An MAE in the time of COVID-19

A thesis submitted for the degree of
Master of Philosophy in Applied Epidemiology
at 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 previously published or written by another person, or substantial proportions of material which have been accepted for the award of any other degree or diploma at the Australian National University or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to the research by others is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation or linguistic expression is acknowledged.

Stephanie Curtis

October 2021

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I wish to acknowledge my field supervisor's Associate Professor Andrew Stewardson and Professor Mark Stoové for their flexibility, support and guidance. I would also like to acknowledge my academic supervisor Professor Colleen Lau for providing opportunities to learn and collaborate, and for sound advice through all projects.

To the team at the Department of Infectious Diseases, thanks for your friendship and support before and during the MAE. To all at the Burnet Institute, thanks for warm welcome. I am grateful for the Health Protection Branch at the Victorian Department of Health and Human Services for the opportunity to be a part of the COVID-19 response. I am also grateful for everyone's hard work through a stressful, rapidly changing and sleep-deprived pandemic. To the Australian Medical Assistance Team, thanks for the fieldwork opportunity and hospitality. This experience was a highlight, and the operation at Howard Springs was remarkable.

To the MAE 2020 cohort, thanks for the good times at course block one and for making subsequent months of Zoom bearable. Notably, thanks to the Tomato Team for supporting each other to get over the line in late 2021, especially Fran Sheehan for being the ultimate friend and fox from start to finish.

Above all, I wish to thank my family and friends, especially my partner Dan, for always supporting me through my career endeavours and to get through life in lockdown.

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Abstract

In this thesis, I present the key projects and experiences that enabled me to fulfill the requirements of the MAE at the Australian National University. During my candidature from February 2020 to December 2021, I was based in Melbourne at the Department of Infectious Diseases at Alfred Health, and the Public Health Discipline at the Burnet Institute.

My field placement activities commenced with a focus on COVID-19, through a secondment to the Victorian Department of Health at Human Services. During the secondment, I was a part of several aspects of outbreak investigation and response, including the implementation of an enhanced surveillance system on hospitalisations with COVID-19, which I later evaluated.

I embarked on several projects that were unable to be completed, and touch on these setbacks in this thesis. In the end, I completed an epidemiological project based at the Alfred Hospital that investigated proximity networks of healthcare workers to quantify and mitigate the risk of COVID-19 transmission in a hospital setting. Additionally, I analysed the performance of International Classification of Diseases codes for identifying injection-related infections in people who inject drugs, and analysed hospital admission trends and outcomes of the cohort at the Alfred Hospital.

The MAE provided the opportunity for a variety of additional field and teaching experiences. The highlight was fieldwork at the Howard Springs International Quarantine Facility at the Centre for National Resilience in the Northern Territory. This thesis provides a comprehensive overview of my key projects and experiences, including lessons learnt along the way.

Acronyms and abbreviations

AIHW	Australian Institute of Health and Welfare
AMR	Antimicrobial resistance
ANZICS	Australian and New Zealand Intensive Care Society
BLE	Bluetooth Low Energy
CDNA	Communicable Disease Network Australia
CHO	Chief Health Officer
CHRIS	Critical Health Resource Information System
CNR	Centre for National Resilience
COVID-19	Coronavirus disease
DART	Data and Reporting Team
DHHS	Department of Health and Human Services
DID	Department of Infectious Diseases
DIMT	Departmental Incident Management Team
FluCAN	Influenza Complications Alert Network
HAI	Hospital-acquired infections
HCW	Healthcare worker
HSIQF	Howard Springs International Quarantine Facility
ICD	International Classification of Diseases
ICU	Intensive Care Unit
IPC	Infection Prevention Control
IQR	Interquartile range
IRI	Injection-Related Infection
LoRa	Long-range data transmission
MAE	Master of Philosophy (Applied Epidemiology)
NCCTRC	National Critical Care and Trauma Response Centre
NNDSS	National Notifiable Diseases Surveillance System
NPI	Non-Pharmaceutical Intervention
OMT	Outbreak Management Team
PCR	Polymerase Chain Reaction
PHESS	Public Health Event Surveillance System

PPE	Personal Protective Equipment
PPV	Positive Predictive Value
QR	Quick Response
RACF	Residential Aged Care Facility
REDCap	Research Electronic Data Capture
RFID	Radiofrequency identification
RHPEM	Regulation, Health Protection and Emergency Management
RTLS	Real-time location systems
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SCV	Safer Care Victoria
SoNGs	Series of National Guidelines
SOP	Standard Operating Procedure
SPRINT-SARI	Short PeRiod IncideNce sTudy of Severe Acute Respiratory Infection
SSTI	Skin and Soft Tissues Infections
VAHI	Victorian Agency of Health Information
VICNISS	Victorian Healthcare Associated Infection Surveillance System
WHO	World Health Organization

Chapter 1: Overview of projects

Introduction

My field placement for the MAE was at the Department of Infectious Diseases (DID) at Alfred Health, and the Public Health Discipline at the Burnet Institute. The two institutions work alongside each other and share the same building in Melbourne.

The DID is part of the Infectious Diseases Unit at Alfred Health and the Central Clinical School at Monash University. This DID integrate clinical services with research and teaching, which enabled me to work with colleagues from diverse backgrounds, from Bioinformatics to Infection Prevention and Control. There are nine main research groups at the DID, and I was based in the Antimicrobial Resistance (AMR) and Healthcare-Associated Infections (HAI) group. My field supervisor was Associate Professor Andrew Stewardson, an Infectious Diseases Physician and National Health and Medical Research Council Early Career Fellow. Andrew regularly collaborates with the Burnet Institute's Health Security group for projects relating to AMR in the Asia-Pacific.

The Burnet Institute is a not-for-profit which combines medical research with practical action to address global health problems. The Burnet Institute has five thematic programs, and three disciplines of expertise. I was based in the Behaviours and Health Risks program and Public Health Discipline, and my field supervisor was Professor Mark Stoové, Head of Public Health, Head of Justice Health Research Group, co-Head of the HIV Elimination Program and Senior Research Fellow. Mark's research focuses on the transmission and impact of sexually transmitted and blood borne viruses among risk populations.

Andrew and Mark provided many opportunities throughout the MAE, including a secondment to the Victorian Department of Health and Human Services (DHHS). In February 2020, before commencing my field placement officially, the DHHS Health Protection Branch requested assistance with the response to the emerging coronavirus disease (COVID-19) pandemic. Therefore, I was seconded from March to June 2020 to assist with the response.

A pandemic was a unique way to commence my training as a field epidemiologist. At the DHHS I worked with and learnt from experienced epidemiologists. I was a part of several aspects of outbreak investigation and response that are presented in Chapter 2. This includes working in the day-to-day activities of the team, completion of ad-hoc reports including an initial evaluation of the State and National physical distancing measures, and investigation of COVID-19 outbreaks. During my time at the DHHS, I further led the implementation of enhanced surveillance on hospitalisations with COVID-19. I subsequently evaluated this surveillance system, which is presented in Chapter 3.

I embarked on two epidemiological projects during the MAE. Firstly, in response to the global threat of AMR and the unknown burden in the Pacific region, I planned a point prevalence survey on HAIs and antimicrobial use at Port Moresby General Hospital in Papua New Guinea. My findings were intended to inform the infection prevention and control program; however, this project was not feasible within the MAE timeframe. In late 2021, we continued to plan the implementation of this study, and I hope that in a post-pandemic era, this project will be completed. The second epidemiology project was a contact network study of proximity networks of healthcare workers at the Alfred Hospital. This project was conceptualised in response to the issue of healthcare worker infection with COVID-19 and limitations of traditional contact tracing methods. The project involved collaboration with the Department of Electrical and Computer Systems Engineering at Monash University to design and trial a Bluetooth Low Energy system for data collection. My involvement in this study is presented in Chapter 4.

I also embarked on two data analysis projects. Firstly, I investigated emergency department presentations and hospital admissions with injection-related infections (IRIs) in a cohort of people who inject drugs in Victoria through use of cohort data linked with state-wide and national datasets. I commenced this project thinking that it would be simple, even amongst the chaos of the COVID-19 pandemic. However, due to security requirements, the data were only accessible onsite at a secure location in Melbourne, which was not available in times of stay-at-home directions from the State Government of Victoria. Unfortunately, I was close to completion of this project in July 2021, when the Victorian COVID-19 situation escalated again, leaving me unable to complete the original project on time. Therefore, I adapted to

complete a similar project of smaller scope on the same topic. I performed a single site analysis of the positive predictive values of International Classification of Diseases (ICD) codes to identify current injecting drug use and IRIs, the used high performing codes to describe the trends and outcomes of people who inject drugs with an IRI at the Alfred Hospital from 2008 to 2020. This project is presented in Chapter 5.

Finally, the MAE provided a variety of additional field experiences. Chapter 6 presents my teaching experience to the first year MAE Scholars and teaching lessons from the field to the MAE 2020 cohort. Chapter 7 demonstrates my involvement in additional activities, including involvement in Professor Lau's project 'CRISPER: COVID-19 Real-time Information System for Preparedness and Epidemic Response', ongoing employment with the DHHS following the secondment, and fieldwork to the Howard Springs International Quarantine Facility at the Centre for National Resilience.

Core Competencies

The MAE focuses on the development and demonstration of the core competencies expected of a field epidemiologist, as defined through the program's accreditation with the Training Programs in Epidemiology and Public Health Interventions Network. This thesis documents how I completed these competencies during my candidature. Table 1 outlines sections of this thesis where each competency was achieved.

Table 1. Summary of projects to meet the core MAE requirements.

Competency	Chapter						
	1	2	3	4	5	6	7
Investigate an acute public health problem		✓					
Evaluate a surveillance system			✓				
Design and conduct an epidemiological study				✓	✓		
Analyse a public health dataset				✓	✓		
Literature review				✓	✓		
Conference presentation			✓	✓			
Teaching requirements						✓	
Communication for a lay person							✓
Peer-review journal publications			✓	✓	✓		✓

The peer-review journal publications I authored are mentioned throughout this thesis, and are listed below:

- **Curtis SJ**, Cutcher Z, Brett JA, Burrell S, Richards MJ, Hennessy D, Gang RF, Lau CL, Rowe S. An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria. Communicable Diseases Intelligence. 2020;44.
- **Curtis SJ**, Rathnayaka A, Wu F, Al Mamun MA, Spiers C, Bingham G, Lau CL., Peleg AY, Yuce MR, Stewardson AJ. Feasibility of Bluetooth Low Energy wearable tags to quantify healthcare worker proximity networks and patient close contact: A pilot study. Infectious Diseases & Health. 2021.
- **Curtis SJ**, Langham FJ, Tang MJ, Vujovic O, Doyle JS, Lau CL, Stewardson, AJ. Hospitalisation with injection-related infections: validation of diagnostic codes to monitor admission trends at a tertiary care hospital in Melbourne, Australia. 2022 (manuscript under review).
- **Curtis SJ**, Trewin A, McDermott K, Were K, Walczynski T, Notaras L, Walsh N. An outdoor hotel quarantine facility model in Australia: best practice with optimal outcomes. 2022 (manuscript under review).
- Dyda A, Purcell M, **Curtis S**, Field E, Pillai P, Kieran R, Haotian W, Williams G, Moore J, Hewett M, Lau C. Differential privacy for public health data: An innovative tool to optimize information sharing while protecting data confidentiality. Patterns. 2021;2(12);100366.
- Field E, Dyda A, Hewett M, Weng H, Shi J, **Curtis S**, Law C, McHugh L, Sheel M, Moore J, Furuya-Kanamori L, Pillai P, Konings P, Purcell M, Stocks N, Williams G, Lau CL. Development of the COVID-19 Real-Time Information System for Preparedness and Epidemic Response (CRISPER), Australia. Frontiers in Public Health. 2021;214(8);753493.

In Chapters 4 and 5, I utilised Ovid Medline and EMBASE to perform targeted literature reviews after attending classes with the Alfred Health Library Services. Therefore, for each of these chapters I was able to perform a systematic search review, export these to Endnote, filter those that were not relevant based on their title and/or abstract, then again

based upon the full text of these articles. I was then able to gather the most relevant literature to include the background and discussion of each of these chapters.

In Chapter 7, I present two examples of communication for a lay person, with additional background on my involvement in these two projects. The first was part of the CRISPER project, which aimed to provide up-to-date and reliable information on COVID-19 through a dashboard by linking data from multiple sources. Therefore, I filmed a video on one of the key tools in this project to communicate its use to a lay person. The second was part of the Optimise Study at the Burnet Institute, which aimed to find out how Victorians were experiencing COVID-19 and responding to government interventions to inform national policy and practice. The Optimise Study included regular reporting to the State and Federal Governments on strategic information collected from the study. I was part of a team that produced the preliminary public facing report on participants' demographics, perceptions of government response, vaccine preparedness and adoption of risk reduction behaviours.

This thesis provides a glimpse into the work I completed during the MAE, and additional experience was gained through a range of activities pertaining to the essential day-to-day functions of public health. The overall experience of an MAE during a global pandemic assured my successful development of the key skills of a field epidemiologist.

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Chapter 3: An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria

Prologue

In response to the COVID-19 pandemic the DHHS launched 'enhanced surveillance to inform COVID-19 public health response in Victoria'. This activity aims to use and enhance existing surveillance activities to comprehensively capture the State's situation on COVID-19. During my secondment to the Victorian DHHS, I led the implementation of enhanced surveillance to capture and report the daily status of hospitalised COVID-19 cases in Victoria. This surveillance system utilised an existing reporting platform and collaboration with the Victorian Healthcare Associated Infection Surveillance System (VICNISS).

My role in the systems implementation and management provided the opportunity to learn the intricacies and nuances of the system and to make ongoing improvements in consultation with stakeholders. After my secondment to the DHHS, I evaluated the surveillance system through evidence using guidelines from the United States Centers for Disease Control and Prevention. All surveillance activities were conducted for and on behalf of the DHHS under the Public Health and Wellbeing Act 2008. The evaluation was approved by the Australian National University Human Research Ethics Committee [909/17].

My role during implementation included:

- Write the SOP for the implementation and function of the enhanced surveillance activity within the Intelligence Team, and update the SOP as required.
- Discuss, inform, and resolve issues within the SOP and system with stakeholders to ensure the activity integrated with these systems.
- Troubleshoot and resolve systems issues as they arise, including statistical software code to ensure the output enabled the system to function, as required.
- Provide training to DHHS staff on the systems processes, in line with the SOP.
- Be a central source for advice and knowledge regarding the intricacies of the surveillance system.

- Ensure that DHHS staff had adequate access to the system's online platforms to perform the surveillance system activities.
- Manage relationships and be the key liaison personnel between the DHHS Intelligence Team and VICNISS.
- Arrange and chair ongoing meetings between the DHHS Intelligence Team and VICNISS, including managing the meeting agenda, minutes, and actionable items.
- Maintain communication with the 'contact tracers' in the OMT regarding the surveillance system, to ensure needs were being met.
- Engage in prospective evaluation of the system to provide ongoing recommendations and improvements in consultation with stakeholders.

My role during the evaluation included:

- Discuss the system with a range of stakeholders to ensure that an accurate and comprehensive description of the system was captured.
- Formulate, develop, and administer the surveys and semi-structured interviews used to collect stakeholder views of the system.
- Extract, audit and analyse surveillance data.
- Provide a report on recommendations and lessons learned to the DHHS and VICNISS.
- Disseminate findings at an Australian National University Research School of Population Health Seminar in August 2020 (Appendix 1) and publish the findings in a peer-review journal, Communicable Diseases Intelligence in December 2020 (1).

Acknowledgements

I would like to thank the Intelligence Team at the DHHS for providing the opportunity to assist with the COVID-19 response. Thank you to all staff who continue to work to keep the surveillance system operating. Zoe Cutcher, thanks for being a mentor and encouraging the idea of this evaluation. Thank you to all those who took the time to contribute to the evaluation – notably Rebecca Gang, Stacey Rowe, Ann Bull, Judy Brett and Simon Burrell.

Lessons Learnt

My involvement in this surveillance system was a great opportunity to learn about the rapid deployment of disease surveillance during a complex and rapidly changing situation. The key lessons I learnt include:

- The true meaning of 'complicated workflows' and 'breaking systems'. When I commenced my secondment, I did not believe the power behind these commonly communicated phrases. The systems and workflows in a large organisation with thousands of staff and high pressure to deliver accurate and timely information are complex. Systems functionality prevails over simplicity, especially during a pandemic.
- The importance of listening and settling into a workplace and learning things such as the complicated workflows and systems.
- The need to consult and collaborate with long-term employees in an organisation, in this case, the DHHS staff that existed before the COVID-19 response team was assembled. These people had the best working knowledge of organisational function and are essential to successful implementation of systems.
- The importance of building a sustainable public health workforce and surge capacity for public health emergency response. Immediate secondments are useful for short-term surge capacity; however, a long-term team facilitates continuity within the response, and for experiences and lessons learnt to be shared for future outbreaks.
- That evaluating a surveillance system during a pandemic was difficult and likely resulted in low stakeholder participation.
- The importance of engaging a range of external stakeholders and allowing them to lead the conversation during interviews.
- That an evaluator should be independent to the system and organisation where the evaluation takes place. Although my ongoing involvement in the system enabled an understanding of the system's intricacies and had strong rapport with stakeholders to facilitate consultation, it is difficult to drop preconceived biases.
- That recommendations from an evaluation need to focus on practicability, despite the tendency to focus on more challenging improvements.

Abstract

The following abstract is from the peer-review journal article: Curtis SJ, Cutcher Z, Brett JA, Burrell S, Richards MJ, Hennessy D, Gang RF, Lau CL, Rowe S. An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria. Communicable Diseases Intelligence. 2020;24.

Background

Public health surveillance is crucial for supporting a rapid and effective response to public health emergencies. In response to the coronavirus disease (COVID-19) pandemic, an enhanced surveillance system of hospitalised COVID-19 patients was established by the Victorian Department of Health and Human Services (DHHS) and the Victorian Healthcare Associated Infection Surveillance System Coordinating Centre. The system aimed to reduce workforce capacity constraints and increase situational awareness on the status of hospitalised patients.

Methods

The system was evaluated, using guidelines from the United States Centers for Disease Control and Prevention, against eight attributes: acceptability; data quality; flexibility; representativeness; simplicity; stability; timeliness; and usefulness. Evidence was generated from stakeholder consultation, participant observation, document review, systems review, issues log review and audits. Data were collected and analysed over a period of up to three months, covering pre- and post-implementation from March to June 2020.

Results

This system was rapidly established by leveraging established relationships and infrastructure. Stakeholders agreed that the system was important but was limited by a reliance on daily manual labour (including weekends), which impeded scalability. The ability of the system to perform well in each attribute was expected to shift with the severity of the pandemic; however, at the time of this evaluation, when there were an average 23 new cases per day (0.3 cases per 100,000 population per day), the system performed well.

Conclusion

This enhanced surveillance system was useful and achieved its key DHHS objectives during the COVID-19 public health emergency in Victoria. Recommendations for improvement were made to the current and future systems, including the need to plan alternatives to improve the system's scalability and to maintain stakeholder acceptability.

Introduction

In response to the COVID-19 pandemic the DHHS launched the 'enhanced surveillance to inform COVID-19 public health response in Victoria'. This activity aimed to enhance existing surveillance activities to comprehensively capture the State's situation on COVID-19. The surveillance platforms included the Critical Health Resource Information System (CHRIS), the Influenza Complications Alert Network (FluCAN), the Short PeRiod IncideNce sTudy of Severe Acute Respiratory Infection (SPRINT-SARI), the Australian and New Zealand Intensive Care Society (ANZICS), and the VICNISS.

For this activity, VICNISS agreed to assist the Victorian DHHS to rapidly expand their surveillance activities to include daily status reports for all suspected and confirmed COVID-19 inpatients in public and private hospitals. The activity was initiated in February 2020 and by mid-March, VICNISS had built a secure online reporting module within their existing infrastructure and provided hospital Infection Prevention Control (IPC) staff with a comprehensive user guide and online training, resulting in many hospitals to commence reporting immediately. In 2020, an evaluation of the system was performed in June/July, results were distributed in an internal report in August, then published in Communicable Diseases Intelligence in December (1). This chapter details the evaluation which was performed.

Public Health Significance

COVID-19 is a significant public health problem that is resource intensive for the public healthcare systems. A key concern of COVID-19 was the pressure on hospitals to support people affected with severe forms of the disease, including the availability of Intensive Care Unit (ICU) beds, critical care devices, staffing levels and the ability to appropriately isolate cases. The consequences of limited capacity for health services were observed early in the pandemic when overwhelming demand for ICU services resulted in otherwise preventable deaths in high income countries (2).

Modelling studies can provide valuable insights into the likely clinical burden and anticipated resource requirements of the COVID-19 pandemic in Australia. Early in the

pandemic, modelling in Victoria forecasted that there would be an immense burden on ICU services due to COVID-19 (3). This modelling estimated that 6% of cases would require hospitalisation, 30% of these hospitalised cases would require a stay in the ICU, and 70% of these ICU admissions would require invasive ventilation. The average length-of-stay was estimated to be 10 days in the ICU, and 8 days in a ward. This modelling was independent of workforce and equipment constraints and assumed effectively infinite capacity for health services to triage and treat cases.

