my fellowship was to prepare and conduct a final presentation on a topic within the region. The aim was to use official and unofficial resources, such as relevant guidelines, protocols, accessible national surveillance data to present a topic of choice that was appropriate the WHE and my home country. I was supported by being provided in-depth and timely feedback on the task at hand. I was able to present a presentation that aim to answer the question of "Why there was an increase in excess mortality in Australia in early 2022?". I was able to use an "All-Cause Mortality (ACM) tool", an online dashboard that uses up-to-date mortality data from respective Member States in the region. The dashboard used a negative binomial regression model developed by WPRO to provide information on mortality trends in

an Australian context. This project highlighted the importance and use of this tool, and how it can have a place in guiding policy and guidance for Member States. The final presentation was presented in the WHE weekly meeting on Tuesday 27 September 2022, with the attendees asking relevant questions to the topic and initiated thoughtful discussions. My presentation was also used as an important resource by the I&P team, whereby my suggested recommendations and action points was utilised to inform further preparedness planning and research for the team. After returning from the fellowship program, I was also asked to prepare a presentation to the COVID-19 Response Branch about my experience and lessons learned during my time with WHE WHO (Appendix 2).

Acknowledgements

I would like to acknowledge the HIM Team, WHE and all the individuals I had the privilege to work with at WPRO WHO during my time as a FEFP fellow in Manila, Philippines. These individuals are as follows; Dr Tamano Matsui, Dr Sangjun Moon, Dr Manilay Phenxay, Dr Viema Biakula, Laura Goddard, Jozica Skufca, Jessica Kayamori, Frida Sparaciari, Alfonso Vargas and Kareena Hundall.

I would like to give thanks to Meg Dalmau, who was the second scholar to be awarded the fellowship who undertook their placement after my time at WPRO. I enjoyed communicating my challenges and highlights during my experience with the fellowship program with Meg so that she could also be prepared with her placement. Yasmin Lisson and Aruna Phabmixay were also two people that were very supportive from the outset, from the time I first received the formal offer for the fellowship through to when I returned to Canberra. I really value your words of affirmation and lifting me up during such a challenging time trying to juggle MAE commitments during my time in Manila. Additionally, I would like to thank Tony Stewart, Emma Field and Amy Parry for the support and helping me with the logistics of getting to the field placement in Manila, Philippines. I would also like to acknowledge my field and academic supervisors; Tim Sloan-Gardner, Rebecca Hundy and Matthew Kelly, ASEAN-Australia Health Security Fellowship Program, NCEPH and ACT Health Directorate (ACTHD) for supporting my fellowship.

2.0 Large Foodborne Outbreak in the ACT

2.1 Background

An Acute Response Team (ART) and an outbreak investigation was initiated after instances of gastrointestinal illness from patrons who consumed products from a donut shop in Canberra was reported to Health Protection Services (HPS), ACTHD in late November 2021. I was requested to help the team due to the increase in food complaints and notifications associated to the event. This public health threat was managed by the team at Communicable Disease Control (CDC) section, HPS. After the outbreak investigation ceased, the full epidemiological investigation was developed into a manuscript that was published by a fellow MAE scholar. It was the one of the largest foodborne outbreak investigations in the history of HPS, ACTHD.

2.2 My role and lessons learned

The CDC section of HPS reached out to me as the team was getting overwhelmed regarding the volume of notifications and follow-up required for the outbreak investigation. I was initially involved in the public follow up of probable cases in the outbreak to collect epidemiological information such as potential environmental and food exposures prior to becoming ill. Due to my expertise in automated surveys, the team requested help in developing a case questionnaire that would capture the relevant food history of all complainants. This was instrumental in reducing the time for data collection. The CDC section was able to then analyse the response through the online questionnaire and inform the daily situation report and report to the ART.

This outbreak investigation gave me an opportunity to work with a different team within ACTHD, namely the CDC section. I was able to sharpen my skills regarding phone case interviews and asking a different set of questions compared to COVID-19 contact tracing. I have learnt a tremendous number of skills working with ACT Government Analytical Laboratory (ACTGAL) regarding the environmental health and laboratory investigation aspect of the outbreak investigation. This further consolidated my understanding of the concepts and steps of an outbreak investigation (which was delivered in Course Block 1, 2021 at the beginning of my candidature) as I was involved in the ART throughout the full investigation. This also provided opportunities for me to conduct food business inspections with the Food Business team which allowed me to get a better understanding of how food sampling was conducted in the

ACT. The team voiced their appreciation that I was able help them, even though I was involved in the investigation and management of multiple COVID-19 outbreaks at the same time. The epidemiological investigation found that the single incident was related to one food business and did not pose further risks to the public. The epidemiological analysis and write up was led by another fellow MAE scholar.

Acknowledgements

I would like to acknowledge Nevada Pingault, Jenny Post, Felicity Greenville, and Maggie Wilson, including the broader team of the CDC section. I would also like to acknowledge the Lyndall Hudson and the Food Business team from the Environmental Health section; and microbiologists from the ACTGAL team who were all involved and contributed to the acute response to this incidence.

3.0 Data analysis of multiple episodes of SARS-CoV-2 infection in the Australian Capital Territory

3.1 Background

Between February and March 2022, global studies suggested that there was an increase instances of reinfection of SARS-CoV-2 due to the spread of the B.1.1.529 lineage, Omicron B.1 subvariant. At the time, the ACT had one of the highest ratios of specimen sample processed through WGS by population compared with any other Australian jurisdiction. Since we had a person-centric disease management system, we could detect multiple episodes of SARS-CoV-2 infection for an individual based on the national definition outlined by the Series of National Guidelines (SoNG) for public health units. We also had a robust system, whereby we could track instances of SARS-CoV-2 infection and their respective hospitalisation status. During this time, experts from the Communicable Diseases Network Australia (CDNA) requested if ACTHD could conduct a rapid analysis on the topic of reinfections. Due to this emerging issue, the Epidemiology team conducted a research project that was aimed to inform respective public health guidance.

3.2 My role and lessons learned

My field supervisor suggested that it would be beneficial for me to have more of a supervisor role for this research project. I worked closely with the public health officers of the Epidemiology team within the COVID-19 Response Branch, namely, Victoria Marriott and Josie Jones, to extract, clean, analyse and interpret the dataset. I was required to understand how much time was needed to complete the project, as I was responsible for ensuring that we met key deadlines. I believe that this was a skill that I have developed throughout my MAE candidature. Strong time management skills were key in ensuring that each of deadlines were achieved. It required that I set out measurable and achievable objectives for the team and set out clear expectations from each of the project officers. This was in addition to the routine and ad-hoc tasks that the team had already committed to. Once we had a clean dataset, we conducted a rapid analysis whereby the preliminary findings were shared with key stakeholders (including the modelling team) to inform guidance relevant to the public health response.

As per the recommendations and clearance of our supervisor, senior executives, and ACT Chief Health Officer (CHO), we aimed to share our findings to a broader scientific audience. This research project was presented at the Canberra Health Annual Research Meeting (CHARM), which was held virtually between 26-29 July 2022 (presentation slides attached in Appendix 3). The conference was hosted by the Centre for Health and Medical Research, ACTHD and Canberra Health Services (CHS). Our presentation was chaired by the CHO, and she highlighted the importance of such a rapid and comprehensive research in such as fast-moving world of COVID-19 research. We also intend to submit this research project into a scientific journal This was an important and highly valued piece of research produced by the project team.

Acknowledgements

I would like to acknowledge the Epidemiology team, specifically; Tim Sloan-Gardner, Victoria Marriott, and Josie Jones. I would also like to thank the Case Investigation team, and Mric Gomez who conducted the formal data validation process for this project. The project team would also like to thank the Centre for Health and Medical Research, ACTHD and CHS for organising CHARM2022 conference.