In response to growing concerns about the clinical and health services burden of COVID-19, state and federal governments prepared for additional surge capacity and implemented measures to preserve clinical resources. In Victoria, these measures included the activation and expansion of additional clinics to manage increasing volumes of patients, deferring non-urgent elective surgeries, opening additional beds in hospitals, and increasing stock of critical care equipment and supplies (4). These measures were intended to be temporary and adapt according to the severity of the pandemic.

Two key components of the Victorian and Federal COVID-19 pandemic plans were situational awareness and public health surveillance (4, 5). Situational awareness, the comprehensive capture and understanding of the State and Federal situation on the public health emergency, is important to assist with determining the expansion or contraction of surge capacity and to prepare for complex ethical discussions about rationing scarce resources. In hospitals, situational awareness on the occupancy of beds and utilisation of critical care devices enables an understanding on the demands that are being placed on hospital services.

Public health surveillance is the ongoing systematic collection, analysis and interpretation of health-related data essential to the planning, implementation, and evaluation of public health practice (6). Surveillance can provide situational awareness on hospital utilisation, monitor if the healthcare system is currently or soon to be overwhelmed and inform of possibilities to relax community interventions. Surveillance mechanisms are well established across Australia and within jurisdictions, including passive reporting, active case finding, sentinel and syndromic surveillance and genomic surveillance (5). Enhanced surveillance

greatly supported the public health response to COVID-19, such as the surveillance of hospitalised COVID-19 patients through VICNISS. The evaluation of surveillance systems can facilitate improvements in the systems performance and the overall public health response for the issue that relates to the system.

Description of the surveillance system

Purpose

The purpose of the surveillance system was to detect and monitor the daily suspected and confirmed COVID-19 inpatients in Victorian hospitals to facilitate and inform the State's public health response. The system enhanced Victoria's existing passive surveillance system which required medical practitioners and laboratories to urgently notify the DHHS under the Public Health and Wellbeing Regulations (2019). The population under surveillance, daily suspected and confirmed COVID-19 inpatients in Victorian hospitals, was recorded in an online reporting module on the VICNISS portal and the patient's location is updated daily until discharge, death, or recovery. The data were accessed by the DHHS and used to inform public health follow up, reporting and planning.

Context

An important consideration of this evaluation is that the surveillance system of suspected and confirmed COVID-19 inpatients was designed and implemented during a rapidly changing pandemic. The system was intended to be temporary to support the initial stages of the pandemic, and if the pandemic scaled in intensity, other surveillance mechanisms were intended to be established that did not involve individual case follow up whilst in hospital. The system was initiated in early February 2020 shortly after the COVID-19 case in Victoria was notified on 25 January 2020. At this time, the impact of the pandemic had already been seen in other high-income countries such as Italy who had over 22,000 cases and 1,625 deaths by mid-March (2). During the systems implementation in March, there were an average 50 cases per day in Victoria. During the period of this evaluation there was an average 15 cases per day in April, 9 cases per day in May and 17 cases per day in June.

Objectives

Due to the context in which the surveillance system was established, there were no objectives explicitly defined in a Terms of Agreement or Surveillance Plan. A letter of agreement from the Victorian CHO outlined the formal engagement of DHHS and VICNISS for the activity. The key benefits of this activity were explicitly stated verbally and in email correspondence. These benefits were:

1. Reduce the time required by the DHHS Existing Cases Team to make daily phone calls to hospital staff to record the status of hospitalised patients with confirmed COVID-19.
2. Enable the DHHS to record and report hospitalised patients with confirmed COVID-19 with increased accuracy and timeliness, including their status and resource utilised (e.g., ventilation in ICU).
3. Enable hospitals to have a simple platform to use to report to their executive, IPC team and others, on their current situation of suspected and confirmed COVID-19 patients.

Case definition

The surveillance system used the confirmed case definition of COVID-19 from the Communicable Disease Network Australia (CDNA) Series of National Guidelines (SoNGs) for all those that were hospitalised in Victoria at the time of data collection. The CDNA confirmed case definition adapts according to changing knowledge on the clinical and epidemiological profile of cases of COVID-19 presenting in Australia and internationally. At the time of this evaluation, the confirmed case definition presented in Table 1, SoNG Version 3.2 published 12 June 2020 (7). A probable case definition had commenced being used in some States and Territories at this point, however it was not included in the CDNA definition, and was not used by this surveillance system.

Table 1. The enhanced surveillance system case definition of suspected or confirmed coronavirus disease.

Confirmed case:

A person who:

i. tests positive to a validated specific SARS-CoV-2 nucleic acid test;

OR

ii. has the virus isolated in cell culture, with PCR confirmation using a validated method;

OR

iii. undergoes a seroconversion to or has a significant rise in SARS-CoV-2 neutralising or IgG antibody level (e.g. four-fold or greater rise in titre).[1]

Suspect case:

A person who meets the following clinical **AND** epidemiological criteria:

Clinical criteria: Fever (≥37.5°C)[2] or history of fever (e.g. night sweats, chills) **OR** acute respiratory infection (e.g. cough, shortness of breath, sore throat)[4] **OR** loss of smell or loss of taste.

Epidemiological criteria:

i. In the 14 days prior to illness onset:

- Close contact[5,6] (refer to Contact definition below) with a confirmed or probable case
- International or interstate travel
- Passengers or crew who have travelled on a cruise ship
- Healthcare, aged, or residential care workers and staff with direct patient contact
- People who have lived in or travelled through a geographically localised area with elevated risk of community transmission, as defined by public health authorities[7]

ii. Hospitalised patients, where no other clinical focus of infection or alternate explanation of the patient's illness is evident.

1 Antibody detection must be by a validated assay and included in an external quality assurance program.

2 It is recommended that temperature is measured using a tympanic, oral or other thermometer proven to consistently and accurately represent peripheral body temperature.

3 If the person is a close contact of a probable case, at least one person in the chain of transmission must be a confirmed case.

4 Other reported symptoms of COVID-19 include: fatigue, runny nose, muscle pain, joint pain, diarrhoea, nausea/vomiting, and loss of appetite. Clinical and public health judgement should be used to determine if individuals with sudden and unexplained onset of one or more of these other symptoms should be considered suspect cases.

5 Testing household contacts of confirmed or probable cases of COVID-19 may not be indicated where resources are constrained. These cases would be considered 'probable cases' (refer to definition above).

6 In certain high-risk outbreak settings, PHU may consider testing asymptomatic contacts to inform management of the outbreak. For a list of settings, refer to high risk settings.

7 For further information on geographically localised areas with elevated risk of community transmission, refer to (https://www1.health.gov.au/internet/main/publishing.nsf/Content/cdna-song-novel-coronavirus.htm)

Stakeholders and organisational location

The surveillance system involved a range of stakeholders including VICNISS, IPC staff in hospitals, various divisions of the DHHS COVID-19 response, Safer Care Victoria (SCV) and the Victorian Agency for Health Information (VAHI). The background and role of each stakeholder in this surveillance system are outlined below.

VICNISS Coordinating Centre

The VICNISS Coordinating Centre was established by the DHHS in 2002 to coordinate standardised surveillance of healthcare associated infections in Victorian healthcare facilities. The scope of work performed by VICNISS has since expanded from preventing infections in hospital settings to healthcare in outpatient and community settings including Residential Aged Care Facilities (RACFs). All Victorian public and private hospitals are required to perform surveillance for specified healthcare associated infections and relevant processes, such as healthcare worker annual influenza vaccination. RACFs currently participate on a voluntary basis. VICNISS is fully funded by the DHHS, and usually works across the DHHS Health and Wellbeing division, VAHI and SCV.

For this surveillance activity, VICNISS agreed to assist the Victorian CHO and the RHPEM division. A key role of VICNISS for the surveillance activity was to build and maintain a secure and reliable online reporting module on their existing portal with agreed data specifications. Additionally, their role was to continually communicate with IPC staff at hospitals and provide resources to ensure the reporting requirements were performed.

Hospital Infection Prevention and Control

All Victorian hospitals, over 300, report to the DHHS through VICNISS for various public health surveillance activities. This reporting is usually performed by Infection Control Practitioners or staff within IPC departments. For this surveillance activity, the role of hospital staff was to use the reporting module on the VICNISS platform to report daily suspected and confirmed COVID-19 inpatients at their hospital and provide daily updates on the location within the hospital (ICU or ward) and ventilation status of these patients.

During the surveillance system implementation, hospital staff had two key responsibilities. Firstly, each hospital was required to develop a system to find all admitted COVID-19 cases. Examples for how this could be performed include; (1) run a daily list of patient administration system alerts for COVID-19, (2) run daily pathology reports to capture test results for confirmed COVID-19, (3) review inpatients on wards allocated for COVID-19 cases, (4) request staff on ward rounds to record the data, (5) request Emergency Department staff to notify of newly admitted suspected or confirmed cases, (6) request a list from infectious disease departments who may record this information elsewhere, (7) request wards to share Electronic Patient Journey Boards. Secondly, each hospital was required to develop a system for entering daily data into the platform. This did not have to be an IPC staff; recommendations for who could enter this data included nurse coordinators, administration clerks or database managers.

Victorian Department of Health and Human Services

The DHHS was the control agency for the COVID-19 public health emergency response in Victoria. The response functioned from the RHPEM division and was structured as a DIMT. In the Intelligence Team branch of the DIMT, the surveillance system operated from the DART. The system was used for daily reporting by the Intelligence Team, for operational purposes by the contact tracing team and for logistics and planning across the DIMT.

During the systems implementation, Intelligence Leads coordinated with stakeholders to scope the feasibility, obtain legal advice and to establish the data specifications for the surveillance system. Subsequently, the DART were responsible for systems implementation, including the establishment of a SOP and coordination with stakeholders to ensure the SOP did not have an adverse impact on existing workflows, particularly those between the Intelligence Team and the Existing Cases Team, described below.

A Systems Manager in the DART was the key liaison person who arranged ongoing meetings with VICNISS, and ad hoc meetings with other stakeholders to ensure the needs of all stakeholders were being met. The Systems Manager and DART Team Leads ensured that relevant staff had access the VICNISS portal, provided training in line with the SOP, and troubleshooted issues within the system as required, including statistical software code. The

DART performed data processing, cleaning, entry, extraction, and analysis, which will be outlined in a subsequent section of this evaluation. Concurrently, the Development Team developed and maintained code in statistical software to provide the required workflows between the Intelligence Team and the Existing Cases Team.

The Case Contact and Outbreak Management Team was divided into four teams, New Contacts, Existing Contacts, Existing Cases and Outbreak Management. A key purpose of this surveillance system was to shift the daily responsibility of reporting confirmed COVID-19 inpatients in hospitals from the Existing Cases Team to the DART. Prior to systems implementation, Public Health Officers from the Existing Cases Team called hospitals daily to follow up the clinical status of confirmed cases. The surveillance system was intended to allow Public Health Officers to focus on calling confirmed cases in the community, reduce follow-up calls to busy hospital staff and to provide timely data about newly hospitalised COVID-19 cases. The Existing Cases Team Leads managed and trained Public Health Officers and coordinated with the Intelligence Team to ensure the daily workflow of confirmed cases and close contacts was provided, which determined the daily list of confirmed cases in the community that require follow up.

Data from the surveillance system were intended for secondary use by logistics and planning across the DIMT, to contribute to situational awareness on the occupancy of beds and utilisation of critical care devices. The data may be used to inform decisions regarding the expansion or contraction of surge capacity and interventions in the community.

Safer Care Victoria and the Victorian Agency of Health Information

SCV and VAHI are agencies supported by the DHHS that also had a role in the surveillance system. SCV is the state authority for quality and safety improvement in healthcare. SCV are the usual relationships managers of VICNISS for other reporting requirements and were involved with the feasibility scoping of the surveillance system. As the system was for and run by the RHPEM division, SCV were not involved in the implementation and management of the surveillance system. VAHI is responsible for providing data and information on quality of clinical care in Victoria. Data from the surveillance system were used to provide VAHI with updates for Australian Institute of Health and Welfare (AIHW) reporting.

Resource implications

There were no resource implications directly attributable to the surveillance system as of June 2020. Before and during the surveillance system implementation, the VICNISS administration had comprised of a Director, an Operations Director, two Infectious Diseases Physicians, five Clinical Nurse Consultants in Infection Control, two Software Developers, a Database Manager, Biostatistician, Epidemiologist and Administrator. The VICNISS team temporarily paused some non-essential work during the establishment of the system and subsequently added the systems maintenance into their regular work hours. Funding arrangements did not change, however there was the ability to increase funding to VICNISS from the DHHS, if further scale up of activities were required. The DHHS seconded and employed hundreds of new staff for the COVID-19 response, however individuals were not directly employed to implement or manage this surveillance system, and tasks relating to the surveillance system were allocated according to the needs of the response at the time.

Legal authority

The formal engagement for the surveillance activity was expressed as a letter of agreement under the Public Health and Wellbeing Act 2008. The Victorian CHO requested hospitals contribute to assist with the public health response by reporting to the surveillance system, however reporting was not mandated by legal authority.

Confidentiality

The Victorian CHO authorised the collection of identifiable information for the surveillance system activity, therefore a high level of precautions was taken to maintain confidentiality. The data entered in the VICNISS portal and Victoria's electronic notifiable diseases database, the PHESS, were stored on secure encrypted Microsoft SQL Servers. All data collected on the VICNISS portal for this surveillance activity was owned by the DHHS but can be used for the reporting needs of VICNISS and hospitals.

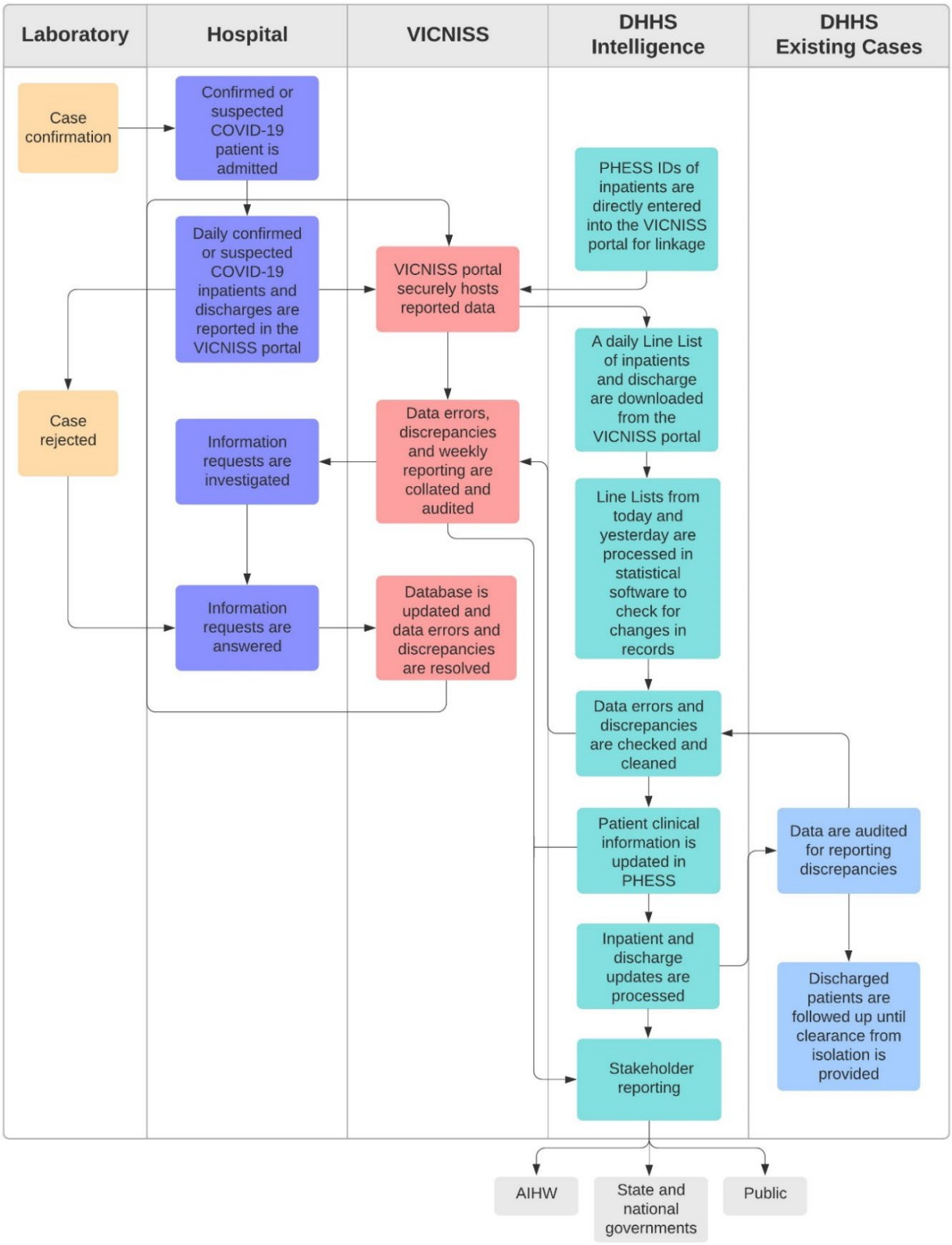
The VICNISS portal used an authentication system to restrict access. At the hospital level, automatic access to the COVID-19 reporting module was provided to the designated 'Facility Manager' of other reporting requirements. The Facility Manager must update the access

rights of other users at their facility to access the COVID-19 reporting module. System users were only able to see patient reporting at the hospital they were registered for. At the DHHS level, individuals must apply for access to the COVID-19 online reporting module of the VICNISS portal using their DHHS email. This application was approved by the VICNISS Operations Director and the DHHS Systems Manager. DHHS were not able to edit hospital level data. When the surveillance system is deactivated, patient names will be deleted from the reporting module however there was no long-term data management plan.

Surveillance system operation

This section outlines the operation of the surveillance system, including data sources, information collected, data management, entry, cleaning, analysis, and reporting. A flow diagram of the surveillance system is provided in Image 1.

Image 1. Flowchart to describe the components and operation of the enhanced surveillance system.



Data sources and information collected

The data in the surveillance system commenced at the hospital-level. When a new patient was admitted to the hospital who fulfilled the COVID-19 case definition, or a current patient newly met the case definition, the patient episode was created in the online reporting module on the VICNISS platform. The confirmed case definition was supported by results from a laboratory, at the hospital site or an offsite laboratory. Case rejection was rare but occurred when the patient did not correctly meet the Table 1 case definition, usually due to new clinical information such as the return of a negative PCR. Paper forms were available for data collection; however, the data must be entered into the online reporting module each day by 16:00, including weekends.

Subsequently, the location and ventilation status of each patient was required to be updated in the reporting module daily by 16:00 to show the status of the case. If the patient location was not updated by 16:00, a reminder email was automatically sent to all COVID-19 module users at that hospital, and it was the responsibility of the hospital staff to delegate the task. The daily update was required until the patients' discharge, death, or recovery. Recovery was when the patient is cleared as no longer infectious by the DHHS. When the patient was transferred, the sending hospital must specify the receiving hospital. Subsequently, all COVID-19 module users at the receiving hospital were notified by email with a link to open the online reporting module with pre-populated patient details.

The role of the individual who enters the data differed at the hospital level, however the data collected were standardised across hospitals. The online reporting module had numerous data quality checks that prompted the user to complete the fields correctly with an appropriate value. The online report could not be submitted if data quality requirements were not met. The data were entered manually, and the online reporting module did not have the function to be auto populated by a data file upload.

Additionally, on Tuesdays, hospitals were required to report whether there were any suspected and/or confirmed COVID-19 cases admitted to their facility in the previous week. This reporting was completed through a panel that appears on the COVID-19 reporting module with a 'Yes' or 'No' option. A reminder email was sent to all COVID-19 module users

at each hospital on Tuesday at 10:00, and again at 16:00 if not yet completed. This reporting was a validation process used to confirm whether a hospital had no cases, or if the reporting was not complete.