4.0 COVID-19 in childcare: Evidence of spread and effective preventative measures to limit SARS-CoV-2 Delta transmission

4.1 Background

On 12 August 2021, the first local COVID-19 case was detected in the ACT which initiated a rapid and organised response by the Health Emergency Control Centre (HECC) to the public health threat. The Epidemiology team of the COVID-19 Response Branch was supported by other epidemiologist and public health officers and specialists from CDC HPS, NCEPH, ANU and the Australian Government Department of Health and Aged Care.

During the COVID-19 Delta variant outbreak from August to late November 2021, the Epidemiology team undertook more than sixty cluster outbreak investigations. The education sector; where many early childhood education and care centres (ECEC), primary and secondary schools were one of the main sectors that was affected by COVID-19 exposures in the ACT. In addition to the collection of enhanced epidemiological information through case interviews and contact tracing, the COVID-19 Response Branch and respective response teams were able to engage public health laboratories and experts from the ANU to increase capacity for Whole Genome Sequencing (WGS) analysis. This was crucial in supporting informed public health action during the peak of the COVID-19 Delta variant outbreak in the ACT.

4.2 My role and lessons learned

The Epidemiology team within the COVID-19 Response Branch was required to be agile in their response to the emerging situation. Since this was my primary field placement, I took responsibility in ensuring that the epidemiologist and public health officers who joined the team was appropriately onboarded and were across the systems, processes, and structures in place. Yasmin Lisson, a fellow MAE2021 scholar, based with the Australian Government Department of Health and Aged-Care was one of the individuals that helped the Epidemiology team. Prior to this, I was leading the majority of COVID-19 outbreak investigations with the help of other public health officers in the team. After initially conducting the outbreak investigation for one ECEC, senior staff and supervisors proposed that Yasmin could undertake the full investigation of one cluster that I was investigating to meet one of her MAE core requirements. I was able to successfully hand over the progress and relevant

documents to her, in which I supported her throughout until the outbreak investigation ceased. She was able to convert her overall work into an advance manuscript, which was submitted to Communicable Diseases Intelligence (CDI) journal and was able to present her work at a national conference at the Communicable Disease and Immunisation Conference (CDIC2022) in Sydney, Australia.

I was able to support Yasmin with her outbreak investigation, along with the formulation of the respective advanced draft of the research manuscript. As part of the original Epidemiology team, I was comfortable in leading most of the outbreak investigations with the support of other public health officers. This whole process allowed me to have a different perspective on conducting an outbreak investigation and project management. I was able to have a more of a team lead role whilst supporting Yasmin with her work. Although I found this beneficial in terms of developing my higher-level management skills, I have learnt that there is also a fine balance between reviewing someone else's work without taking over their writing style or impeding the flow of information. I believe that my experience during the peak of COVID-19 outbreak in August-September 2022 would not have been the same without the support Yasmin, Aruna and Anna, along with the other knowledgeable epidemiologist from the Australian Government Department of Health and Ageing. These lessons learnt in developing my management and leadership skills were also highlighted in the previous section (**section 3.0**) of this chapter.

Acknowledgements

I would like to acknowledge Yasmin Lisson, for leading the outbreak investigation and research project. As mentioned above, I would also like to acknowledge Aruna Phabmixay and Anna Rafferty for their efforts helping the Epidemiology team, COVID-19 Response Branch during the Delta wave in August 2021. I would like to acknowledge the research team; Alexandra Marmor, Aparna Lal, Amy Parry, Robyn Hall and Rose Wright who all contributed to the final manuscript. I would like to make a special mention to Sue Reid and Jodie Huet, team leaders of the Case Investigation team, who were crucial to the response for many COVID-19 outbreaks in the ACT. I would like to acknowledge Mric Gomez for his work on validating immunisation history for this project.

5.0 Appendices

Appendix 1: MAE Newsletter, Australian National University, 29 August 2022

Australian National University

National Centre for Epidemiology and Population Health

MAE Newsletter

August 2022

WHO fellowships for MAE Alumni Algreg Gomez

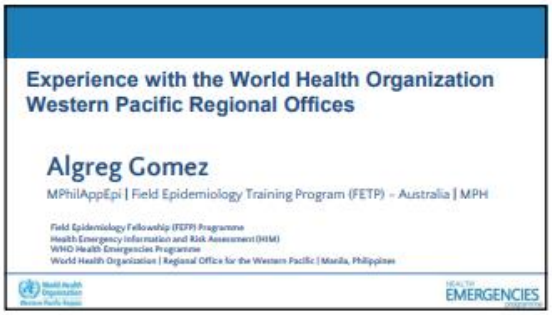
Congratulations to Al Gomez (MAE 2021) for being awarded a fellowship opportunity with the World Health Organization, Philippines.

Al will spend the next few months in Manila with the WHO to further develop his skills as an applied epidemiologist. Al has already been working as an epidemiologist at ACT Health and has been assisting the Canberra community since the start of the pandemic.

'It's been a challenging few years for Canberrans and like everyone else, I'm quite tired. But working in a public health emergency to help our community, whilst combining my interest in studying infectious diseases has made it worthwhile,' says Al.

'It's great to also see epidemiology and what epidemiologists do being highlighted – and I'm very proud of the work we do.'

Appendix 2: Presentation slides for "Education Sessions", COVID-19 Response Branch, ACTHD, 18 October 2022



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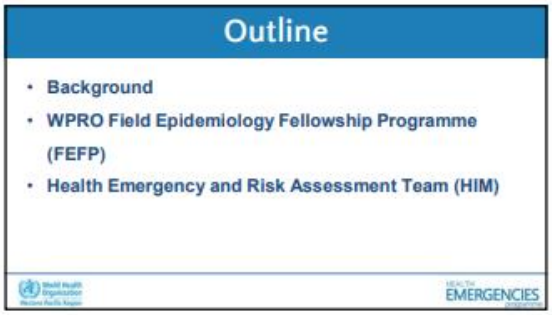

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Background

WPRO Field Epidemiology Fellowship Programme (FEFP)

- Aim to strengthen countries' capacities for surveillance and risk assessment,
- Build a workforce to tackle public health emergencies,
- Contribute to and improve WHO's regional and global event-based surveillance and response systems,
- Establish a regional network of Programme alumni to facilitate information sharing and collaboration to enhance health security

- **Targeted at/for public health professionals, specifically Field Epidemiology Training Program (FETP) trainees.**

7

Background

Master of Philosophy in Applied Epidemiology (MAE Program), the Australian National University (ANU)

- 22-month program that trains public health leaders of the future.
- The MAE program is Australia's only Field Epidemiology Training Program (FETP).
- The National Centre for Epidemiology and Population Health has run the MAE program since 1991.

Australian National University

8

Date: DD MM YYYY

9

Date: DD MM YYYY

10

Background

WHO Health Emergencies Programme (WHE)

To rapidly detect, respond to and recover from any emergency health threat.

The Programme aims to minimize the health consequences of outbreaks and emergencies by:

- **Ensuring WHO's work in emergencies is effectively managed, sustainably financed, adequately staffed and operationally ready to fulfil its mission.**

11

Background

Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies (APSED III)

- Working with the **APSED III** framework, the Regional Fellowship Programme is effective for training future leaders in field epidemiology to respond to health emergencies and strengthen national and regional capacities.

12

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13

Background: APSED III

14

Background: APSED III

Focus areas

Focus area 1: Public health emergency preparedness
Focus area 2: Surveillance, risk assessment and response
Focus area 3: Laboratories
Focus area 4: Zoonoses
Focus area 5: Prevention through health care
Focus area 6: Risk communication
Focus area 7: Regional preparedness, alert and response
Focus area 8: Monitoring and evaluation

15

Background: IHR 2005

The **International Health Regulation ("the IHR" or "Regulations")** were adopted by the Health Assembly in 1969.

The purpose:
"to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade"

16

Background: IHR 2005

Annex 2
Decision Instrument for the Assessment and Notification of Events that may Constitute a Public Health Emergency of International Concern

17

Background: IHR 2005

I. **Is the number of cases and/or number of deaths for this type of event large for the given place, time or population?**
II. **Is the event unusual or unexpected?**
III. **Is the Public Health Impact of the event serious?**
IV. **Is there a significant risk of international spread or trade restriction?**

State Parties that answer "yes" to the question whether the event meets any two of the four criteria (I-IV) WHO under Article 6 of the International Health Regulations.