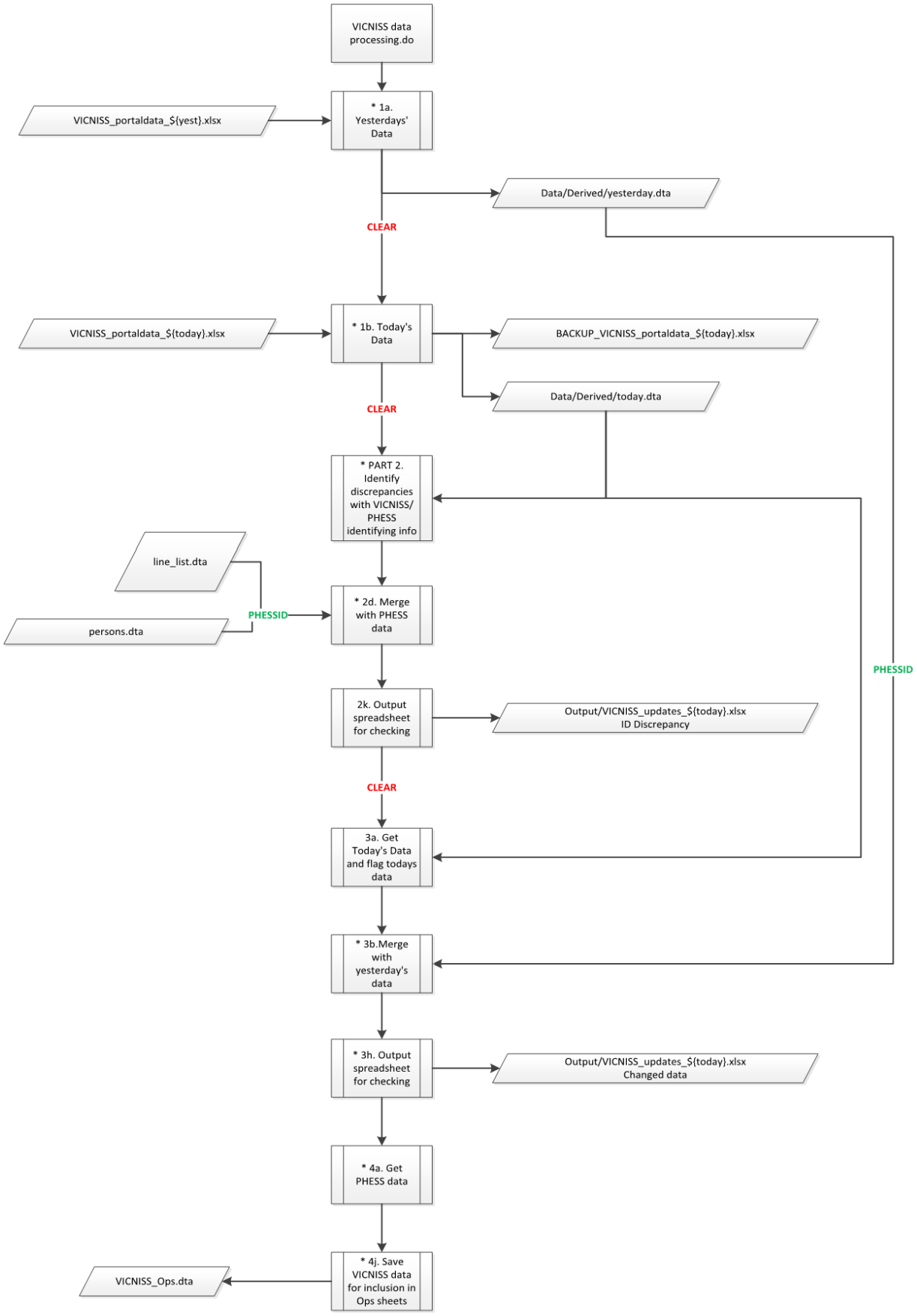
Data management

The surveillance system data transfer and management were predominately at the DHHS-level. At approximately 17:00 each day, an approved member of the DART directly entered the PHESS ID of newly reported patients in the VICNISS reporting module. The PHESS ID was found through searching for the patient in the PHESS database, using name, date of birth and confirmed COVID-19 status. After the PHESS ID was entered, the DART extracted the daily line list from the VICNISS reporting module, placed it on the DHHS secure Microsoft Azure cloud service, and processed the data using Stata code (8). The function of the Stata code is described in Image 2.

The code exported two key outputs. The first output was a spreadsheet that included information on new admissions, new discharges, and newly cleared from isolation, and was automatically appended to the daily morning file provided to the Existing Cases Team. This file was used to determine the follow up calls required, and to formalise isolation clearance certificates with hospitals. The spreadsheet also included whether the patient was a healthcare worker according to VICNISS, but was not listed in PHESS, as an additional data quality check.

The second output included data discrepancies between the personal identifiers in the VICNISS portal to those already recorded in PHESS. This was used for data cleaning and entry by the DART. Discrepant PHESS IDs were followed up immediately, however other discrepancies such as sex and date of birth were followed up weekly on a Sunday. The output also included a list of variables that had changed in today's VICNISS record compared to yesterdays, such as a change in the patient's current location and ventilation status. Subsequently, this information was entered into PHESS manually.

Image 2. Flowchart to describe the Stata code function in the enhanced surveillance system



During the systems implementation, data transfer and management were different. In March and April, the daily line list was uploaded to a shared Microsoft SharePoint folder by the VICNISS Database Manager. Missing PHESS IDs were entered manually, and the patient's current location and ventilation status were updated in PHESS through an 'eye-balling' method, with prioritisation to records without a discharge date or with a recent discharge date. This interim process permitted time for the DHHS staff to gain access to the VICNISS portal, receive training and integrate the system into existing work and information flows.

Data analysis and reporting

Data from the system were reported to the COVID-19 response teams within State and federal governments, and the public. Hospitalisation data, including the number of cases currently admitted to hospital, in ICU, and requiring ventilation, were reported daily in the Victorian State Situational Report. This report was the source of truth provided to key decision makers and stakeholders, including the media. On weekdays, hospitalisation data were also provided by the Intelligence Team to VAHI, for the AIHW, who collated national hospitalisation data for the Federal Situational Report. Additionally, data from the surveillance system were used to respond to ad hoc requests to the Intelligence Team, for example, the trends in the number of cases ventilated. These analyses were performed using PHESS data extracts and statistical software.

Methods

Objective

The purpose of this evaluation was to provide recommendations to improve the current surveillance system and to inform the planning and implementation of future enhanced surveillance activities for public health emergencies.

Framework

The framework for this evaluation was adapted from the United States Centers for Disease Control and Prevention updated guidelines for the evaluation of public health surveillance systems (6). The surveillance system was assessed against eight attributes identified in the framework and evidence were generated through mixed methods, including participant

observation, stakeholder consultation (survey and/or interview), document review, systems review, issues log review, data analysis and audits. The eight attributes, their definition and source of evidence are provided in Table 2.

Table 2. The enhanced surveillance systems attribute, definition, and source of evidence for the evaluation.

Attribute	Definition	Source of evidence
Usefulness	The system's ability to achieve the defined objectives	Participant observation Stakeholder consultation System review
Simplicity	The ease of the systems to be operated and the systems integration with existing systems	Document review Issues log review Participant observation Stakeholder consultation Systems review
Acceptability	The willingness of users to participate in the surveillance system	Stakeholder consultation
Flexibility	The ability for the system to adapt to changing information needs and/or operating conditions without significant changes in time, staff contribution or funding	Document review Issues log review Stakeholder consultation Systems review
Timeliness	The entry, cleaning, analysis, and reporting of data on time by users	Audit Data analysis Stakeholder consultation System review
Data quality	The accuracy, completeness, and reliability of data captured by the surveillance system	Audit Stakeholder consultation
Stability	The system's reliability to perform without failure and during adaptation, along with the reliability to maintain confidentiality	Stakeholder consultation System review
Representativeness	Geographical appropriateness and coverage of hospital reporting	Participant observation Stakeholder consultation System review

Stakeholders

Stakeholders from the DHHS and VICNISS were identified as individuals that contributed to the surveillance system during and/or after implementation. Stakeholders from hospitals were identified through a convenience sample of an IPC department in a health service responsible for VICNISS reporting in three hospitals. The hospitals were a mix of a public acute-care principal referral hospital, a public acute-care large hospital and a public mixed sub- and non-acute medium hospital (9). The stakeholders from SCV were identified as the usual relationships managers of VICNISS.

Data collection and analysis

Documents and systems were reviewed through letters issued by the Victorian CHO, the DHHS SOP, VICNISS educational materials, an issues log, and informed by additional information from stakeholders during interviews. The issues log was created in Microsoft Excel and consisted of systems issues, solution, rationale for solution, attribute improved and attribute sacrificed. It was created through a review of all emails exchanged during the implementation and management of the surveillance system from March 19 to June 6. Participant observation also occurred during this period.

A survey was administered to DHHS stakeholders using Research Electronic Data Capture (REDCap), hosted on the Australian National University server (10, 11). Respondents were asked to assess each system attribute using a Likert scale of the following options: Strongly Agree, Agree, Neutral/Undecided, Disagree and Strongly Disagree. A comments box was available to allow for additional stakeholders input. Respondents identified their role in the system, however they remained anonymous unless they were willing to further discuss their survey responses. The survey is provided in Appendix 2. For stakeholders from VICNISS and hospitals, and DHHS stakeholders that wished to discuss their survey response further, semi-structured interviews were performed face-to-face or through online telecommunication. Interview notes were recorded on a structured interview template according to each attribute, and subsequently coded into themes in Microsoft Excel.

Four audits were performed to assess the timeliness and data quality of the surveillance system (below). Data were extracted from the PHESS database and the line lists from the

VICNISS reporting module. Data analysis and random selection of records were performed using R Version 3.6.2 (12).

1. The first audit was of ***pre-systems reporting*** and compared 20 records in the VICNISS reporting module to the data entered in the PHESS record notes by the Existing Cases Team from phone calls, prior to the systems implementation. The period of interest was April 5 to April 25 and the sample was limited to hospitals that commenced reporting prior to the Victorian CHO reporting request.
2. The second audit assessed the ***accuracy*** of data entry by the DART post-implementation, by comparing 20 records in PHESS to the VICNISS line lists. The period of interest was April 26 to June 6 and the audit compared both demographics and patient admission episode details.
3. The third audit assessed ***reporting errors***, including how many, what proportion and what type of incorrectly reported data fields were entered into the VICNISS reporting module. The period of interest was April 5 to June 6 and was collected through email review of DHHS emails to VICNISS regarding data errors and discrepancies. The proportion was calculated as the number of records with errors divided by the total number of new admissions in the audit period.
4. The fourth audit assessed ***reporting bias*** on days of the week through an analysis of data from the VICNISS reporting module to compare the number of admissions to a ward, to an ICU, to receive ventilation and the number discharges that occur on each day of the week. The period of interest began from the date of the first entry in the reporting module, March 19 to June 6.

Results

Stakeholders

The following stakeholders were consulted during the evaluation: the DHHS Intelligence Team, the DHHS Existing Cases Team, VICNISS and hospital IPC staff. The number and type of stakeholders that contributed to the evaluation are provided in Table 3, along with the estimated number of stakeholders that contribute, or contributed to the system from implementation to the evaluation. The role of each stakeholder group is provided in Table 4. The stakeholders were involved in a variety of stages of the surveillance system; design

(3/24, 13%), implementation (16/24, 62%), and post-implementation (22/24, 92%). There were 18 survey respondents, and other stakeholders were consulted face-to-face or online.

Table 3. The number of stakeholders that participated in the evaluation, by group.

Stakeholder group	Participate in the system*, N	Participated in the evaluation, N
Managers, Leads and Supervisors, Intelligence, DHHS	8	4
Development, Intelligence, DHHS	5	3
Data and Reporting Team, Intelligence, DHHS	20	6
Existing Cases Team Leader, DHHS	4	2
Existing Cases Public Health Officer, DHHS	12	3
VICNISS	8	3
Hospital IPC staff	300+ hospitals	3**
Total	57 (excluding hospitals)	24 (including hospital staff)

**The estimated number of stakeholders that contributed during and/or after implementation; this contribution ranges from one day to daily.*

***Three stakeholders from one health service that report to the surveillance system for three hospitals.*

Table 4. The role of each stakeholder group in the enhanced surveillance system.

Stakeholder group	Role in the surveillance system
Managers, Leads and Supervisors, Intelligence, DHHS	During systems design, stakeholder engagement and establishment of data specifications. They also provide ongoing technical expertise, governance and manage staff.
Development, Intelligence, DHHS	Development and coordination of workflows across the COVID-19 incident response team through data transfer, usually derived from coding in statistical software.
Data and Reporting Team, Intelligence, DHHS	Perform the daily data processing, cleaning, entry, and reporting for the surveillance system.
Existing Cases Team Leader, DHHS	Coordinate information flows from the Intelligence Team and manage and train Existing Cases Public Health Officers.
Existing Cases Public Health Officer, DHHS	Utilise information flows to make daily contact with existing COVID-19 cases in Victoria. Prior to the systems implementation this included contacting hospitals about inpatients with COVID-19.

VICNISS	Design and maintain the online reporting module used by the DHHS and hospital IPC staff. Provide expertise on the surveillance system design and management, whilst being the key liaison people between the DHHS and hospital staff to resolve issues and/or questions relating to the system.
Hospital IPC staff	Perform daily reporting on the status of current COVID-19 cases using the VICNISS reporting module.

Usefulness

Most survey respondents (17/18, 94%) agreed or strongly agreed that the system achieves its key objectives in detecting changes in hospitalizations with COVID-19. Most survey respondents (17/18, 94%), including all Existing Cases Team respondents, agreed, or strongly agreed that the system reduced the time required for DHHS to perform follow up calls to hospitals about inpatients with COVID-19. One respondent was undecided/neutral for each question (1/18, 6%).

Data generated from this surveillance system were useful for the DHHS reporting, including daily reporting in the Victorian State Situational Report, and for weekday reporting to the AIHW through VAHI. The latter reporting requirement was introduced after the introduction of this surveillance system. Input from the DHHS logistics and planning was not available due to the busy time in which the evaluation was performed, however, given the far-reaching dissemination of data, in combination with other systems, this system was likely to contribute to informing public health decisions.

For the third objective, hospital staff did not utilise the platform as a mechanism to report on their situation of COVID-19 patients. Rather, the system was perceived as a reporting requirement by the DHHS. At the time of this evaluation, no hospital had requested a formal report from VICNISS that summarised the facility's reporting. For many hospitals, this may be due to limited or no cases admitted, however all three hospital stakeholders noted that they were not aware of this function of the surveillance system. Furthermore, this function was not perceived as useful as the hospitals noted they have existing infrastructure and processes for internal reporting. The existing processes were noted to be more accurate as they utilise hospital definitions of patient clearance from isolation, opposed to DHHS

definitions, and because these provide real-time updates opposed to a daily point in time data.

There were minimal recommendations on how the surveillance system could be more useful. One stakeholder recommended the system capture whether the inpatient normally resided in a RACF to facilitate outbreak detection. An additional stakeholder recommended the system expand to capture Emergency Department presentations. A hospital stakeholder reported it would be useful to access a history of the weekly Tuesday report about whether there had been COVID-19 patients admitted to the facility or not, as only the previous week's report was able to be viewed.

Acceptability

All stakeholders interviewed and survey respondents agreed or strongly agreed that the reporting of COVID-19 inpatients to the DHHS was of public health importance, however the willingness of users to participate in the surveillance system varied. Acceptability was high for VICNISS, high for most DHHS staff and neutral for hospitals.

Over half of respondents strongly agreed or agreed (10/18, 56%) that the system reduced their workload, and one third of respondents were undecided/neutral (6, 33%). All Existing Cases Team respondents strongly agreed or agreed that the system reduced their workload. Of the two respondents who disagreed that the system reduced their workload, one was in the Development Team and the other was in the DART. Two thirds of respondents strongly agreed or agreed (12/18, 67%) that the time required by the system was justifiable because of the value of the information collected, however the other respondents were undecided/neutral (6/18, 33%). In two interviews, DART stakeholders noted that the system created a large time burden during implementation, however the time required by the system was justifiable and acceptable during the post-implementation period.

Over half of respondents agreed or strongly agreed (10, 56%) that recommendations for systems improvement made were considered, however five were undecided/neutral (28%) and three respondents disagreed (17%). Two respondents that disagreed noted that recommendations to automate the system were not considered. Two thirds of respondents

strongly agreed or agreed that they and/or their team received acknowledgment for contribution to the system, (11/18, 66%), four were undecided/neutral (22%) and one disagreed, (6%).

Stakeholders from VICNISS were highly accepting of their role in the surveillance system. The large increase in workload during the systems design and implementation was justifiable because of the value of the system, and because their workload was reduced post-implementation, allowing a return-to-work activities that were temporarily paused or performed at reduced capacity. The system was less acceptable for a principal referral care hospital with many hospitalised cases, as it increased the workload during a busy period, including the impractical expectation of weekend reporting. Acceptability was neutral for hospitals with no cases admitted, however it was noted that if cases were admitted, the system would be a large burden of time. Additionally, hospitals reported that the system duplicated other DHHS reporting requirements such as the requirement of clinicians to immediately notify the department when a patient returns a newly positive COVID-19 test result. Furthermore, there was duplication with other hospital-based enhanced surveillance activities, including ANZICS, SPRINT-SARI, FluCAN and CHRIS.

Simplicity

Most survey respondents strongly agreed or agreed (13/18, 72%) that the system had a simple process for data collection and reporting on hospitalisation status for inpatients with COVID-19, however four disagreed (22%) and one was undecided/neutral (6%). One respondent added that the system was as simple as it can be, but data entry errors and cleaning make it more complex. Two respondents added that the lack of understanding about the process in statistical software adds complexity. One of these respondents referred to this step as a "black box" that reduces the systems simplicity for day-to-day users. Stakeholders from VICNISS and hospitals agreed that system was simple from their perspective.

Document review of the systems DHHS SOP contradicts survey respondents' opinion that the system was simple for DHHS stakeholders. The SOP incorporates 16 data entry rules, provided in Table 5. Many of these rules require an intricate knowledge of the PHESS

database and DHHS reporting needs. Participant observation support that the system was complex, as there were regular queries by the DART when performing the system's daily tasks. Key issues that required clarification were caused by data entry rules that were not instinctive but were established due to their impact on workflows. For example, as per rule 15 in Table 5, once a case was cleared from isolation by the DHHS, the hospitalisation status of the patient was no longer required for reporting, even if the patient were in ICU. This topic also appeared in the issues log review, along with confusion regarding redundant fields in PHESS. For example, as per rule 13 in Table 5, the 'clinical summary' data fields in PHESS were used at the beginning of the COVID-19 response but were subsequently considered redundant. This adds complexity and confusion if the DART do not comprehensively read the systems SOP.

Table 5. An extract from the surveillance systems Standard Operating Procedure, explaining the rules for data entry of hospitalised COVID-19 cases in the PHESS database.

1	To update a patient's location, click "Add new" in Clinical Risk
2	"New" entry is required for all movements into hospital, within a hospital, when discharged, when a patient enters ICU, enters ventilation, leaves ventilation, leaves ICU, when in hospital in the home and when home isolation is commenced, for example: Emergency department presentation. Hospital admission (to ward, please click ICU "No"). Hospital admission to ICU (create new admission, select ICU "Yes". MUST select Ventilated "Yes"/ "No"/ "Not stated". Every ICU admission needs Ventilation status updated to reflect the status for that period in ICU). Movement between ventilated and non-ventilated (as above, create a new admission, click ICU "Yes", then click Ventilated "Yes" or "No" for each move). Hospital admission (back to ward). Home isolation.
3	Always enter an admission date when you commence a new entry
4	Always enter a discharge date on the previous entry, before you start a new one
5	If the patient has been discharged and readmitted, "Add new" clinical episode. Do not delete previous admissions. Do this even if the admission and discharge is on the same day.
6	When a patient has been discharged: If the patient has already been cleared by the Existing Cases Team, do not add a presentation episode, even when the case is recorded in VICNISS as Hospital in the Home; (clearance can be assessed by referring to the Administration package – COVID-19 Actions, "Case cleared from Isolation"). If the patient has not been cleared by Operations, add a home isolation presentation episode, leaving the discharge date blank.
7	Always leave a detailed note in the notes section of the PHESS record about action made, for example: Clinical risk update: Patient discharged from the Alfred 01/04/2020 as per VICNISS. OR; Clinical risk update: Patient moved from ward to ICU at the Alfred 01/04/2020 as per VICNISS. OR; Clinical risk update: VICNISS has reported Hospital in the home but case has been cleared. If no change in patient status occurs, you do not need to add a note in the PHESS record explaining this. The Existing Cases Team will be informed of any cases with" VICNISS update – no change in status" through the routine morning information flows. There is no need to add notes in the clinical package regarding current hospital status of confirmed case.
8	Do not edit/change ''where is case currently" as this field is not used for reporting currently
9	"Cleared from isolation" in "Most Recent Location" variable.

	- Hospitals will not be entering data into VICNISS once the patient is cleared by the hospital. When this response appears: enter a discharge date in PHESS equal to the "cleared from isolation" date provided by hospital (Both for Hospital in the Home and Admissions); no further presentations data will be captured. Add a comment saying "remains in ward, discharged form isolation (date)" in the general PHESS comments field. - The Existing Cases Team will be notified in routine morning information flows that these patients have been "Cleared from isolation" and they will follow up with hospitals (if they have not already contacted us) to formalise the clearance/issue certificates.
10	Hospital in the home is not a hospital admission for DHHS COVID-19 reporting. This translates to the patient being classified as in-home isolation. If the case has not been cleared by Operations, enter this as a new presentation with a blank discharge date.
11	Notify Surveillance lead if a patient is newly deceased according to VICNISS, update death in PHESS with Surveillance lead approval.
12	Previously discharged patients will remain as a static entry in the daily VICNISS Line List; however, their status will no longer be updated daily
13	Ignore the "Clinical Summary" section in PHESS – reporting is derived from the "Hospitalisations and medical presentations':
14	For patients who are re-admitted to hospital, that have been previously cleared by Operations, clearance can be checked in notes and the Administration package – COVID-19 Actions – "Case cleared from Isolation". Do not re-enter this hospitalization but leave a detailed note in the patient file. Hospitals are not required to enter this data, and we do not expect to enter it. Further data regarding subsequent hospitalisations will be collected later through data linkage.
15	For patients who are cleared of COVID-19 during hospital admission, enter the discharge date as the date they were cleared by Operations. Then put a note in PHESS clearly stating that the patient is cleared but remains in hospital as per VICNISS. This ensures the patients are coded as "recovered" for daily reporting purposes (to reflect their "Case cleared from Isolation" status). When an update comes through from VICNISS in later days, add a new PHESS note with change. Do not reopen a hospital presentation.
16	For patients in State Border Hospitals, e.g., Albury-Wodonga. Please follow these steps: If the patient is not in PHESS, request VICNISS to provide the patient's address immediately. As per section 5 of this protocol. If the patient is in PHESS and is a Victorian Resident in an NSW/SA hospital, follow the standard procedure of this protocol. If the patient is in PHESS and is an NSW/SA Resident in an NSW/SA hospital, inform the relevant State Health Department as a duty of care. NSW: MoH-PHEOSurveillance@health.nsw.gov.au SA: HealthCommunicableDiseases@sa.gov.au If the patient is an NSW/SA Resident in a Victorian Hospital, inform the relevant State Health Department as above, and inform the Existing Cases Team.