18

Field Epidemiology: Core Concepts

19

Public Health Surveillance

The ongoing, systematic collection, analysis, and interpretation of health-related data essential to planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those responsible for prevention and control.

20

Types of Surveillance Systems

21

Detection of Unusual Events

Event based surveillance (EBS)

- Organized and rapid capture of information about events that are a potential risk to public health. This information can be in the form of rumors, ad-hoc reports, and (social) media. EBS is normally complementary to the formalized surveillance systems.
- Advantages: often faster, easier to establish, also unknown diseases.

Indicator based Surveillance (IBS)

- Reports of specific diseases from health care providers to public health officials. Such information may be described as structured information because the information obtained is standardized.

22

Detection of Unusual Events

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Indicator based Surveillance (IBS)

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23

	Event-based Surveillance	Indicator-based Surveillance
Objectives	Detect Outbreaks	Detect outbreaks, define disease trends, seasonality, burden, risk factors
Information sources	Official and unofficial reports of potential disease events from a wide variety of sources including media, rumors, blogs, community members, etc.	Reports of cases of diseases from health care providers, including physicians and hospital laboratories
Information credibility	Reports need verification to ensure cases meet a specific case definition, and are most credible when supported by laboratory confirmation	Reports are usually credible because health care providers are motivated to only report cases that meet specific case definitions, but the most credible reports involve laboratory-confirmed cases
Timeliness	May be reported early, even before ill persons have sought medical attention	Reported by health care provider after ill persons have sought medical attention, may sometimes be delayed while awaiting laboratory confirmation or due to reporting requirements
Where is it used?	Can be used anywhere	Where health infrastructure exists and health care providers and laboratories are willing to participate in public health surveillance
What diseases is it used for?	All public health events involving potential disease, including events caused by unknown disease	Usually known diseases

Source: Centers for Disease Control and Prevention

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Field Epidemiology: Core Concepts

Public health surveillance is an essential component of WHO's role in health emergencies;

→ Enabling the early detection,

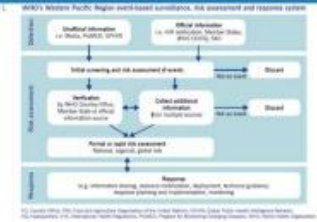
→ Assessment and response to public health events,

Whether their impact is at the national, regional or global level.

Source: WPSAR Vol 11, No 2, 2020

25

EBS Screening Process



Source: WPSAR Vol 11, No 2, 2020

26

Surveillance and Response Function

Source: WPSAR Vol 11, No 2, 2020

27

Epidemic Intelligence (EI)

EI is defined as the systematic collection, analysis and communication of any information to detect, verify, assess, and investigate events and health risks with an early warning objective (as opposed to monitoring of disease trends or burdens).

Source: The EIOS system - WHO

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Epidemic Intelligence from Open Sources (EIOS)

About EIOS

A system that brings together new and existing initiatives, networks and systems to create a unified all-hazards, One Health approach to early detection, verification, assessment and communication of public health threats using publicly available information.

Source: The EIOS system - WHO

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Epidemic Intelligence from Open Sources (EIOS)

Source: The EIOS system - WHO

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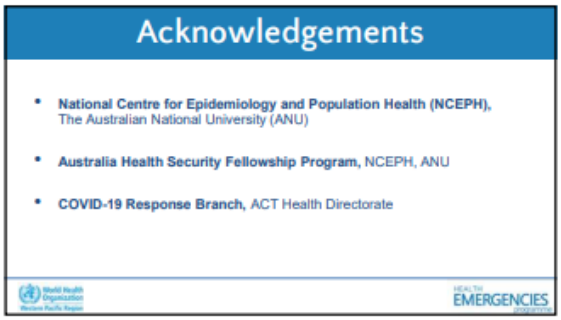
Acknowledgements
National Centre for Epidemiology and Population Health (NCEPH), The Australian National University (ANU)
Australia Health Security Fellowship Program, NCEPH, ANU
COVID-19 Response Branch, ACT Health Directorate
EMERGENCIES