A system review supported that the level of data necessary for the surveillance system to function is simple. Over the course of a patient's admission there were 12 mandatory fields to be entered by hospital staff, an additional field was required if the patient was a healthcare worker or if the patient was transferred to another facility. These data fields were easy to collect and readily available through running facility reports or by searching the patient in the hospital's online medical records system. The DHHS enter one mandatory field into the VICNISS reporting module and a minimum of 5 mandatory fields in PHESS, with additional fields required if the patient moves throughout the hospital or if their ventilation status changes. Hospital staff can add information in a comments box in the patient's record on the reporting module, however this comments box did not appear in the DHHS interface.

The level of integration of the system was high for hospitals and VICNISS, as the system uses an online platform regularly used for other reporting, and communication was done between organisations and individuals with an established relationship. Hospital stakeholders reported that the system was promoted as useable by non-clinical staff, however there were complexities with medical terminology that required clarification from clinical staff. The system integration was poor for the DHHS as it required a high degree of manual labour and human thought. Due to the complex data entry rules, it was not possible to automate this component. The use of statistical software to inform what records need to be updated and how the records have changed since yesterday may reduce clarity of the process to some systems users, but it was beneficial to improve timeliness and data quality as the alternative was to manually review the changes in yesterday's line list to todays.

The total person-hours needed to maintain the surveillance system varies daily for stakeholders. At the time of this evaluation, the system required an average 10 minutes per day for hospital staff to review if there were new admissions to report to the system, and an additional 5 minutes per inpatient record update was required. At the DHHS, the system required an average 15 minutes per day to perform data processing, which commenced at downloading the Line List from the VICNISS reporting module and concluded with having the Stata output that informs which records need to be updated in the PHESS database. The time required for this task was likely to be consistent regardless of case numbers. An additional 3 minutes per inpatient record update was required, along with an additional 5

minutes per data entry error required to be followed up. For the period of this evaluation, March 19 to June 6, there were a total 182 hospital admissions reported in the surveillance system, with a median of 2 [Interquartile range (IQR): 1-4] new hospitalisations per day and a median of 6 [IQR: 4-9] patient status updates required per day.

Additional person-hours required per week include two people over an average four hours from VICNISS and one Systems Manager at the DHHS over an average three hours. The time required was variable and dependent on the number of inpatient cases. The time required was much higher during implementation for all stakeholders, when SOPs were being developed and when new situations which were not prepared for occurred, such as the re-admission of cases to the same, or a different hospital, which were originally not easily captured in the reporting module.

Flexibility

In response to whether the system can rapidly adapt to changing information, half of survey respondents were undecided/neutral (9/18, 50%), seven strongly agreed or agreed (39%), and two disagreed (11%). In response to whether the system can rapidly adapt to changing operating conditions, most strongly agreed, or agreed (12/18, 67%), four were undecided/neutral (22%), and two disagreed (11%). One respondent added that detailed systems SOP enabled operational flexibility, whilst another added that operational flexibility was poor due to delays in the authentication process for VICNISS portal access. Various DHHS stakeholders mentioned that the system was not flexible as the manual processes cannot be automated.

The VICNISS platform was highly flexible and new data fields can be integrated with little to no systems interruptions. However, the addition of data fields was constrained by the prioritisation of hospital stakeholder acceptability. The reporting module had the ability to adapt, for example data uploads can be introduced as an alternative to manual data entry of new patients by hospital staff, however this function has not been introduced or requested, likely due to the small number of data fields and cases reported. Hospital staff were very complementary on the flexibility of the system, stating that recommendations were considered and acted upon promptly. The education resources on the VICNISS platform

facilitate changing staff conditions, however hospital-level systems flexibility was likely to differ as they were required to decide their most suitable method for obtaining and entering the data. For example, hospital stakeholders explained the use of handover emails, and comments in the patient record on the reporting module, to facilitate an understanding of complex admissions between the individuals responsible for the daily task. To facilitate flexibility and useability, hospital staff recommended the compilation of education resources into one resource with appendices, as resources were spread over several documents.

The PHESS database was flexible and new data fields can be integrated, however this may result in the addition of data fields that were not used consistently or be added for objectives outside of the surveillance system. Therefore, no additional data fields were requested to achieve the objectives of this surveillance system. Additionally, the PHESS database has capacity to receive information directly through data uploads however most information was entered manually due to the human thought that was required during data entry. Finally, the system was financially flexible, as increased funding was possible according to document review. However, the system was not built to be scalable and there was an undefined threshold point of when it could no longer be operational.

Data quality

A systems review revealed that the system consists of several processes of data cleaning to ensure that it captures data of high accuracy, completeness, and reliability. These processes included automated checks in the VICNISS reporting module and the use of statistical software to identify data discrepancies. Half of respondents reported that the system was vulnerable to data quality errors (9/18, 50%), and more than half of respondents disagreed that the system often has data quality errors (10/18, 56%). A key concern discussed by stakeholders was the timeliness of data, which was the subsequent attribute to be reviewed.

Survey respondents had mixed opinions as to whether they received quality training and supervision in their role for the system; around half strongly agreed or agreed (10/18, 56%), a quarter disagreed or strongly disagreed (5/18, 28%) and others were

undecided/neutral (3/18, 17%). A respondent added that the detailed SOP helped understand the system and contribute to high data quality. It was the responsibility of the individual to learn about the systems intricacies through reviewing the SOP. Acceptability was high for most stakeholders and was unlikely to have had a negative impact on data quality, and poor data quality would be identified and addressed during the daily data cleaning processes.

The pre-systems audit of 20 records entered by the Intelligence Team from VICNISS, compared to data entered by the Existing Cases Team from phone calls prior to implementation from April 5 to April 25, revealed that for all cases, demographics, identifiers and facility name were entered correctly. All cases that had been to ICU or were discharged were also reported, however the dates recorded in case notes were different to the VICNISS data for three quarters of cases (15/20, 75%). The admission date was recorded with delay for thirteen cases (65%), with a median time delay of 2 days. Discharge date was recorded with delay for two cases (10%), with a median time delay to discharge admission was 1.5 days. One case was entered into the reporting module for an extended duration as they remained under hospital isolation but had been cleared of isolation by the definition of the DHHS.

The accuracy audit of 20 records entered by the DART into PHESS, showed that data were complete and accurate post-implementation from April 26 to June 6. Cases were updated daily throughout the entirety of their hospitalisation, with 17/20 (85%) of records entered correctly. The three errors were as follows; one record had an admission date entered as a day early, one had a discharge date entered a as a day early, and another had a discharge date entered as a day late. The audit of reporting errors by hospital staff, showed that twenty percent (16/81) of new admissions entered in the reporting module from April 5 to June 6 had an error. The most common errors that required followed up were date of birth (10/16, 63%), sex (3/16, 19%) and discrepancies in isolation definitions (3/16, 19%). Finally, participant observation prior to the implementation of the system demonstrated that clinical information about COVID-19 cases were not captured accurately, and that the system provided a systematic way to improve data accuracy.

Timeliness

Most survey respondents strongly agreed or agreed (13/18, 72%) that the system informs of current hospitalisation status for patients with COVID-19 in a timely way, however three were undecided/neutral (17%), and two disagreed (11%). There were mixed opinions as to whether the system was not vulnerable to errors during weekends, public holidays, or other interruptions, as some agreed (8, 44%), others were undecided/neutral (4, 22%), and others disagreed or strongly disagreed (6/18, 33%). Stakeholder consultation and participant observation highlighted two issues with timeliness. Firstly, there was often a time lag as reporting was performed at a point in time rather than real-time. Secondly, reporting updates were not always provided on weekends and public holidays.

A systems review supported that the data was timely for the morning DHHS reporting requirements, as patients were likely have been discharged in the morning and subsequently entered the reporting module in the afternoon. However, for the Existing Cases Team follow up the next day, this data was 24 hours old and may not have been accurate. The once-a-day point in time element of reporting by hospital staff affects the time intervals of the surveillance system, however it would not have been reasonable to ask for real-time reporting.

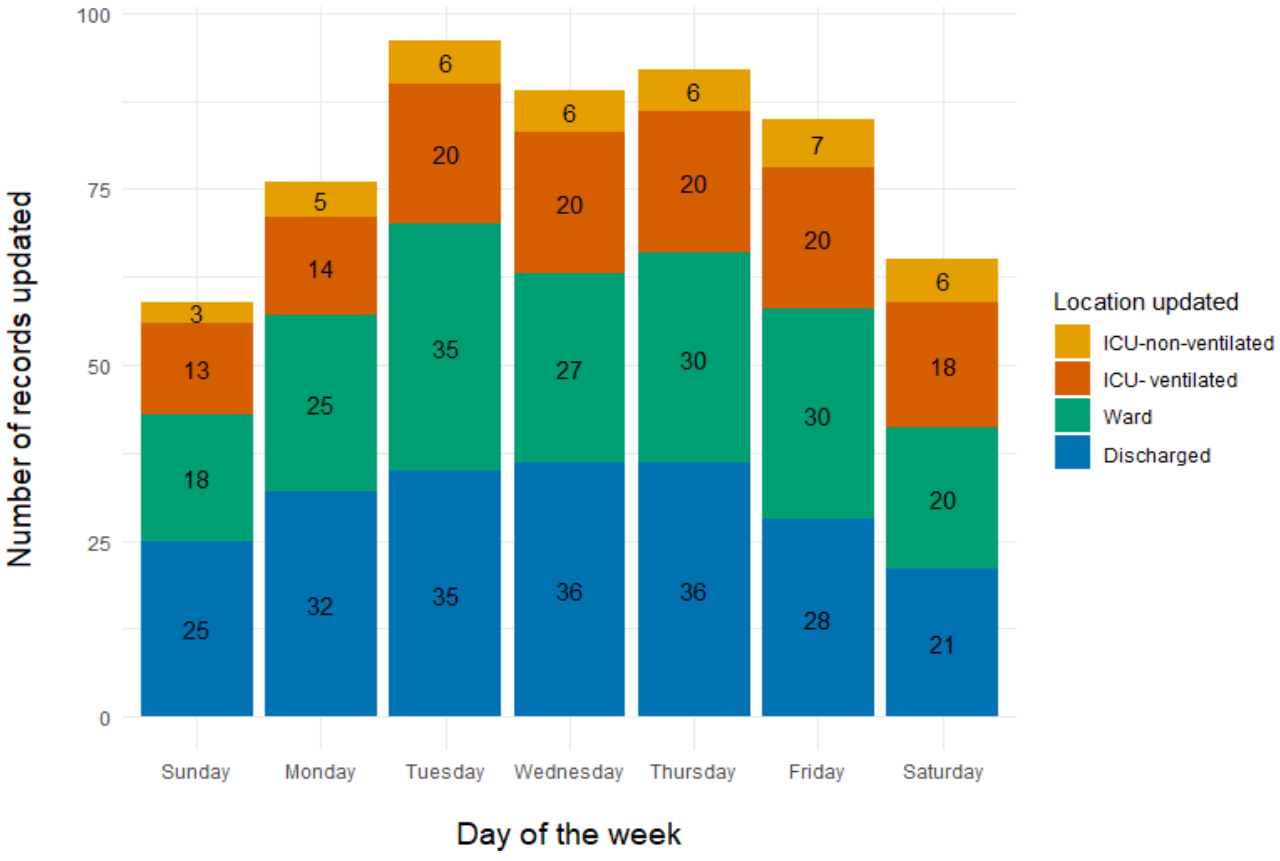
The audit of reporting bias supported that the system was vulnerable to data errors during weekends. As demonstrated in Table 6 and Figure 1, of 564 location record updates, most updates occurred on Tuesday (17%), Wednesday (16%), and Thursday (16%), slightly fewer occurred on Monday (14%), and Friday (15%), and the least updates occurred on Saturday (12%), and Sunday (10%). The highest number of record updates was on a Tuesday, this may relate to the fact that the weekly facility reminder email was sent that day, which requests hospitals to report if there had been hospitalised COVID-19 cases that week, or not. Table 6 explores the number of records updated by the location of the patient for each day of the week, demonstrating that all categories were updated the least on weekends. However, there appears to be less discrepancy in updating the ICU location on a Saturday, compared to updating discharge or ward.

Table 6. The total number of records updated each day of the week from March 19 to 6 June 2020, by the patient's most recent location status.

Day	Number of records updated (%)	ICU-non-ventilated %	ICU-ventilated %	Ward %	Discharged* %
Sunday	59 (10.5)	0.5	2.3	3.2	4.4
Monday	76 (13.5)	0.9	2.5	4.4	5.7
Tuesday	96 (17.1)	1.1	3.6	6.2	6.2
Wednesday	89 (15.8)	1.1	3.6	4.8	6.4
Thursday	92 (16.4)	1.1	3.6	5.3	6.4
Friday	85 (15.1)	1.2	3.6	5.3	5.0
Saturday	65 (11.6)	1.1	3.2	3.6	3.7

**Discharged includes death, DHHS clearance from isolation and discharged against medical advice.*

Figure 1. The number of records updated for each day of the week from March 19 to 6 June, by the patients most recent location status.



Stability

The ability of the surveillance system to perform daily relies on the stability of a few key platforms and processes. The VICNISS platform was highly stable with no outages reported by stakeholders, and all survey respondents strongly disagreed or disagreed that there were often failures in the platform. Although there were occasional failures with the DHHS processes using Stata statistical software, Excel spreadsheet output, and the PHESS database, 75% of survey respondents that use these platforms, disagreed that there were regular failures. Three stakeholders explained that failures in these elements impacted the surveillance system temporarily, but issues were usually resolved before the subsequent reporting period. The surveillance system was also highly stable in protecting privacy and confidentiality using secure encrypted Microsoft SQL Servers for both the VICNISS platform and the PHESS database, with no breaches reported. Various stakeholders reported that the system was not stable if there was a large increase in cases. The system was not built to be scalable, however there was no definition of when scalability would no longer be feasible.

Representativeness

The surveillance system accurately described inpatients in Victoria with COVID-19 by person, place, and time when data from the VICNISS reporting module were combined with the PHESS database. The system was highly representative, with around 95% of the 300 hospitals in Victoria consistently contributing to the surveillance system. The contribution of hospitals was limited when there was a lack of staff to perform the daily reporting requirements. Additionally, at the time of the evaluation, one rural facility was unable to complete the reporting as they did not have an IPC staff member. The weekly Tuesday reporting requirement was often delayed but promptly completed following a call by VICNISS staff. The late reporting was most common in small, rural, and private hospitals, who were most vulnerable to poor representativeness as they have lower staff levels. Participant observation at the DHHS revealed low reporting and awareness of whether cases were Aboriginal and Torres Strait Islanders, and this was not captured in this system which limits data quality and representativeness.

Discussion

This surveillance system was an important component of surveillance in Victoria that provided timely accurate data on the status of hospitalised COVID-19 cases. The system shifted a responsibility within the DHHS and assigned a considerable responsibility to hospitals for daily reporting, however it produced quality data to inform the public health response. The ability of the surveillance system to perform well in each attribute will shift with the severity of the pandemic, however at the time of this evaluation, the system performed well.

The system was rapidly deployed and operational within two months of conceptualisation. This was possible for various reasons. Firstly, there were long standing good relationships between all stakeholders. VICNISS and IPC staff in Victorian hospitals have almost 20 years of frequent interaction on surveillance, education, infection control advice, interventions, quality improvement tools and health services research. Additionally, VICNISS had worked with many program divisions of DHHS since its establishment. Secondly, VICNISS had established infrastructure including a secure online portal with an experienced information technology team that supported the implementation, management, and ongoing maintenance. This portal was designed to be of high-quality for user experience and was regularly used by IPC staff in Victorian hospitals prior to the emergence of COVID-19, which enabled a simple transition to use the reporting module launched for this surveillance system. Thirdly, VICNISS had experience with rapidly implementing and managing surveillance programs for emerging issues, which facilitated the rapid deployment of the new reporting module and educational activities. Finally, the DHHS rapidly adapted to operational change to integrate this surveillance system at the beginning of the public health emergency.

The system was very useful for the DHHS, but less useful for hospitals, who saw it as a reporting requirement for the government. The system had a trade-off between the acceptability of hospital staff and the data quality and detail the system could capture. Despite the low utility for hospitals, the system balances this trade-off well resulting in the acceptability of most stakeholders to participate. There was limited utility of the system

identified by hospital staff, although further consultation could enable an understanding of additional utility, the ongoing feasibility of the system, highlight when and how the system could be scaled-back.

Weekend reporting was a key issue in data quality and the acceptability of hospital staff. The system was vulnerable to delays in reporting over the weekend, which adversely impacted the DHHS follow up of cases that may be discharged over this time. The system was otherwise timely for the user's entry, cleaning, analysis, and reporting of data. It consisted of multiple layers of data checking which resulted in data quality that was higher than the processes pre-implementation.

Acceptability by hospital staff was also hindered due to potential duplicate reporting requirements. The system did not replace the mandatory urgent notification to the DHHS to report a test result that indicates that a person permanently or temporarily residing in Victoria has COVID-19. This one-off notification was an ongoing legal requirement for many infectious diseases in both the hospital and community settings, however it did not inform the status of hospitalised patients, or when the patient was discharged to inform the DHHS follow up of cases. Therefore, these reporting requirements had a distinct legal and functional basis and would be complex to integrate.

Hospitals may have also been required to report to other enhanced surveillance systems, which duplicate each other. ANZICS, SPRINT-SARI, FluCAN and CHRIS are separate hospital-based surveillance systems that do not integrate with this surveillance system. ANZICS was first established in 1994 and collects daily data on all ICU admissions in 207 ICUs across Australia, New Zealand and overseas. Therefore, the system includes, but is not limited to, patients in ICU with suspected or confirmed COVID-19. Data captured include patient demographics, primary diagnosis, and outcomes. ANZICS is limited to ICU patients at voluntary sentinel sites, and excludes patients admitted to other wards, and hospitals that do not voluntarily participate. SPRINT-SARI is an extension of ANZICS but restricted to a subgroup of 76 ICUs across Australia. At these sites, additional information is collected on ICU patients with acute respiratory infection, including the clinical care provided (i.e., surgery and medications administered), patient comorbidities and symptoms. SPRINT-SARI

is useful to share real-time clinical care information, particularly for novel diseases such as COVID-19, however it is not representative of all patients in the participating hospital, as they reflect only ICU patients.

FluCAN was launched in 2009 to capture severe influenza inpatient admissions at 15 tertiary care hospitals across Australia and New Zealand. In early 2020, the system expanded to include confirmed and suspected COVID-19 cases. Data captured include clinical and laboratory information, patient demographics, symptoms, comorbidities, and outcomes. The network of sentinel hospitals was established based on a pre-existing coalition of thoracic physicians and predominantly represent tertiary care adult hospitals in capital cities. Whilst FluCAN includes both ICU and non-ICU patients, the small number of participating sites are not representative of the state-wide situation.

CHRIS was launched in May 2020 as a collaboration between Telstra Purple, Ambulance Victoria, ANZICS and the Australian Department of Health. CHRIS is a dashboard used to monitor ICU occupancy in 191 hospitals in Australia. Each site updates ICU occupancy data throughout the day to provide real time updates which inform patient transport and retrieval agencies, including early diversion of ambulance presentations to hospitals that do not have ICU capacity. CHRIS was not intended to provide detailed patient-level data but is an operational tool that provides information to improve patient services and outcomes.

The VICNISS enhanced surveillance system has the distinct benefit of existing across all hospitals in Victoria, whilst the other systems are sentinel systems, based at specific hospitals. Additionally, this system directly informed the daily activities of the DHHS Intelligence and Operations Teams, whilst the other systems appeared to be more research and planning focused. Hospitals that regularly participated in research surveillance activities were vulnerable to additional reporting requirements, which may add to the time burden and reduce acceptability for this system.

The system required many manual processes that had a reliance on daily person-time availability to complete the tasks by a defined time. For the DHHS, complexities arose from the processes that were used to maintain information flows between teams in the public

health response. These processes were difficult to adapt during a health emergency, which causes a reliance on manual labour as opposed to automation of components of the system. However, educational efforts could facilitate the day-to-day users understanding of these information flows, which were often unknown by the DHHS and hospitals.

The system was reliable to perform without failure and to maintain confidentiality but was not flexible or stable to operating conditions if daily case numbers were to increase largely. The system was not intended to be scalable, however this has not been well communicated to users who expressed concerns regarding scalability. The system can be flexible to adapt to changing information needs, such as the introduction of new data fields, however these should be limited to prioritise acceptability. Minor adaptions could be considered that provide additional benefit to the public health response, such as the addition of whether the patient was known to reside in a RACF or identifies as Aboriginal and Torres Strait Islander. Overall, the system was representative of hospitals, however small, rural, and private hospitals were at risk of poor representativeness due low staffing levels that may cause an inability to report.

Strengths and limitations

This evaluation has several strengths and limitations that should be considered in the interpretation of results and recommendations. The evaluation was performed by an internal evaluator, who worked to implement and later manage the system. The key strengths of this position were that there was a strong understanding of the system, an extended period of participant observation and the ability to make ongoing improvements throughout the implementation. However, an insider perspective may create bias due to existing stake in the evaluation, as opposed to acting purely as an arbitrator or facilitator between stakeholders in this evaluation.

This evaluation was further limited by resource-constraints. The emergency response setting reduced stakeholders' engagement and participation and resulted in a lack of hospital staff representativeness. If the evaluation were performed outside of the emergency response setting, additional efforts would be made to engage a more representative group of stakeholders. The inclusion of hospitals from various locations and sizes, would reduce

assumptions and generalisations about the systems attribute, and help to inform recommendations. Finally, this evaluation was performed at a discrete time point, prior to a large surge in hospitalised cases in Victoria and cannot be extrapolated to the functionality under surge pressure.

Conclusion and recommendations

The enhanced surveillance system of suspected and confirmed hospitalised COVID-19 patients was rapidly established to facilitate the public health emergency response. This system was useful; however, lessons can be learnt to improve the current system and inform future systems. Therefore, recommendations are proposed below.

Recommendations for the current system

- The DHHS and VICNISS to have regular consultation with hospitals, to understand the feasibility and time required to contribute to the system and facilitate a decision for when the system could be scaled back. A focus should be given to small, rural, private hospitals and large hospitals that were at risk of reduced reporting capacity if cases were to increase.
- All stakeholders to consider alternative arrangements to weekend reporting to improve acceptability, data quality and timeliness. This could include the use of weekend calls by the DHHS or an acceptance of delayed reporting over this time. It was recommended that these arrangements focus on hospitals mentioned above that were at risk of reduced reporting capacity if cases were to increase. This will be required to occur in consultation with the DHHS Operations Team, to ensure the solution does not negatively affect workflow requirements.
- The DHHS to develop a detailed plan for how the system could be scaled back and how it will be dismantled in consultation with stakeholders. This will help resolve users concerns regarding the scalability and stability of the system and enable a smooth transmission for when this process was required.
- The DHHS to perform a comprehensive review of existing enhanced surveillance systems to see opportunities to integrate, restructure, or dismantle systems. This

review would help inform aspects of the plan in Recommendation 3, such as the shift from individual case-level follow up to the use of aggregate data to track the severity of hospitalised patients with COVID-19.

- The DHHS may benefit from providing additional staff training for this surveillance system as there were mixed opinions as to whether individuals felt they received quality training and supervision in their role for the system. Educational efforts could also facilitate the day-to-day users understanding of the system's information flows and manual process constraints, which were not clearly understood by many stakeholders. Training sessions were recommended to occur through live online training sessions with demonstration of data entry, in line with the SOP.
- VICNISS to integrate the ability for an automated facility report download on the reporting module. Currently, this report was provided through a request to VICNISS, however it would be simpler and more useful to have this report accessible at the hospital user's discretion.
- VICNISS to integrate access to hospitals history of the weekly Tuesday report on the reporting module. Currently, hospital stakeholders were unable to access a history of these reports about whether there had been COVID-19 patients admitted to the facility or not, which can reduce simplicity and usefulness for facility-level handover where there were multiple staff members performing this task.
- VICNISS to provide access to the DHHS to view the 'comments' data field that was used by hospitals for each patient on the reporting module. There was no direct communication between hospitals and the DHHS, however hospital stakeholders reported that the 'comments' data field in the reporting module was regularly used to explain the patient's information. This recommendation may facilitate the timeliness of the DART members who were performing the daily data cleaning and entry and may experience uncertainty about the reported patient's status and situation.
- DHHS to consider additional data specifications that could facilitate the public health response, such as the representativeness of reporting and outbreak detection. Specifically, the addition of whether a hospitalised case normally resides at a RACF and if they identify as Aboriginal and Torres Strait Islander may be useful. This

information could be captured in the surveillance system as Yes, No or Unknown, without adding a large time burden to hospitals.

- DHHS to remove redundant fields in the PHESS database to increase simplicity of data entry if this does not negatively impact on current workflows.
- All stakeholders to provide additional consideration to recognising the contribution of others to the system, as this was a theme amongst stakeholders. Strong interpersonal relationships were an important component to ensuring the system operates, but also to promote the morale and wellbeing of others.

Recommendations for future systems

- To increase engagement with all stakeholders during conceptualisation, to gauge how the system would impact workloads where workforce capacity was constrained, and to determine the feasibility of such systems.
- In the process of stakeholder engagement during conceptualisation, all data definitions were aligned and agreed upon. The differing definitions of isolation between hospitals and the department resulted in complexity both within and between stakeholders and reduced the utility of the system.
- Educational resources intended for non-clinical staff were reviewed by non-clinical staff so that they were immediately useable.
- For the DHHS and VICNISS to work together for enhanced surveillance system deployment in hospitals and/or RACFs during public health emergencies. The partnership in responding to the COVID-19 pandemic was highly effective.

Public Health Implications

The outcomes of this evaluation were provided to stakeholders with the aim of making real-time improvements to the surveillance system, and to inform the implementation of future systems that can be rapidly deployed. In October 2020, I engaged in a follow up debrief with three staff members who managed the system at that time. This enabled an understanding of key changes to the system, as recommended by the evaluation, along with how the system performed through the 'second wave' in Victoria, from July to October 2020 where there were over 7,000 active cases at one point in time and an increased burden on the hospital system. This debrief revealed the following points:

- DHHS had performed a review of potential additional data specifications that could provide utility to the public health response. This revealed a key opportunity to facilitate outbreak detection, the inclusion of 'was this a healthcare associated coronavirus infection'. After several healthcare outbreaks in Victoria's second wave, this data specification became instrumental in working together with IPC departments to determine acquisition. The DHHS had limited hospital-level transmission event detail, whilst IPC departments collected detailed information on risk factors, including description of PPE use, rostering schedules, and proximity and duration of interactions with individual staff and patients, that can better inform decisions on acquisition. This led to the establishment of a working group on healthcare associated infections which included senior DHHS officials, senior IPC staff and hospital CHOs.
- DHHS had provided additional staff training for this surveillance system and spread responsibility of the system across two System Managers, and a senior supervisory staff member. This training included further live demonstrations with demonstration of data entry, and video recordings, in line with the most recent SOP.
- VICNISS immediately provided access to the DHHS to view the 'comments' data field that was used by hospitals for each patient on the reporting module. This was reported as extremely useful to understand the patient's situation, and to reduce the time needed by the DHHS to grasp the situation, which had previously required follow up with VICNISS staff.

- VICNISS integrated access for hospitals to access history of the weekly Tuesday report on the reporting module, to increase simplicity of facility-level handover where there are multiple staff members performing this task.
- The system had sustained Victoria's second wave, despite concerns around the stability and limited flexibility. The daily time required by the DHHS increased to 2.5hrs for an employee to enter and process data, however there were no issues in staff resourcing to perform the task. It was noted that there were concerns around data quality during this period, however an additional audit was completed by DHHS that revealed the system continued to capture high-quality data, and data discrepancies were more commonly a data entry result of errors in the DHHS database.
- There was recognition that future system planning should consider the results of this evaluation, notably, the recommendation to increase engagement with all stakeholders during conceptualisation. However, as this debrief was performed at a time when the pandemic remained a large threat to Victoria and Australia, there had yet to be the opportunity to plan for future systems.

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Appendices

Appendix 1. Presentation abstract for the Australian National University Research School of Population Health Seminar, August 2020.

Australian National University

Research School of Population Health Seminar Series

MAE SEMINAR

An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response in Victoria

Stephanie Curtis, MAE Scholar

Thursday 27th August 2020, 12:30 – 12:45

Zoom Link Meeting ID: 989 2327 2351 Password: 037507

Steph is currently undertaking the MAE with a joint placement at the Alfred Hospital and Burnet Institute. She commenced the MAE with a secondment to the Victorian DHHS to assist with the COVID-19 public health response. She has a background in research, community health and emergency preparedness & response, and remains actively involved in harm reduction and emergency services in Victoria.

Abstract

***Background*:** Public health surveillance can help facilitate a rapid and effective response to public health emergencies. In response to coronavirus disease (COVID-19), an enhanced surveillance system of hospitalised COVID-19 patients was established by the Victorian Department of Health and Human Services (DHHS). The system aimed to reduce workforce capacity constraints and increase situational awareness on the status of hospitalised patients to assist with the response.

Methods: This evaluation used guidelines from the United States Centres for Disease Control and Prevention to evaluate the surveillance system according to eight system attributes. Evidence were generated through stakeholder consultation (survey and/or semi-structured interviews), participant observation, document review, systems review, issues log review and audits. Data were collected and analysed over a period of up to three months, covering pre- and post-implementation.

Results: This enhanced surveillance was rapidly established in response to a new disease threat. Established relationships and infrastructure enabled the system to be launched within one month of conceptualisation, and operational within two months. The system is useful for the public health response, and all 24 stakeholders agreed that the system was of importance. A key limitation of the system is untimely data on weekends, due to a reliance on daily reporting by hospitals. Additionally, the system lacks flexibility and relies on a high degree of manual labour because the systems data informs workflows for the public heath follow up of confirmed cases.

Conclusion: These results from this evaluation were presented to stakeholders and will be used to improve the current system and inform future rapid response systems.

ANU College of Health and Medicine

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Appendix 2. REDCap survey disseminated to the DHHS stakeholders for the evaluation of the enhanced surveillance system of hospitalised COVID-19 patients in Victoria.

Confidential

An evaluation of enhanced surveillance of hospitalised COVID-19 patients to inform the public health response

This work was performed under the Public Health and Wellbeing Act 2008 (the Act) and is approved under the Australian National University Human Research Ethics Committee 2017/909.

The evaluation has been approved by the Intelligence Team Leads. Participation in this evaluation is voluntary and confidential. Your decision to participate, or not participate, will not have any ramifications.

What was your role in the enhanced surveillance of inpatients with COVID-19 using VICNISS data? *can select more than one	☐ DHHS Intel - Lead/Manager/Supervisor ☐ DHHS Intel - Development ☐ DHHS Intel - Data and reporting ☐ DHHS Intel - Governance ☐ DHHS Operations - Manager/Team Lead ☐ DHHS Operations - Public Health Officer ☐ Other
What was your other role?	_____
Which of the follow DART activities did you participate in?	☐ VICNISS data processing ☐ AIHW reporting ☐ Sit Rep reporting ☐ Respond to ad hoc data requests
Which stages were you involved with for the surveillance system? *can select more than one	☐ Design ☐ Implementation (when the system was rapidly adapting) ☐ Post-implementation (when the system was mostly finalized)

Usefulness

	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree
The system reduced the time required for DHHS to perform follow up calls to hospitals about inpatients with COVID-19	○	○	○	○	○
The system detects changes in hospitalizations with COVID-19	○	○	○	○	○

Additional comments about usefulness (optional)	_____

Acceptability	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree
The reporting of COVID-19 inpatients is of public health importance	○	○	○	○	○
The system reduced my workload	○	○	○	○	○
The time required by this system was justifiable because of the value of the information collected	○	○	○	○	○
Recommendations for systems improvement I/my team made were considered	○	○	○	○	○
I/my team received acknowledgment for contribution to the system	○	○	○	○	○

Additional comments about acceptability (optional) _____

Simplicity and Timeliness	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree
This is a simple process for data collection and reporting on hospitalisation status for inpatients with COVID-19	○	○	○	○	○
The system informs DHHS of current hospitalisation status for patients with COVID-19 in a timely way	○	○	○	○	○

Additional comments about simplicity or timeliness (optional) _____

Data Quality	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree
The system is vulnerable to data quality errors	○	○	○	○	○
The system often has data quality errors	○	○	○	○	○

I received quality training and supervision in my role for the system	○	○	○	○	○

Additional comments about data quality (optional) _____

Stability

	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree	Not applicable
There are often failures in the PHESS database	○	○	○	○	○	○
There are often failures in the VICNISS portal (leave blank if N/A)	○	○	○	○	○	○
There are often failures in STATA processing and Excel spreadsheet output	○	○	○	○	○	○
The system is stable and not vulnerable to errors during weekends, public holidays, or other interruptions	○	○	○	○	○	○

Additional comments about stability (optional) _____

Flexibility

	Strongly Agree	Agree	Undecided / Neutral	Disagree	Strongly Disagree
The system can rapidly adapt to changing information e.g. including new information or integrating other information sources	○	○	○	○	○
The system can rapidly adapt to changing operating conditions e.g. changes to personnel	○	○	○	○	○

Additional comments about flexibility (optional) _____

Conclusion

Please share any additional thoughts or information (optional) _____

Would you be willing to further discuss your answers in a call/face-to-face discussion? ○ Yes ○ No

What is your email address so I can contact you to organise this? _____

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Chapter 4: Proximity networks to quantify and mitigate the risk of COVID-19 transmission in healthcare

Prologue

In response to the public health issue of transmission of SARS-CoV-2 in healthcare settings, I collaborated with a multidisciplinary team to investigate how healthcare proximity networks may impact the transmission of SARS-CoV-2 in the hospital setting. This chapter explores my involvement in the design, implementation and analysis of this epidemiological study as part of my field placement with Alfred Health.

This project was conceptualized in late March 2020, followed by 10 months of study preparation. The study preparation involved working side-by-side with the Department of Electrical and Computer Systems Engineering at Monash University to design and trial a Bluetooth Low Energy (BLE) system for data collection on proximity networks in a laboratory setting. The study preparation also required extensive stakeholder consultation across Alfred Health and Monash University, to inform and advocate on the importance of our project, and to ensure the project could be implemented with minimal burden to staff and without impact to existing electronic systems in the hospital.

In 2021, data collection was piloted twice on a section of the Infectious Diseases ward at the Alfred Hospital, first from 27 January to 31 January and again 13 April to 18 April. We anticipated the final study data collection would be implemented on the COVID-19 ward for 30 days, however this was not feasible within the context of a pandemic and duration of the MAE. Therefore, this chapter presents the results of both pilot studies and explores barriers to the anticipated project implementation.

My role in this project included:

- Identify a problem of public health importance, transmission of SARS-CoV-2 in healthcare settings and limitations of conventional contact tracing.

- Conduct a literature review on transmission of SARS-CoV-2 in healthcare settings and engineering and information technology systems used to augment conventional contact tracing methods.
- Develop methods to address the problem of public health importance through collaborating with a team of engineers at Monash University and stakeholders across Alfred Health.
- Lead the project coordination, including preparation of the study protocol, Patient Information Consent Forms, other documents required for ethics submission, and grant applications.
- Obtain ethics approval from Alfred Health and the Australian National University Human Research Ethics Committees.
- Identify and engage with stakeholders at Alfred Health, to gather support and approval for the project through face-to-face and online meetings and presentations.
- Be the key contact person for the research study, including liaising with study participants to explain the project and respond to all queries.
- Work with the engineering team to scope the hospital environment, install and dismantle the data collection system for both pilot studies.
- Perform real-time audits of the data collection system during the pilot studies and try troubleshooting data collection system issues with guidance from the engineering team, as required.
- Develop a data analysis plan and work with the engineering team to analyse and interpret the results of the pilot studies.
- Publish the results of the second pilot study in a peer-reviewed journal, which was accepted by Infectious Diseases and Health in October 2021.
- Present the findings of the study as an oral presentation at the Alfred Health Video Showcase in October 2021 and the Australasian College for Infection Prevention and Control International Conference in November 2021.
- Continue to lead the study project coordination with the goal to complete the anticipated study outside of the MAE timeframe.

Acknowledgements

Thank you to the Monash University engineering team, Associate Professor Mehmet Yuce, Dr Fan Wu, Mr Adikari Rathnayaka and Mr Md Abdulla Al Mamun for your hard work to rapidly develop and adapt the system. Thank you to all staff at Alfred Health who supported the implementation of this project, including all study participants.

Lessons Learnt

My involvement in this epidemiological study was an opportunity to learn about the hurdles of prospective research projects, which were heightened due to the pandemic. The key lessons learnt include:

- Prospective epidemiological research requires the most planning and preparation, and for me, it was the most difficult project to complete for the MAE. I commenced the MAE with an alternative epidemiological study planned, 'A Point Prevalence Survey of Healthcare-Associated Infections in a hospital in Papua New Guinea.' In early 2020, I spent an intense two months collaborating with international partners to develop materials for the project's ethics submission to the Medical Research Advisory Committee of Papua New Guinea, however it was then announced that the ethics committee would be suspended indefinitely due to the pandemic. The project team remained in contact throughout 2020 and 2021, and when the ethics committee meetings recommenced, I updated all documentation and submitted the application in February 2021, which was later accepted in June 2021. Recognising that prospective research requires much planning and preparation, it was important to be adaptive and rapidly pursue another epidemiological project in early 2020.
- The hospital setting is a difficult place to implement prospective research, as the project will require involvement of stakeholders from many departments and at all levels of hospital staff. Our project required consultation with numerous stakeholders to consider the risks, benefits, and impacts of the project from the perspective of each department. We presented the project to all levels of hospital staff, from the executive team, to nursing staff at ward handover time. We also undertook safety and technology reviews with relevant heads of departments including Engineering, Data Governance and Security. An additional barrier was the

changing governance structures and location of the COVID-19 ward, which resulted in the need to repeatedly obtain the support and approval of new stakeholders.

- There will be components of an epidemiological project that are unlikely to be at the forefront of thought for an epidemiologist. This was my first involvement in a project that produced a novel product, which required drafting a Research Collaboration Agreement to define Intellectual Property, liaising with legal departments, and setting clear expectations within the team of future commercialisation, and within the framework of the National Health and Medical Research Council guidelines.
- It is common for grant applications to be rejected. We submitted the project proposal to three funding bodies over 2020-2021, however were not successful for any funding. The process of putting in a large amount of time and effort into grant applications, only to be rejected, can be disheartening; however, I learnt that the probability is that most grants will not be awarded. Each application can be used as a learning opportunity to refine grant writing skills.
- Multidisciplinary collaboration provided an exciting opportunity to develop novel ideas and learn from each other, however it created some challenges. In this project, it commenced with a learning curve for all to understand each other's technical background, and the strengths and weaknesses this creates. From an epidemiology perspective, this project required learning technicalities around BLE systems, including how they function to collect and deliver data, and how adaptions can be made. For example, the parameters of BLE systems are based on a programming language setup on a computer that speaks to the physical device, so changes often required adaption to code rather than the physical system. From an engineering perspective, this required learning about IPC, healthcare worker behaviour and how these may impact the implementation of a BLE system. For example, understanding that healthcare workers are unable to wear lanyards in the hospital environment and that the system needed to be durable when sprayed and wiped with hospital grade disinfectant. Importantly, these learning curves required minimising technical language where possible to communicate each other's expertise and suggestions.
- Multidisciplinary collaboration also highlighted the need for clear communication, physical documentation of meetings, outcomes, and expectations, especially when

using online telecommunication platforms for meetings. Our team experienced one key communication breakdown, which was not recognised until later in the project: differing timeline expectations for the pilot(s) and final project implementation. The Alfred Health research team anticipated there would be one or two pilot studies, followed by a study period implementation of 30 days. Conversely, the engineering team did not think there was a limit on pilot studies and that the study period implementation would be longer than 30 days, potentially 6 months. Although the timeline was specified in the protocol, expectations should be documented, and regularly discussed and adapted as required. As the study coordinator of this project, this was a key responsibility of mine which could have been facilitated by a shared project management platform tool.

- Finally, analysis of data outside of one's disciple can be very difficult. The data structure was complex and required programming of extensive algorithms to extract the anticipated metrics. I was only able to 'crack' some of the code required for data analysis, and therefore part of the analysis had to be performed in Microsoft Excel, which is not easily reproducible. However, I was proud to successfully learn how to perform a network analysis in statistical software and present these results in this chapter.

Public Health Implications

Although we were unable to complete the project for the anticipated scope and duration, we demonstrated the design and implementation of a novel idea in a hospital environment that with more resources, may be useful to quantify proximity networks and facilitate future contact tracing efforts. Further collaboration and funding applications will contribute to the development of this project beyond pilot studies. This future work may have public health impact in an environment where COVID-19 remains a high risk of transmission, such as hotel-quarantine, or for future infectious diseases outbreaks and/or pandemics.

Abstract

The following abstract is from the peer-review journal article: Curtis SJ, Rathnayaka A, Wu F, Al Mamun MA, Spiers C, Bingham G, Lau CL., Peleg AY, Yuce MR, Stewardson AJ. Feasibility of Bluetooth Low Energy wearable tags to quantify healthcare worker proximity networks and patient close contact: A pilot study. Infectious Diseases & Health. 2021.

Background

The hospital environment is characterised by a dense network of interactions between healthcare workers (HCWs) and patients. As highlighted by the coronavirus pandemic, this represents a risk for disease transmission and a challenge for contact tracing. We aimed to develop and pilot an automated system to address this challenge and describe contacts between HCWs and patients.

Methods

We developed a bespoke Bluetooth Low Energy (BLE) system for the hospital environment with anonymous tags worn by HCWs and fixed receivers at patient room doors. Proximity between wearable tags inferred contact between HCWs. Tag-receiver interactions inferred patient room entry and exit by HCWs. We performed a pilot study in four negative pressure isolation rooms from 13 April to 18 April 2021. Nursing and medical staff who consented to participate were able to collect one of ten wearable BLE tags during their shift.