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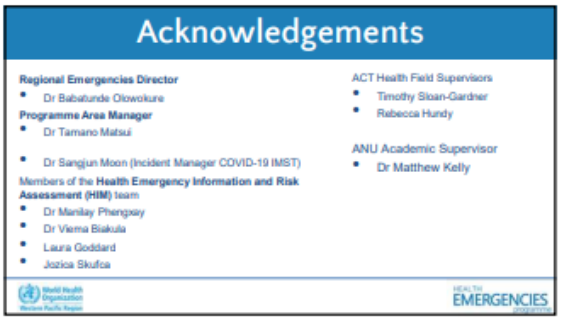
Acknowledgements
Regional Emergencies Director
Dr Babatunde Olowokure
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Members of the Health Emergency Information and Risk Assessment (HIM) team
Dr Maniiay Phengsay
Dr Vierna Biakula
Laura Goddard
Jozica Skufca
ACT Health Field Supervisors
Timothy Sloan-Gardner
Rebecca Hundy
ANU Academic Supervisor
Dr Matthew Kelly
EMERGENCIES

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Appendix 3: Presentation slides for the Canberra Health Annual Research Meeting (CHARM2022), 26-29 July 2022

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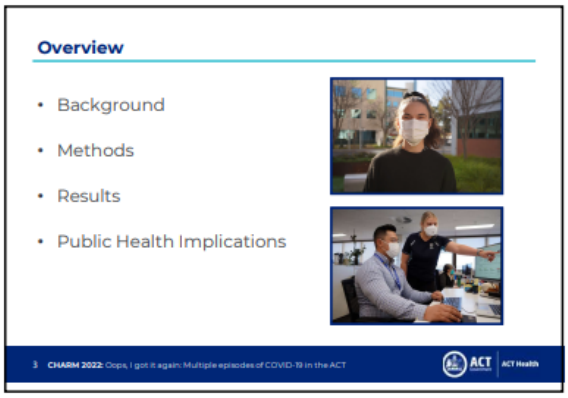

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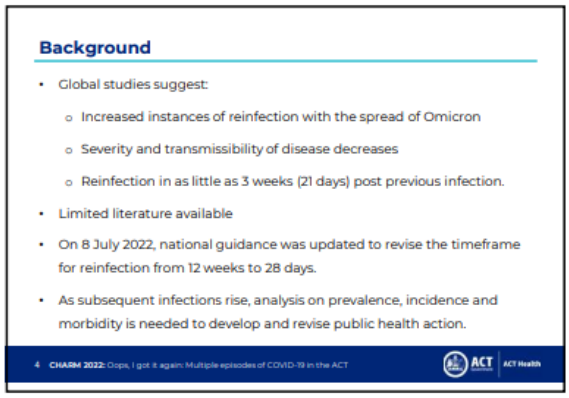

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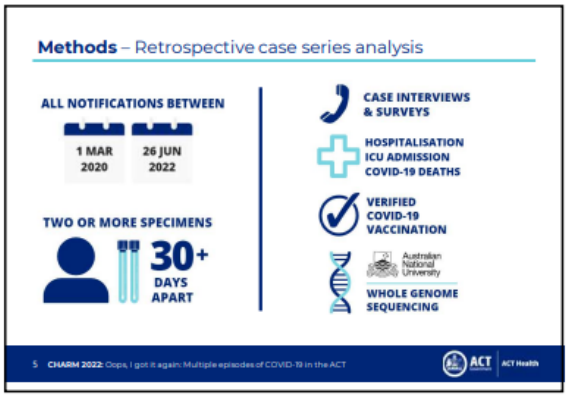