Results

Over the four days, when divided by shift times, 27 nursing tags and 3 medical tags were monitored. We recorded 332 nurse-nurse interactions, for a median duration of 58 seconds [interquartile range (IQR): 39-101]. We recorded 45 nursing patient room entries, for a median 7 minutes [IQR: 3-21] of patient close contact. Patient close contact was shorter in rooms on airborne precautions, compared to those not on transmission-based precautions.

Conclusion

This pilot study supported the functionality of this approach to quantify HCW proximity networks and patient close contact. With further refinements, the system could be scaled-up to support contact tracing in high-risk environments.

Introduction

Background

There is a critical need to protect healthcare workers (HCWs) from infectious diseases to maintain the capacity of the health system to care for hospitalised patients and to prevent illness amongst HCWs. SARS-CoV-2, the virus responsible for COVID-19 is transmitted from person-to-person via aerosols, respiratory droplets and contact with contaminated surfaces. HCWs are at high risk of contracting infectious diseases, such as COVID-19, due to time spent interacting with patients and their co-workers at close proximity (1, 2).

High rates of HCW infection with COVID-19 emerged early in the pandemic. These infections were most related to inadequate PPE and high prevalence of patients with COVID-19, rather than the HCWs demographics or professional profile (3, 4). During the initial phase of the COVID-19 epidemic in Victoria, Australia from January to May 2020, HCW infections were largely acquired outside of the healthcare setting, however a series of hospital outbreaks followed across Australia, with at least 36 outbreaks in healthcare facilities reported and 536 HCW infections between 25 January and 8 July 2020 (5, 6). These outbreaks occurred in a time of low prevalence of COVID-19 in the community, which highlights the high-risk transmission settings of hospitals.

When a patient or HCW is diagnosed with COVID-19 and is identified as having been at a hospital while infectious, IPC teams perform contact tracing. Conventional contact tracing involves an interview with the infected case to identify any close contacts, casual contacts and suspected acquisition events. Close contacts are generally defined as people who have had either face-to-face contact for more than 15 minutes or sharing a closed space for more than two hours with a person diagnosed with COVID-19 (7). In Australia, confirmed COVID-19 cases and their close contacts are required to quarantine for 14 days and until they are no longer symptomatic. If a HCW attends work whilst infectious with SARS-CoV-2, and close contacts are required to quarantine, it presents a risk to the capacity of the health system as the healthcare workers are unable to work.

Conventional contact tracing methods are limited by cost, workforce capacity and rely on subjective data collection to recall events that occurred up to two weeks earlier. These limitations became apparent early in Australia's COVID-19 epidemic and resulted in a National Contact Tracing Review commissioned by the Commonwealth of Australia in November 2020. The report made a series of recommendations to improve contact tracing through technology so that disease transmission is terminated while minimising disruption to staff, patients, and health provision (8).

Electronic monitoring has typically been used in healthcare settings to track physiological parameters but has recently been used for contact tracing (9). Real-time location systems (RTLS) can be used to augment conventional contact tracing through collection of objective data, which can further facilitate modelling the transmission of pathogens (10). Two well-established RTLS are radiofrequency identification (RFID) and Bluetooth Low Energy (BLE) technology. Both RFID and BLE can be deployed as wearable technologies and share many similarities, however BLE technology uses more energy efficient beacons, enabling longer periods of data collection between recharging, and uses long-range data transmission (LoRa) as opposed to a short-range communication technology of RFID.

RFID and BLE have been deployed in healthcare settings for research and have continued to be deployed in response to COVID-19. A systematic review of RFID in hospitals explored 17 studies in a range of wards which reported varied accuracy and precision for location identification, however no studies were used for contact tracing (11). There is limited literature exploring BLE systems in the hospital setting, likely because they are more costly than RFID. However, BLE technology has been used at the population level using phone applications, as illustrated by the Australian Government's COVIDSafe application. Additionally, commercial BLE contact tracing platforms began to emerge in late 2020, however there is currently no studies in published literature that explores their implementation in the hospital setting.

In Singapore, a wearable RTLS tag had higher sensitivity for detecting HCW-patient contacts than the national Bluetooth phone application used for community-driven COVID-19 contact tracing (12, 13). RTLS are advantageous over mobile phone applications, through avoiding

the need for individuals to install and activate the application and continuously carry their phone. RTLS have also been combined with data from Electronic Medical Record systems to leverage existing hospital information and develop a digital ecosystem for contact tracing of infectious diseases (14, 15).

There are practical, ethical and legal considerations required when designing a RTLS to be implemented in healthcare settings. The system needs to be acceptable by HCWs, including limiting any time or practical burden. The system also needs to protect privacy, preserve autonomy, maintain beneficence and non-maleficence, and in the context of COVID-19 where technology is accelerating, the system may require an expiration date (9, 16). Therefore, the success of RTLS in the healthcare environment is dependent on these considerations, along with its validity and reliability.

The COVID-19 pandemic quickly revealed the public health issues of the high risk of SARS-CoV-2 infection for HCWs, the risk this poses to the capacity of the health system and the limitations of conventional contact tracing. Innovative approaches, such as the automation of contact-tracing, can facilitate real-time information for proactive decision-making and outbreak management. Despite substantial promise of contact tracing technologies, the effectiveness of digital solutions is largely unproven as there are few published data in real-world outbreak settings (17). Therefore, this study investigated how a BLE system can provide data to construct contact proximity networks in the healthcare setting and be used to augment contact tracing.

Aims and objectives

The aim of the study was to develop and pilot a BLE system that could augment contact tracing in health care settings. The three objectives were:

1. To record the frequency and duration of primary close contact between HCWs and patients to estimate the average exposure time per patient-day for various HCW professional categories.
2. To characterise the network of contacts between HCWs to identify critical opportunities for intervention to reduce the risk of SARS-CoV-2 transmission.

3. To perform a series of accuracy and precision tests to demonstrate proof of concept for the BLE system to be used to assist with contact tracing efforts.

Methods

Study design, setting and population

This was a single-site contact network epidemiology study. Two pilot studies were performed to test the functionality of a novel BLE system (see below) in a hospital setting, from 27 January to 31 January, then 13 April to 18 April 2021. The pilot studies were set on the Infectious Diseases ward at the Alfred Hospital in Melbourne, Australia, and a section of the ward was used to capture patient interaction; four negative pressure rooms used to isolate patients. The study population were nurses or doctors whose primary role was based on the Infectious Diseases ward.

Participant recruitment

Potential participants were first approached by a senior member of their department through an email invitation. The email consisted of a web link and Quick Response (QR) code to a survey where participants could sign an online Participant Information Consent Form using REDCap, hosted on the Monash University server (18, 19). All participants that signed the e-Consent form were automatically sent a copy of their signed form from the REDCap server. The invitation email also contained a copy of the participant information and consent form as a Microsoft Word document, allowing participants to sign and send a copy to the research team if preferred.

Research study posters were also placed on the study ward, with a web link and QR code leading to the e-Consent form to simplify the process. During the pilot studies, the Study Coordinator and/or Principal Investigator were present on the ward throughout the day to present the study at handover meetings, and to answer any questions from participants and/or staff members.

Sample Size

The sample size was determined pragmatically by the number of eligible HCWs that consented to participation and collected a BLE tag for their shift. Both pilot studies were performed using a small group of HCWs, with up to five nurses and five medical staff at any point in time due to wearable tag availability.

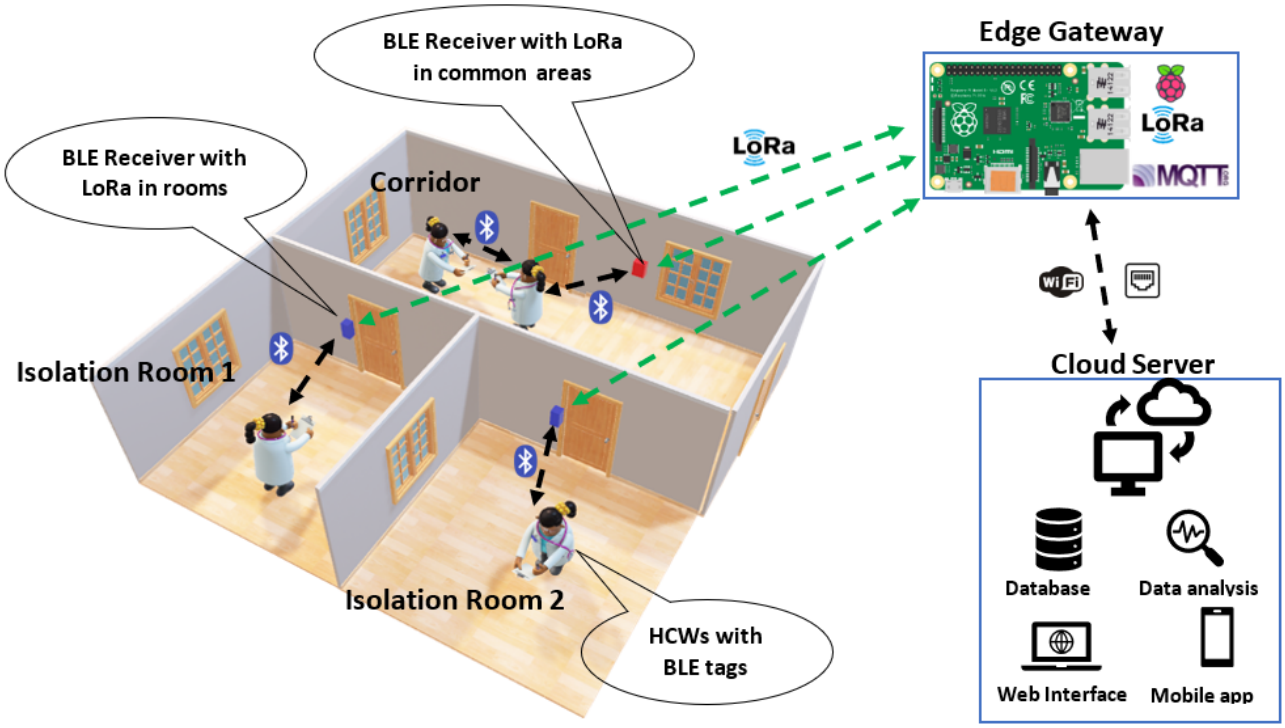
Ethics

Ethics approval was obtained from Alfred Health Human Research Ethics Committee [651/20] and reciprocal ethics approval was obtained from the Australian National University Human Research Ethics Committee.

System explanation

This study utilised BLE technology for data collection. The system consisted of three key physical components: wearable tags, BLE receivers and an edge gateway. Each component is described in detail below and the overall architecture of the system in the hospital setting is presented in Figure 1. The BLE system was built, tested and continuously refined in a laboratory at the Department of Electrical and Computer Systems Engineering at Monash University. The system was designed with contribution by IPC professionals to allow for safe implementation. The initial laboratory system was also refined after a scoping visit to the hospital by the engineering team to ensure the system could be transferred from the laboratory to hospital environment for the pilot studies.

Figure 1. A simple representation of the architecture of the Bluetooth Low Energy system in the hospital setting.



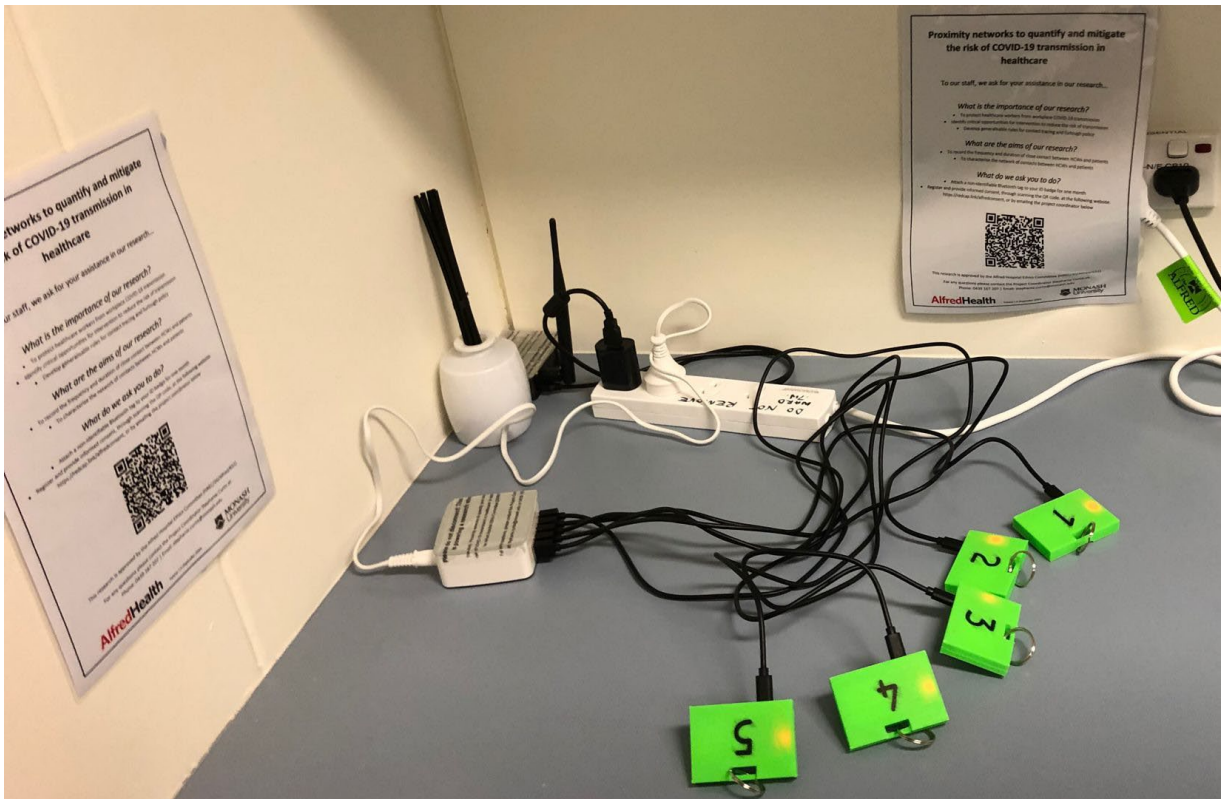
Component 1. Wearable tags

The wearable tags were electronic devices composed of a low-power BLE module (nRF52840). The tags were employed as a movable BLE beacon that functioned continuously with an anonymised identification number. The tags retained a list of interactions with other tags which were uploaded to the BLE receiver with LoRa by making a temporary BLE connection. The operating frequency of the BLE module was 2.4GHz and a baseline transmission power of 0dBm with the capability to transmit up to +8dBm. The tags were powered using a rechargeable lithium-ion battery with a capacity of 400mAh which can last approximately 40 hours in continuous usage. The tags had a light that appeared when it was successfully being recharged via a 5V Universal Serial Bus Adapter with Universal Serial Bus Type C cord.

The wearable tags had an external plastic casing sized 45x65x10mm, that could easily be cleaned according to hospital IPC standards. The tags were placed in a pocket or bag or attached to the identification badge of the HCWs. The tags were coloured according to the

participants' staff group. In the pilot studies, this was red for medical staff and green for nursing staff. In the pilot studies, the tags were also numbered, to facilitate with systems validation testing, whilst maintaining anonymity of participants. Figure 2 presents an example of the wearable tags on their charging port in the hospital.

Figure 2. The Bluetooth wearable tags placed on a charging station on the hospital ward.



Component 2. BLE receivers

The BLE receivers included two proximity sensors that recognized the wearable tags, recorded entries and exits through detecting direction of movement, stored the wearable tag data, and forwarded the data to the gateway device using a RFM95 LoRa module. All data were encrypted using a standard AES-128-bit cipher. Each receiver battery life was estimated to be six days. The receivers had an external plastic casing sized 85x85x30mm and were attached to the door of the patient's room and in the corridors of the ward using a reversable adhesive tape, at a height of around 140cm from the floor to ensure the detection of the human body. An example BLE receiver is provided in Figure 3.

In the first pilot, there were two types of BLE receivers: one with LoRa, and one without LoRa, whereas all BLE receivers had LoRa in the second pilot. The aim of the two types of BLE receivers in the first pilot was to have an intermediate data transfer point that was physically located between the first BLE receiver and gateway to prevent the loss of data transmission due to distance. In the second pilot, the BLE receiver with LoRa included a micro–Secure Digital card to both store and forward the data to the gateway device.

Figure 3. A Bluetooth Low Energy receiver attached to the wall using adhesive tape.

Component 3. Edge gateway

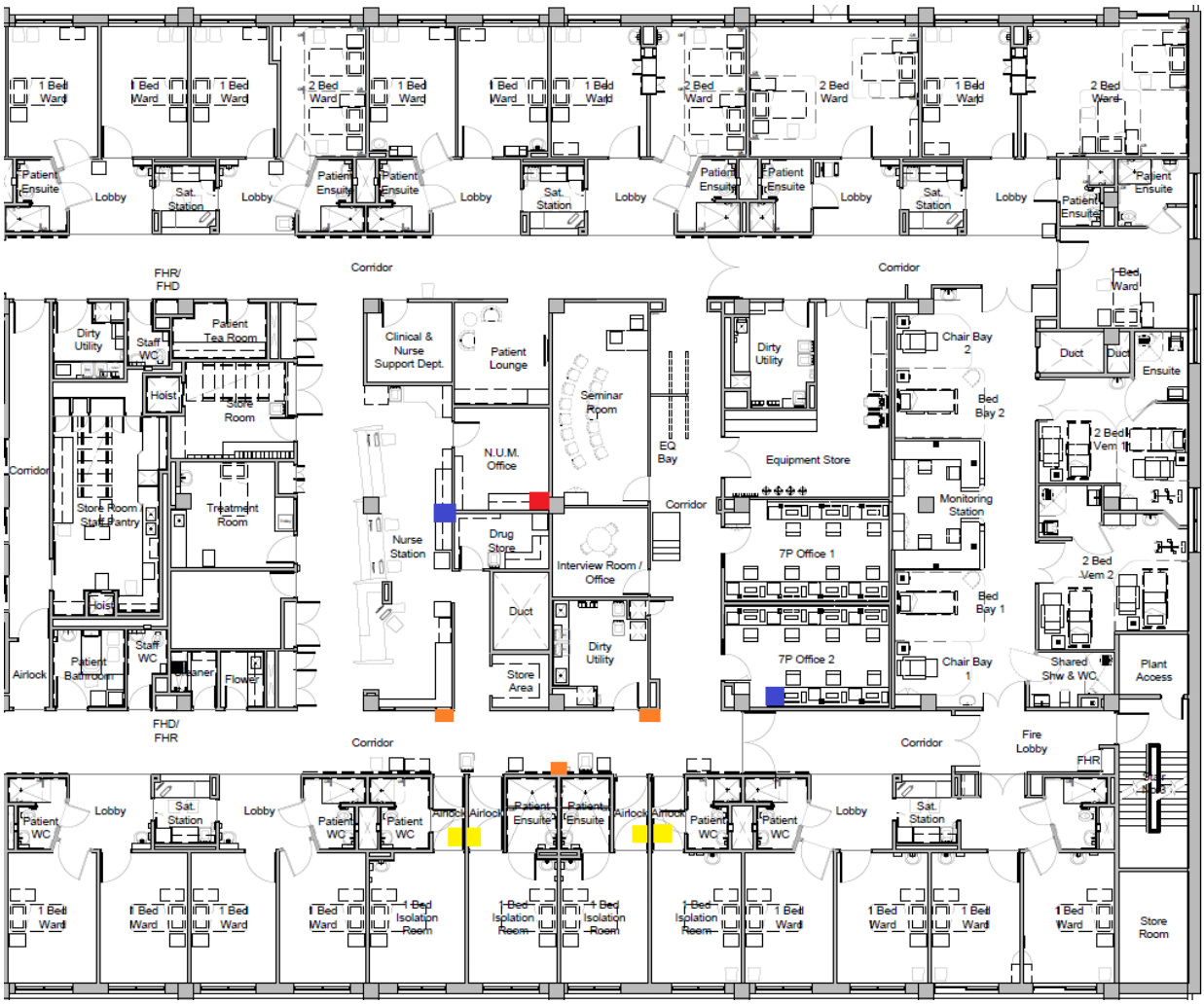
The edge gateway was a local computing device that acted as a bridge to receive the wireless data, then forwarded the data with Message Queuing Telemetry Transport encryption using Wi-Fi to the local secure cloud server hosted by Monash University. The gateway was protected by a firewall to restrict external access and remained powered via a 5V Universal Serial Bus Adapter in the Nurse Unit Managers office to ensure continuous and safe operation. The gateway device is present in Figure 2, in the corner of the table with the black antenna.

System installation

Figure 4 provides a map of the ward with coloured markings of where each device was installed, whereby blue represents the charging ports for the wearable tags, yellow represents the BLE receivers used in both studies, orange represents the BLE receivers used only in the first study, and red represents the gateway device. BLE receivers were placed in

the negative pressure room anteroom (i.e., the small hallway between the patient room and the ward corridor, where the patient bathroom door is located) to infer room entry and exit.

Figure 4. Map of the study ward where the Bluetooth Low Energy system was piloted, with coloured markings of device installation locations.



Data validation

During the pilot studies a member of the study team frequently performed real-time checks to ensure that the wearable tags were being detected on the cloud server. This process involved noting a wearable tag number and BLE receiver room number, monitoring entries and exits into the room, then comparing this to the data on the cloud server. Additionally, an audit was performed after pilot study two to compare data on the BLE receiver micro–Secure Digital card with the cloud sever data to confirm there was no data loss.

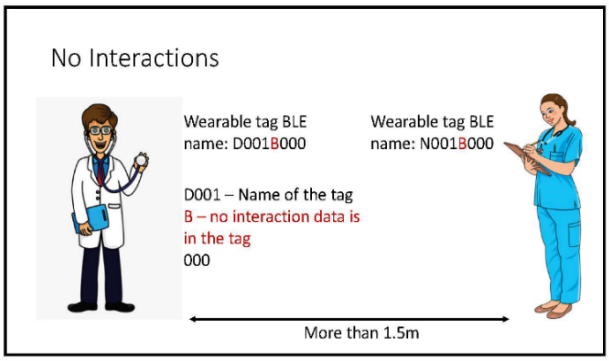
Data processing

Automated data processing commenced as the data arrived at the cloud server through code programmed in Python Version 3.9.0 (20). The code consisted of a series of functions with parameters for how the system would capture data. For example, the parameter of close contacts of tags was set to be within 1.5 meters of each other for at least 30 continuous seconds, or if the tags return to be within 1.5 meters within 20 seconds since the previous interaction, the recent interaction times were aggregated into one interaction, to allow temporary signal loss. Close contact between HCW and patient was inferred by HCW tag-receiver interaction that captured room entry and exit, for a duration of at least 30 seconds. The 30 second threshold was applied to prevent instances where the participant was standing in front of a receiver within the anteroom, whilst eliminating implausible results of short interactions with a patient in airborne precautions. The patient close contact was identified through an entry/exit by the BLE receiver and a detection of a wearable tag with a Received Signal Strength Indicator of $\leq$65 decibel-milliwatts which indicated distance of the tag from the receiver. Post processing, data were available directly from a PHP web interface which provided real time visualisation of all interactions and room entry/exit data. A simple overview of data capture is presented in Figure 5.

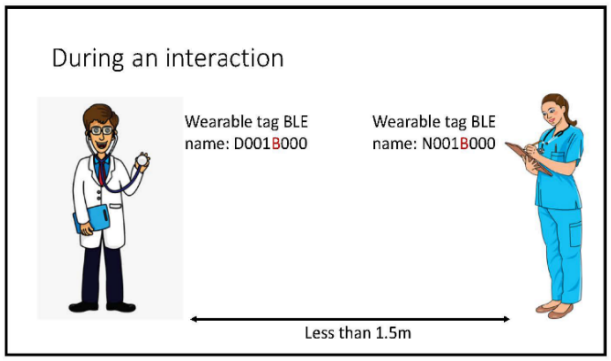
Data analysis

Data were available for download from the cloud server for analysis through extraction as comma-separated values files, for each tag and BLE receiver. Descriptive analysis was performed for interaction and network data, with continuous variables summarised as median with IQR and ordinal variables as count with percentage. We estimated the number of nursing tags monitored overall and per day, by dividing data into shift times morning (7:00-1:59), afternoon (14:00-21:29) and night (21:30- 06:59). There was only one shift time for medical staff on the study ward, therefore, data were divided by days to estimate the number of tags monitored. Data matching of BLE receiver and distance of wearable tags to infer entry and exit was performed using Microsoft Excel, as the format of the data required manual human interpretation, opposed to the use of a coded algorithm. Data collation, visualisation and all other analysis were performed using R Version 4.0.2, with network graphs constructed using 'igraph' R package (21).

Figure 5. A simple overview of the Bluetooth Low Energy system data capture of participant interaction and room entry/exit data.



1



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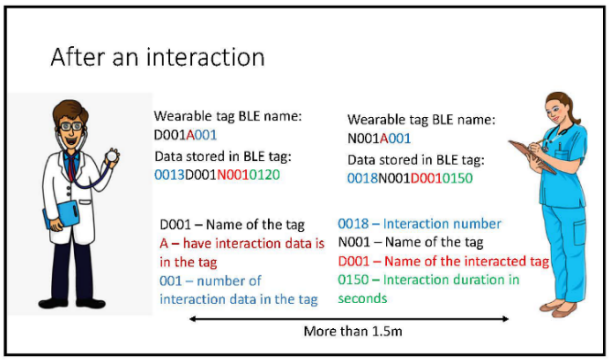

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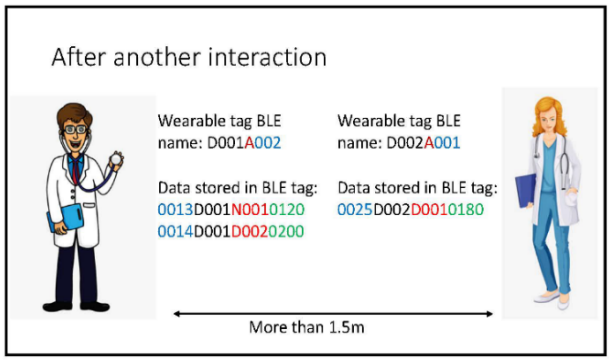

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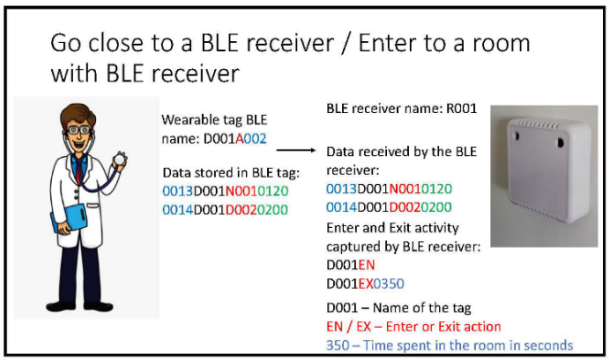

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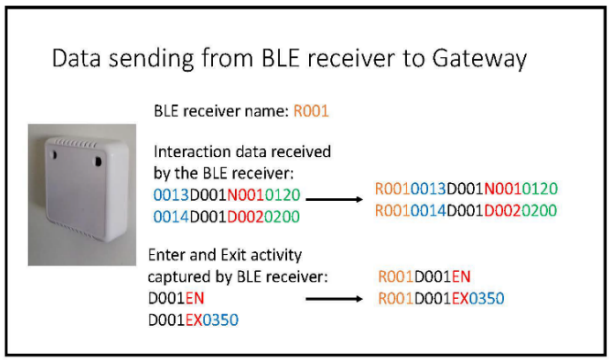


6

Results

Pilot study one

In the first pilot, there were numerous challenges that inhibited the ability to collect reliable data, however these challenges informed the system adaptations required. Data were collected between 10:30 27 January to 22:50 28 January, and we estimated 14 nursing tags and 6 doctor tags were monitored. Room entry/exit was recorded for all four rooms.

Table 3 provides an overview of the issue identified in pilot study one, reason for the issue, and solution implemented in preparation for pilot study two. Firstly, there were over 100 Bluetooth devices detected in the hospital by our BLE receivers, these devices had high transmission power that interfered with data transfer from the BLE receiver without LoRa to the BLE receiver with LoRa. The solution was to remove the intermediate BLE receivers without LoRa and increase the transmission power of BLE receivers.

Table 3. The identified issues, reasons and solutions of the Bluetooth Low Energy system during pilot study one.

Issue identified	Reason	Solution
Detection of other Bluetooth devices	Interference with data transfer from BLE receiver and BLE receivers with LoRa.	Remove the intermediate BLE receivers without LoRa and increase the transmission power of BLE receivers with LoRa.
Missing entering and exiting data	BLE receivers were programmed to perform too many tasks.	Some tasks that were at the individual BLE receiver level, were transferred to be the role of one specific BLE receiver.
	The data processing algorithm code failed to detect quick entry and exit into rooms.	The code was reviewed and fixed, including a reduction in the time required to be near the receiver.
No data received by the cloud server for two days	The data processing algorithm code had errors that prevented data being sent from the gateway to the cloud server by Wi-Fi.	The code was reviewed and fixed. As additional contingency, a micro–Secure Digital card was added to the BLE receiver with LoRa so it could also store all data captured.

Secondly, there were missing entering and exiting data, as revealed during the real-time auditing and overall low quantity of data captured. This was caused by an overload of tasks required by each BLE receiver, including receiving interaction data and forwarding them to the router, while checking entering and exiting tasks. The solution was to shift some of these tasks to be the role of one specific BLE receiver that was placed next to the gateway. Missing entering and exiting data were also caused by a data processing issue in the Python code which failed to detect when a tag quickly entered the negative pressure room anteroom. This was simply resolved through altering the parameters in the code to reduce the time required to be near the receiver.

Finally, no data were detected by the cloud server for the final two days of the pilot study. Investigation revealed that it was due to an error in the Python code, therefore this issue was easily resolved through reviewing and fixing the code. As additional contingency to prevent data loss, a micro–Secure Digital card was added to the BLE receiver with LoRa so it could both store and forward data to the gateway device.

Pilot study two

The second pilot study had significant improvements than the first pilot. Data were received by the system between 12:00 13 April to 08:30 to 17 April. Over this period, we estimated that 27 nursing tag and 3 doctor tags were monitored, when dividing results by shift time and day. Over the four days, it was estimate that eight tags were used in the morning nursing shift (07:00-1:59), 11 in the afternoon nursing shift (14:00-21:29) and eight in the evening nursing shift (21:30- 06:59). Room entry/exit was recorded for all four rooms. Table 4 presents a summary of the nurse-nurse and nurse-patient close contact data.

Table 4. Nurse-nurse and nurse-patient close contact during pilot study two, by nursing shift times.

Data metric	Total	Morning	Afternoon	Night
Tags active, N	27	8	11	8
Nurse-nurse close contact events, N (%)	332	213 (64.2)	90 (27.1)	29 (8.7)
Median time of nurse-nurse interaction event [IQR] (seconds)	58 [39-101]	65 [41-113]	50 [37-71]	52 [34-92]
Nurse-patient close contact events, N (%)	45	23 (51.1)	15 (33.3)	7 (15.6)
Median time of nurse-patient interaction event [IQR] (minutes: seconds)	6:58 [2:57-20:36]	8:25 [2:59-29:00]	5:32 [2:51-11:12]	9:30 [3:59-14:48]

IQR=Interquartile range

A total 332 nurse-nurse interactions were recorded for all participants: 64.2% (213/332) in the morning, 27.1% (90/332) in the afternoon and 8.7% (29/332) in the evening. The median time of nurse-nurse interaction was 58 seconds [IQR: 39-101]; which was similar across all shift times. Additionally, two medical-nursing interactions were recorded, for 80 seconds and 86 seconds. There were no medical-medical interactions detected, and all other medical-nursing interactions did not fit the duration criteria for an interaction.

Figure 6 presents a heat map of the number of nurse-nurse interactions during pilot study two. Medical tag 1 also recorded two interactions, both with nurse tag 4. Figure 7 presents network graphs of the interactions recorded, by the total count (Figure 7A) and total minutes (Figure 7B). There were 545 minutes of interactions recorded, for a median 36 minutes [IQR: 5-67] per HCW-HCW tag combination. Nurse tag 4 and nurse tag 5 had 211 minutes of interaction and nurse tag 2 and nurse tag 4 had 72 minutes of interaction, as represented by dense clustering of the edges between these HCW nodes in Figure 7B, compared to Figure 7A.

Figure 6. Heat map of nurse-nurse close contact events during pilot study two.

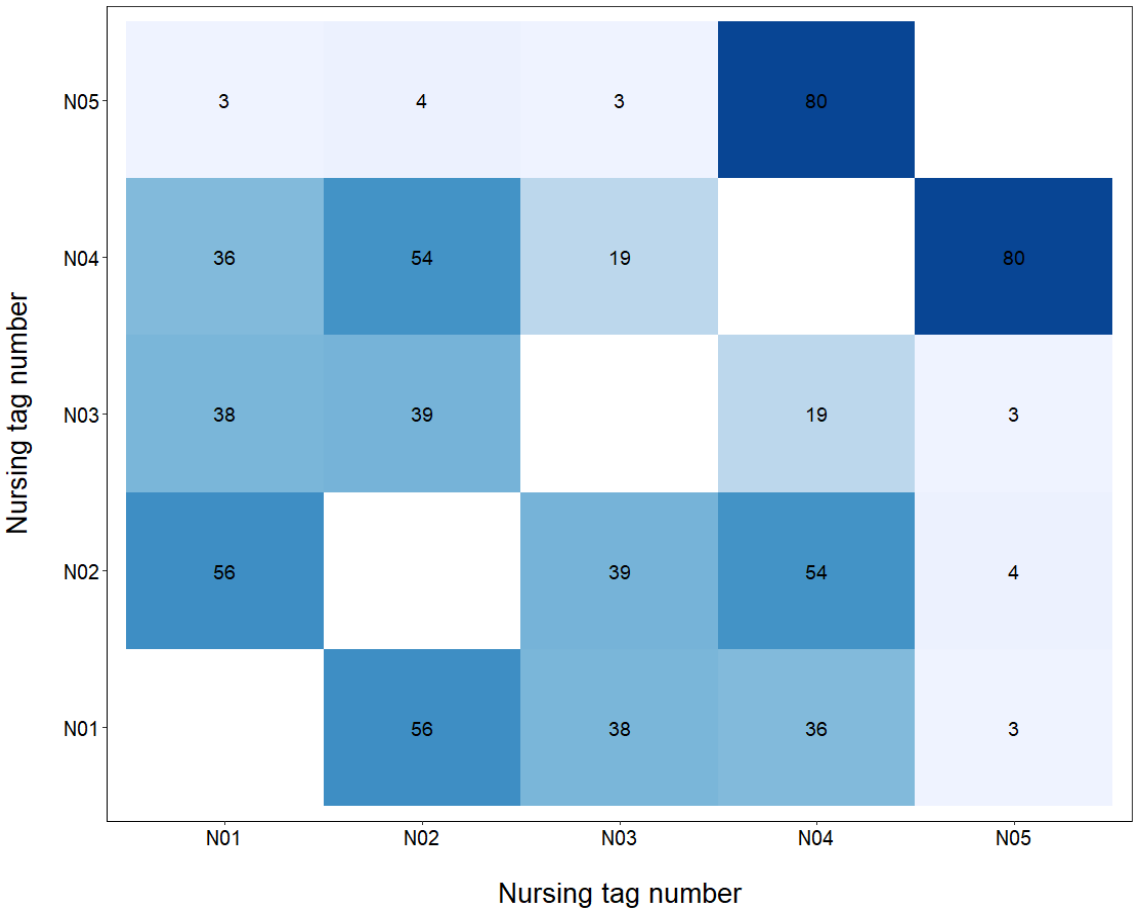
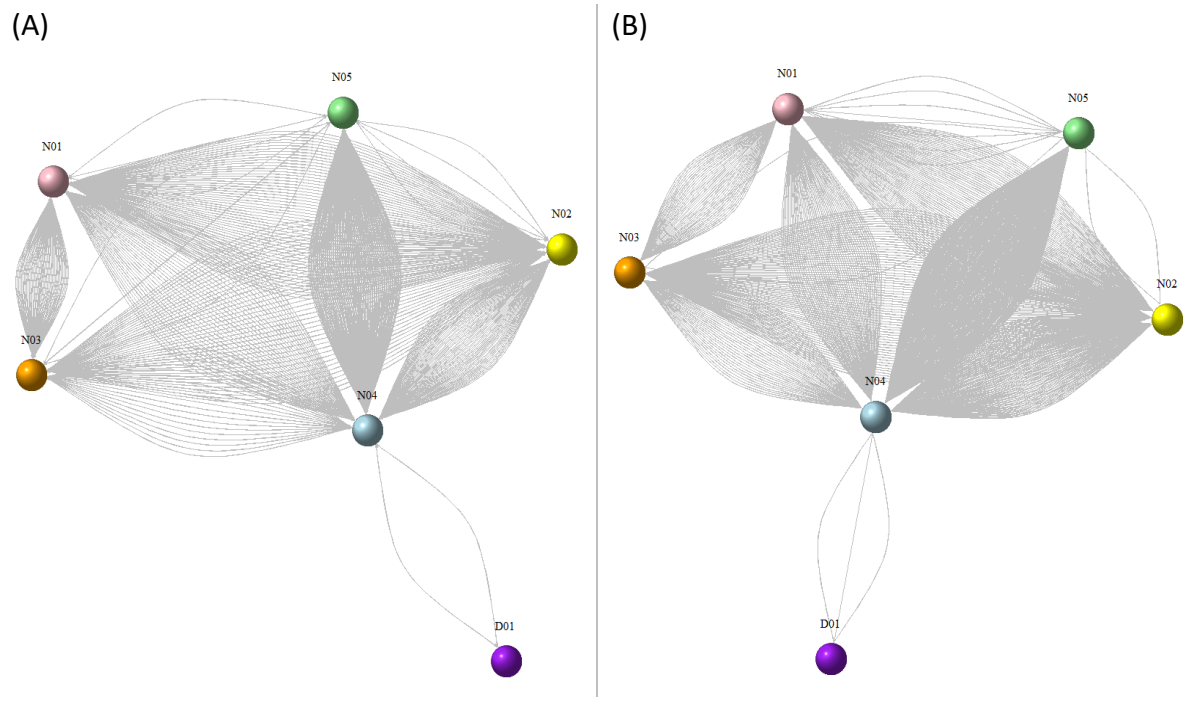


Figure 7. Network graphs of healthcare worker close contact recorded during pilot study two; (A) total number of events, (B) total minutes.



More than half of nursing patient room entries were recorded in the morning shift (23/45, 51.9%). There was a total 622 minutes of nursing-patient close contact recorded across all rooms. The median time of patient close contact events was 6 minutes 58 seconds [IQR: 2:57–20:36]. No medical staff tags recorded entering a patient room. One room was on airborne precautions during the entire study, and one room was on airborne precautions for days 3 and 4. Patient close contact was for a median 4 minutes 19 seconds [IQR: 3:42-4:55] for rooms with airborne precautions, compared to 8 minutes 25 seconds [IQR: 2:55-21:42] for rooms without transmission-based precautions (p=0.989). Per patient-day the median nurse-patient exposure time was 31 minutes [IQR: 1:37-68:18].

Table 5 provides an overview of the issues identified in pilot study two, reasons for the issues, and solutions implemented. Firstly, there were temporary disruptions to programming functions caused by the continuous function of the BLE scanner, which disrupted the data transfer by LoRa and write data to the micro–Secure Digital card. The solution was to programme a temporary pause to the BLE scanner, to allow other functions to be performed. Additionally, there were different battery lives of BLE devices noted. Although no reason was identified, the BLE devices were adapted to include a circuit board to increase battery-life. Finally, data analysis revealed limitations in the format in which the data were programmed to be captured, which resulted in extensive cleaning, manipulation and manual human interpretation for room data. The solution was to adapt the data collection code to enable simpler data analysis. Overall, there were no major issues identified and performance was deemed high by the engineering team.

Table 5. Identified issues, reasons and solutions of the Bluetooth Low Energy system during pilot study two.

Issue identified	Reason	Solution
Temporary disruptions to programming functions	The BLE scanner functioned continuously, which disrupted data transfer by LoRa and write data to the micro–Secure Digital card.	A temporary pause to the BLE scanner was programmed, to allow other functions to be performed.
Different battery lives of BLE devices	There was no key reason identified, however solutions were built.	Construction of a new circuit board within the BLE devices to increase battery-life.
Data capture format required extensive data cleaning and manipulation	The real-time data processing code required adaptions to facilitate post-processing data analysis.	Adaption to the real-time data processing code to enable simpler post-processing data analysis.

Discussion

We successfully built a bespoke BLE system that functioned in the hospital environment to quantify networks of interactions and close contact between patients and staff. With further development, the system could be scaled up in high-risk environments, and be integrated with existing information systems to create a digital ecosystem for semi-automated contact tracing.

We recorded short nurse-nurse close contact interactions, for an average 58 seconds and longer nurse-patient close contact interactions, for an average 6 minutes 58 seconds. We had little participation by medical staff, however those that participated reported no patient close contact, and minimal HCW interaction. Based on pilot data, we estimated the average nurse-patient exposure time of 31 minutes per patient-day.

The results of our pilot study may not be directly comparable with other studies due to substantial differences in study design. However, in a paediatric emergency department in in the United States, the average contact time between nodes (patient-staff or staff-staff) was 20.16 seconds, and HCWs interacted with an average of six patients per shift (22). In a

general paediatrics ward in Italy, HCW had a median of 20 close contacts per day, most for less than 4 minutes (23). In an adult ICU in the United States, staff-staff were more numerous and longer than patient-staff interactions, with interactions occurring for a median 10 minutes compared to 3 minutes, respectively (24). In an adult emergency department in the United States staff had an average close contact with 6 patients and 3 staff per shift and reported interactions to be typically less than 1 minute, for all types of close contact (25). A study setting with rooms on airborne precautions may be most comparable to our study, such as that in France, which reported a median of 2 minutes 6 seconds per HCW-patient close contact and an average exposure time of patients to HCW per patient day of 7 minutes 36 seconds (26).

Strengths and limitations

We faced implementation and technological barriers. During the pilot studies, we had lower uptake of wearable tags than anticipated. We used anonymous tags in the pilot studies to increase HCW acceptability, however participation may still have been limited by privacy concerns, understanding or engagement (27). Additionally, the development of our system was limited by financial capacity, as were unable to obtain specific funding for the project. Financial barriers and poor uptake were key barriers reported in similar studies (10, 13, 26, 28). Analysis of cumulative interaction data over shifts and days may not enable conclusions as it likely represents tags used by different participants, however this analysis contributed to an understanding of potential analytics from this system, which will be more meaningful through data collection over a longer period and with increased participation.