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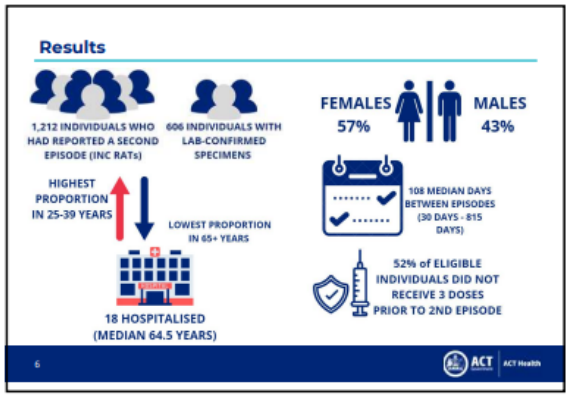

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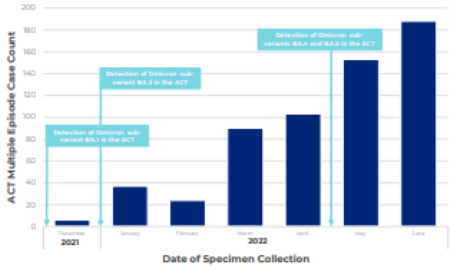
Results



7

Public Health Implications

SUPPORT CURRENT NATIONAL GUIDANCE

28+ DAYS

IMPROVE REINFECTION AWARENESS

TARGET POST-INFECTION VACCINATION

8

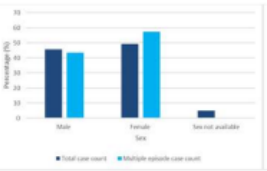
Acknowledgements

- Public Health Emergency Coordination Centre (PHECC), ACT Health Directorate.
- Clinical Health Emergency Coordination Centre (CHECC), ACT Health Directorate.
- Laboratory staff involved in the testing of specimens and reporting of results.
- The Schwessinger Laboratory, the Australian National University (ANU).

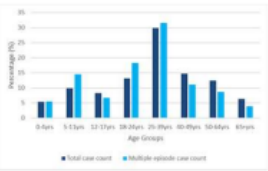
No specific funding was received for this project beyond the salary support from authors received from their institutions or elsewhere.

9

ACT TOTAL CASE COUNT VS MULTIPLE EPISODES CASE COUNT, BY SEX, AS OF 26 JUNE 2022

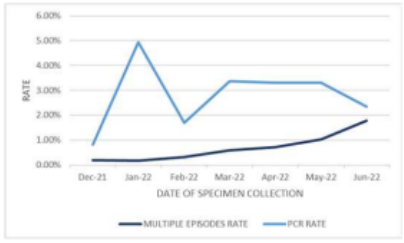


ACT TOTAL CASE COUNT VS MULTIPLE EPISODES CASE COUNT, BY AGE GROUPS, AS OF 26 JUNE 2022



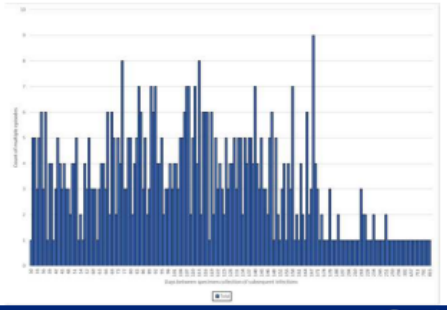
10

ACT PCR RATE VS MULTIPLE EPISODES RATE, BY MONTH OF SPECIMEN COLLECTION, AS OF 26 JUNE 2022



11

DAYS BETWEEN SPECIMEN COLLECTION DATES



12

“In the realm of epidemiology, where data meets diligence, our program became a hub of resilience, banter and camaraderie. The pandemic might have tested our limits, but it was also the backdrop for unforgettable moments, forging friendships as strong as any scientific discovery.”

MAE2021 cohort at the National Centre for Epidemiology and Population Health, Australian National University, Canberra, Australia, March 2022

Back row: Algreg Gomez, Yasmin Lisson, Kirsty Nichols, Josh Montgomery, Aidan Yuen, Connie Slater and Justine Marshall. Middle row: Keeley Allen, Erin Flynn, Meg Dalmau and Hayley Dyke. Front row: Anna Rafferty, Zoe Joo, Aruna Phabmixay, Natasha Egoroff, Jane McAllister and Leonie Williamson.

[End of thesis]