Study planned beyond the pilot studies

We had anticipated that the main study would be for 30 days on a single ward at the Alfred Hospital where patients with suspected or confirmed COVID-19 were admitted to an isolation room. The study population were to be HCWs whose primary role was based on this ward, from one of the five following professional categories: nursing staff, junior medical staff, senior medical staff, allied health (e.g., dietitians, occupational therapists, physiotherapists and pharmacists), and cleaning staff. The exclusion criteria were student HCWs and HCWs who may have worked on the study setting ward, but their primary role was not based there. We estimated there would be a total 70 participants over the duration

of the 30-day main study: 24 nurses, 20 other staff members, 10 allied health professionals, 10 junior medical staff and 6 senior medical staff.

We were unable to perform the pilot studies on the COVID-19 ward as the ward was usually inactive in 2021, due to the low or zero prevalence of COVID-19 in Melbourne. Additionally, during conceptualisation of this project there were often admissions for suspected COVID-19, however the implementation of rapid diagnostic testing in the Emergency Department enabled patients to be cleared of suspected COVID-19 immediately, and not require transfer to the COVID-19 ward. The inability to use the planned ward may have contributed to the low participation. The COVID-19 ward had one point of entry and exit, allowing the use of a tag 'check-in' and 'check-out' station. Conversely, the Infectious Diseases ward had many points of entries and exits and resulted in tags being placed on a bench that may have been overlooked by HCWs.

Future research

Future deployment of the system will require an increase in the number of participants per shift and day, and expansion of the BLE receivers across the ward to allow investigation of critical opportunities for intervention such as the tearoom, at nursing handover, and during medical staff ward rounds. In future execution of the final study anticipated, further accuracy and precision testing will be required to provide quantifiable evidence that the system can be scaled up with confidence. Further research could include an ethnography and needs analysis regarding process, governance, and infrastructure to investigate barriers to participation and to ensure meaningful stakeholder input in the implementation of potential automated contact tracing systems. Beyond the hospital setting, this system could also be useful in an environment where COVID-19 remains a high risk of transmission, such as hotel-quarantine or where vaccination rates are low, such as childcare.

Conclusion

We successfully demonstrated the functionality of a BLE system approach to quantify HCW proximity networks and patient close contact. With further implementation, we can obtain reliable data on contact patterns to better characterize critical opportunities for

intervention to reduce potential infectious disease transmission in healthcare settings. With further developments, the system could be scaled-up to be a digital solution to augment contact tracing in high-risk environments such as COVID-19 wards in hospitals, hotel-quarantine, or for future infectious diseases outbreaks and/or pandemics.

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Chapter 5: Hospitalisation with injection-related infections: validation of diagnostic codes to monitor admission trends

Prologue

In this chapter I present an analysis of the public health dataset I performed as part of my field placement at Alfred Health. Fortunately, after a thesis rich with content on COVID-19, this chapter explores a different topic, hospitalisations with IRIs in people who inject drugs. Unfortunately, I was close to completion of my data analysis project in July 2021, when the COVID-19 situation in Victoria escalated, leading me unable to complete the original project and needing to adapt the project. Therefore, this prologue will explore both the original project that I was unable to complete within the MAE timeframe, and the final project submitted to fulfill the data analysis competency of the MAE.

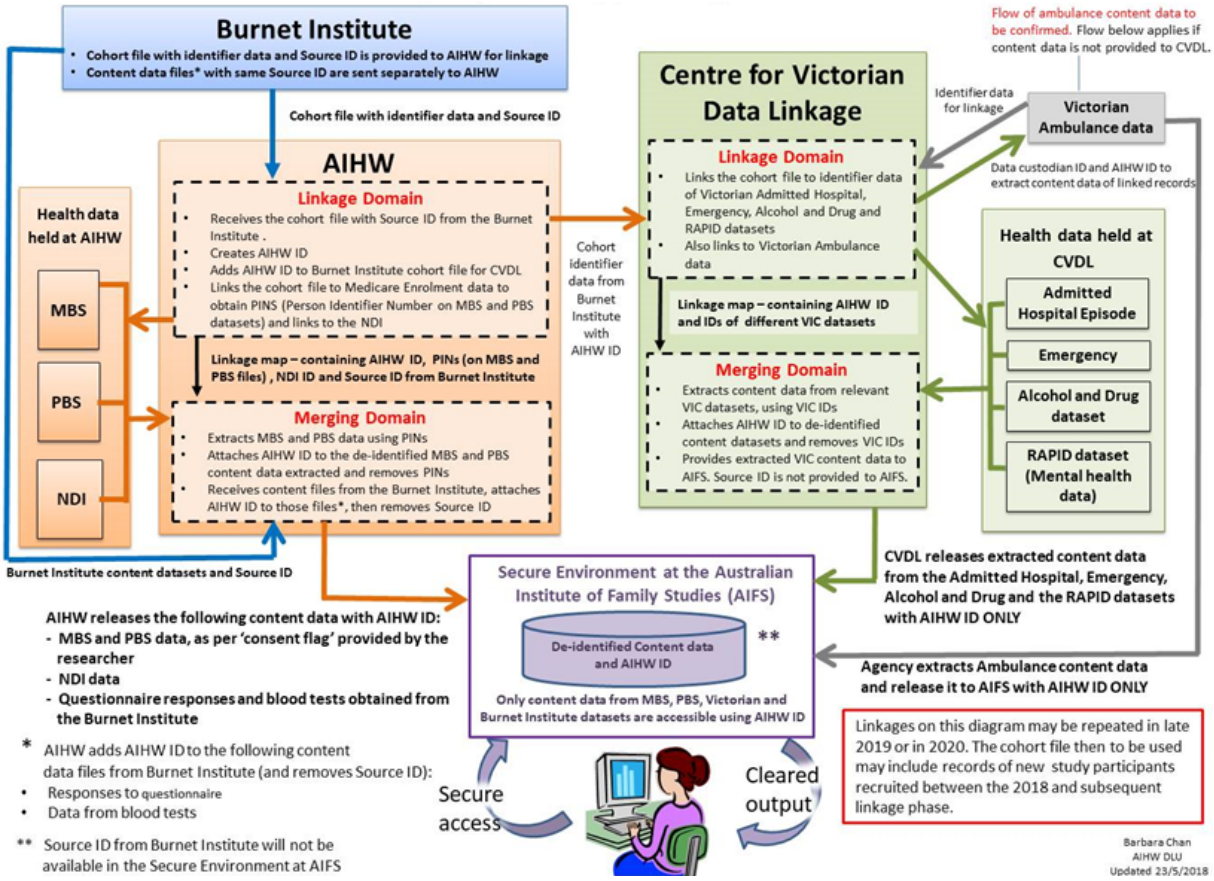
The conceptualisation of the topic evolved from mutual interest and experience of my field supervisors and me. As an Infectious Diseases Physician, Associate Professor Stewardson is experienced in treating patients with IRIs and has seen the clinical burden of IRIs in the hospital setting. Professor Stoové has over 20 years' experience working with community and research projects on people who inject drugs, particularly in prison populations. As a Needle and Syringe Program worker before, and throughout the MAE program, I regularly spoke to clients about the burden of IRIs.

In April 2020, I obtained an ethics amendment from the AIHW to perform a retrospective analysis of hospitalisations with IRIs in a prospective Melbourne cohort of people who inject drugs. This cohort, known as participants of the SuperMIX study, has over 1,300 participants and is the largest cohort study of people who inject drugs in Australia. SuperMIX is managed by the Burnet Institute and aims to investigate the evolution of injecting drug use over time, and to use information to design harm reduction services and interventions.

The original data analysis used state and nation-wide datasets, including the Victorian Emergency Minimum Dataset, Victorian Admitted Episodes Dataset and National Death Index, which were previously linked to the SuperMIX cohort data through full clerical review

probabilistic linkage by the Centre for Victorian Data Linkage. The barrier throughout this project was data access, as data were only accessible in a secure data laboratory onsite at the Australian Institute of Family Studies in Melbourne. Figure 1 describes the complexity of the data linkage and storage for the project, created by Barbara Chan from the AIHW.

Figure 1. Description of the data access and linkage of state and nation-wide datasets to the SuperMIX study.



The data laboratory immediately closed in accordance with stay-at-home directions from the State Government of Victoria during COVID-19 outbreaks. When the data laboratory was open, access was limited to be one day per week from 10:00 to 16:00, there was no internet access on the government laptops used for data access, and file input and output from the laptops required an extensive clearance process. Despite these hurdles, I successfully cleaned, linked and validated data, performed a descriptive analysis of hospitalisation trends and the burden of disease as measured by length of stay and mortality. However, I was unable to clear outputs from the data laboratory in time, prior to

lockdowns in Victoria that occurred from mid-July to October 2021, when the MAE thesis was due.

In August 2021, I re-conceptualised the project to see how it could be performed at a single site, the Alfred Hospital. At the time, I was a co-investigator of an audit led by an Infectious Diseases Registrar which used ICD codes (Tenth Revision, Australian Modification [ICD-10-AM]) to extract hospital admission data on IRIs in people who inject drugs. The audit involved a manual review of medical charts to confirm that the ICD codes had correctly identified the cohort (people who inject drugs) and condition (IRI), and then collected further microbiology and patient management data. The manuscript for this audit is currently in preparation, and not available publicly. Andrew and I saw an opportunity to use the audit data to estimate performance of the ICD-10-AM codes for predicting the cohort and condition, and then perform the single-site descriptive analysis of hospitalisation trends and the burden of disease using the same approach that I used to analyse the linked SuperMIX data.

Overall, my role in the analysis of each of these public health datasets included:

- Develop a study protocol and data analysis plan, after developing an understanding of the data available and the context in which it could be analysed.
- Update existing protocols to include my data analysis within the scope of the original research studies and obtain an ethics amendment to the relevant Human Research Ethics Committees.
- Perform data cleaning and linkage across two or more datasets. For the first project, this included using SuperMIX cohort data, the Victorian Emergency Minimum Dataset, Victorian Admitted Episodes Dataset and National Death Index datasets. For the second project, this included using audit data and Alfred hospital administrative data.
- Perform a descriptive analysis of the data by person, place, time, and quantify disease burden (length of stay and mortality).

- Interpret results of the data cleaning, compare these with findings of other peer-reviewed literature to identify similarities and differences, and provide recommendations based on these findings.
- Prepare journal articles for peer-review submission. The analysis presented in this chapter was submitted to Drug and Alcohol Review and it is planned that the SuperMIX analysis will be submitted for peer-review publication in 2022.

Acknowledgements

Thanks to staff at the Australian Institute of Family Studies for the warm welcome and going above and beyond to facilitate data access. Thanks to the Burnet Institute SuperMIX fieldwork team who perform ongoing data collection and above all, thanks to all SuperMIX participants who have, and continue to, share their story.

Lessons learnt

I had anticipated the data analysis competency to be the 'easiest' project within the MAE program, however this was not the case. The key lessons I learnt during this project were:

- There may be no 'easy' MAE project, especially during a pandemic. Therefore, it was important to explore various options for each project. The switch to a new project took a substantial amount of time, however a contingency plan was a good idea, to prevent last minute stressors.
- The use of sensitive data will likely create hurdles to data access. The SuperMIX research team spent many years arranging access to the linked data, however data access remains difficult. Whilst linked data are highly informative and important for research, data access issues should also be factored into timelines and feasibility of the project.
- I learnt new RStudio coding skills that may be applicable to low resource settings. In the data laboratory, not all statistical software capabilities were available, including limited RStudio packages that I usually use when analysing data downloaded and updated using the internet. This limited my ability to write code and forced me to learn new ways of analysing data without the packages. Whilst this wasn't a learning

goal of mine, it taught me to be more adaptive in settings with statistical software access challenges.

- I learnt in detail about the ICD-10-AM coding process. In Australia, all public and private emergency department and inpatient admissions use ICD-10-AM and Australian Classification of Health Intervention codes to classify diseases, health problems, procedures, and interventions. This process involves a trained clinical coder to translate information from the patient ‘s health record after they have been discharged to assign codes for their relevant health conditions and interventions received during the relevant admission. The coding is used to quantify the number and type of patients treated in a hospital and the resources required by the hospital, which is used to calculate public hospital funding. Whilst this is the primary purpose of the coding, the codes are also useful for monitoring the health of a population, planning how health services are delivered and detecting changes in disease patterns.

Public Health Implications

- We demonstrated that admissions with IRI in our hospital were increasing over time, although this was largely driven by skin and soft tissue infections (SSTI) and bloodstream infections/sepsis. This differs from domestic and international literature that cite increasing trends in infective endocarditis. With current literature focusing on infective endocarditis, our research highlights the need to investigate other IRIs, particularly SSTIs which are often treatable in primary care and hospitalisation may reflect delayed access to care leading to more severe infection.
- We contributed to the body of literature to validate the use of ICD-10-AM codes for identifying people who inject drugs and diagnosed with IRI, revealing both limited utility for some codes which are commonly used in the literature and utility of other codes that are not commonly reported in the literature. Through use of manual chart review data to validate and select only high performing codes in the descriptive analysis, this study overcame the misclassification bias that may occur when using ICD-10-AM codes.

- Finally, further research could contribute to better understanding of the burden of diseases across more hospital sites, and ultimately be used for passive surveillance in a population that currently has little surveillance programs dedicated to understanding health trends. This includes exploring further algorithms that measure the predictive value of the combination of infection and injecting drug use codes to find the combinations with the highest predictive values rather than treating them separately, and further manual chart review to calculate sensitivity, specificity, and negative predictive values of ICD-10-AM codes.

The following manuscript was submitted for peer-review to Drug and Alcohol Review in October 2021.

Title page

Title

Hospitalisation with injection-related infections: validation of diagnostic codes to monitor admission trends at a tertiary care hospital in Melbourne, Australia

Running title

Hospitalisations with injection-related infections

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Competing interest statement

None to declare.

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Data accessibility statement

Derived data supporting the findings of this study are available from the corresponding author, SJC, upon reasonable request.

Abstract

Introduction

Injection-related infections (IRIs) cause morbidity and mortality in people who inject drugs. Hospital administrative datasets can be used to describe hospitalisation trends, but there are no validated algorithms to identify injecting drug use and IRIs. We aimed to validate International Classification of Diseases (ICD) codes to identify admissions with IRIs and use these codes to describe IRIs within our hospital.

Methods

We developed a candidate set of ICD codes to identify current injecting drug use and IRI and extracted admissions satisfying both criteria. We then used manual chart review data from 1 January 2017 to 30 April 2019 to evaluate the performance of these codes and refine our algorithm by selecting codes with a high positive predictive value (PPV). We used the refined algorithm to describe trends and outcomes of people who inject drugs with an IRI at the Alfred Hospital, Melbourne from 2008 to 2020.

Results

Current injecting drug use was best predicted by opioid related disorders (F11), 80% (95%CI: 74%-85%), and other stimulant related disorders (F15), 82% (95%CI: 70%-90%). All PPVs were ≥67% to identify specific IRIs, and ≥84% for identifying any IRI. Using these codes over 12 years, IRIs increased from 138 per 100,000 admissions to 249 per 100,000 admissions, and skin and soft tissues infections (SSTIs) were the most common (797/1,751, 46%).

Conclusion

Validated ICD-based algorithms can inform passive surveillance systems. Strategies to reduce hospitalisation with IRIs should be supported by early intervention and prevention, particularly for SSTIs which may represent delayed access to care.

Keywords: Injecting drug use; injection related infections; Substance-Related Disorders; Infections; Hospitalization; International Classification of Diseases

Manuscript main text

Introduction

People who inject drugs are at risk of acute bacterial and fungal injection-related infections (IRIs), which range from localised skin infections to life-threatening invasive infections such as endocarditis and osteomyelitis. Most localised cutaneous IRIs can usually be managed in a primary care setting; however, hospitalisation may be required if initial treatment is delayed or for more complex IRIs that require further investigations including blood cultures, radiological images, and treatment including intravenous antibiotics, interventional procedures, and surgery (1, 2).

The lifetime prevalence of IRIs among people who inject drugs may be as high as 70% and there is evidence that hospitalisations with IRIs are increasing in the United States and the United Kingdom (2-4). However, there is limited objective evidence on the burden of IRIs in Australia, particularly in hospitals where many IRIs are likely to be diagnosed and treated. Most data on IRIs are self-reported and there are limited surveillance programs dedicated to monitor population-wide health trends for people who inject drugs (5).

Hospital administrative data can be a rich source of information to understand health trends in the absence of surveillance programs. International Classification of Diseases (ICD) codes can be used to identify people who inject drugs and IRIs, and to estimate the burden of disease of IRIs in hospitals. However, ICD codes do not explicitly differentiate non-injection and injection drug use and there are limited studies that validate the use of select ICD codes (6). The use of evidence-based ICD codes can provide more accurate estimations of burden of disease to inform clinical care models, harm reduction strategies and surveillance systems.

To contribute to this body of literature, we aimed to validate a candidate set of ICD 10th edition Australian-Modification (ICD-10-AM) codes to identify hospital admissions for people who inject drugs with an IRI. We subsequently aimed to use these validated codes to

describe the burden and trends of IRIs within our tertiary care hospital in Melbourne, Australia.

Methods

Study design and setting

The Alfred Hospital is an adult-tertiary referral hospital in Melbourne, Australia that services a population of nearly 800,000 people. First, we used data from a previously conducted manual chart review audit of IRIs at the Alfred Hospital from 1 January 2017 to 30 April 2019 to develop an algorithm using ICD-10-AM codes that best identified current injecting drug use and IRI. Second, we used the best performing ICD-10-AM codes to perform a retrospective cohort analysis of all hospitalisations for people who inject drugs with an IRI at the Alfred Hospital from 1 January 2008 and 31 December 2020 to determine the burden and trends in hospital admissions at our health service.

Algorithm Development

Selection of candidate ICD codes

We developed a set of ICD-10-AM codes to identify the following two concepts within hospital admitted episode administrative data: (1) current injecting drug use, and (2) IRI. The selected codes were based on existing literature and manual search of the ICD-10-AM manual, with face validity confirmed by consultation with Infectious Diseases physicians (5, 7-11). The candidate set of ICD-10-AM codes identified to potentially indicate current injecting drug use and IRIs are listed in Supplementary Material Table 1 and Table 2, respectively.

IRI conditions were acute bacterial or fungal infections which included skin and soft tissue infections (SSTI), bloodstream infection (BSI) or sepsis, infective endocarditis, osteomyelitis or septic arthritis, deep abscess, central nervous system infections and other infections. Uncomplicated SSTI were those without an additional more invasive internal or systemic IRI. Other infections were causes of bacterial diseases classified elsewhere, rather than a

specific IRI condition, and were included in the algorithm based on the existing literature and ICD-10-AM coding standards (9-12).

Data from previous audit

At our health service, hospital admission episodes have one primary, and up to 39 secondary ICD-10-AM diagnostic codes. In the previously conducted audit, we used the algorithm specified above to extract all admission episodes that met the following three criteria: (1) Alfred Hospital inpatient episodes with admission date from 1 January 2017 to 30 April 2019, inclusive; (2) diagnostic codes included one or more from list of codes proposed to indicate current injecting drug use (Supplementary Material Table 1), (3) diagnostic codes included one or more from the set proposed to indicate IRI (Supplementary Material Table 2). Subsequently, we performed a manual chart review to audit these admissions which is described comprehensively elsewhere (manuscript under review). In brief, chart review was performed by two physician trainees (an Infectious Diseases Registrar and Basic Physician Trainee) who used medical progress notes, laboratory results, radiological reports, echocardiography, and microbiology data to determine whether an IRI was diagnosed during the admission. Injecting drug use status (current, previous, or never) was assigned based on documentation available from medical records. Current injecting drug use was defined as having injected drugs within the past six months.

Analysis

We calculated the concordance (positive predictive value, PPV) of individual ICD-10-AM codes for identifying current injecting use, and each IRI condition using the audit data as the reference standard against hospital administrative data ICD-10-AM codes. High performing groups were defined as those with a PPV ≥70%, and we included these in the final algorithm. Some candidate ICD-10-AM codes were not present in admission episodes from the audit sample; therefore, we were not able to calculate a PPV. We made a case-by-case assessment of whether to include such codes in our final algorithm.

For our descriptive analysis on the burden and trends of IRIs (below), we excluded codes that were not evaluated relating to injecting drug use but included those relating to IRIs given that 'drug use' related codes do not differentiate non-injection and injection drug use,

whilst coding of IRIs was likely to be more accurate due to clear objective clinical criteria for diagnosis. In addition, we described the demographics of the cohort identified at our health service including sex, age, Emergency Department admission, surgery during admission, intensive care unit stay during admission and age-adjusted Charlson Comorbidity Index. Charlson Comorbidity Index is a validated tool that weights patients' risk of mortality, from 0 to 24, based on 12 comorbid conditions (13, 14).

Trend and outcome analysis

We used high performing codes to refine the algorithm and describe annual incidence (admissions per 100,000 hospital admissions) and outcomes (length of stay (LOS) and in-hospital mortality) for people who inject drugs with an IRI over a 12-year period from January 2008 to December 2020. As an admission episode could have multiple IRIs, we described admissions by any IRI and per IRI condition. Estimations were presented with 95% confidence interval (CI) and data analysis were performed using R Version 4.0.2 (15).

Ethics

Ethics was approved by the Alfred Hospital Human Research Ethics Committee [Project 390/19].

Results

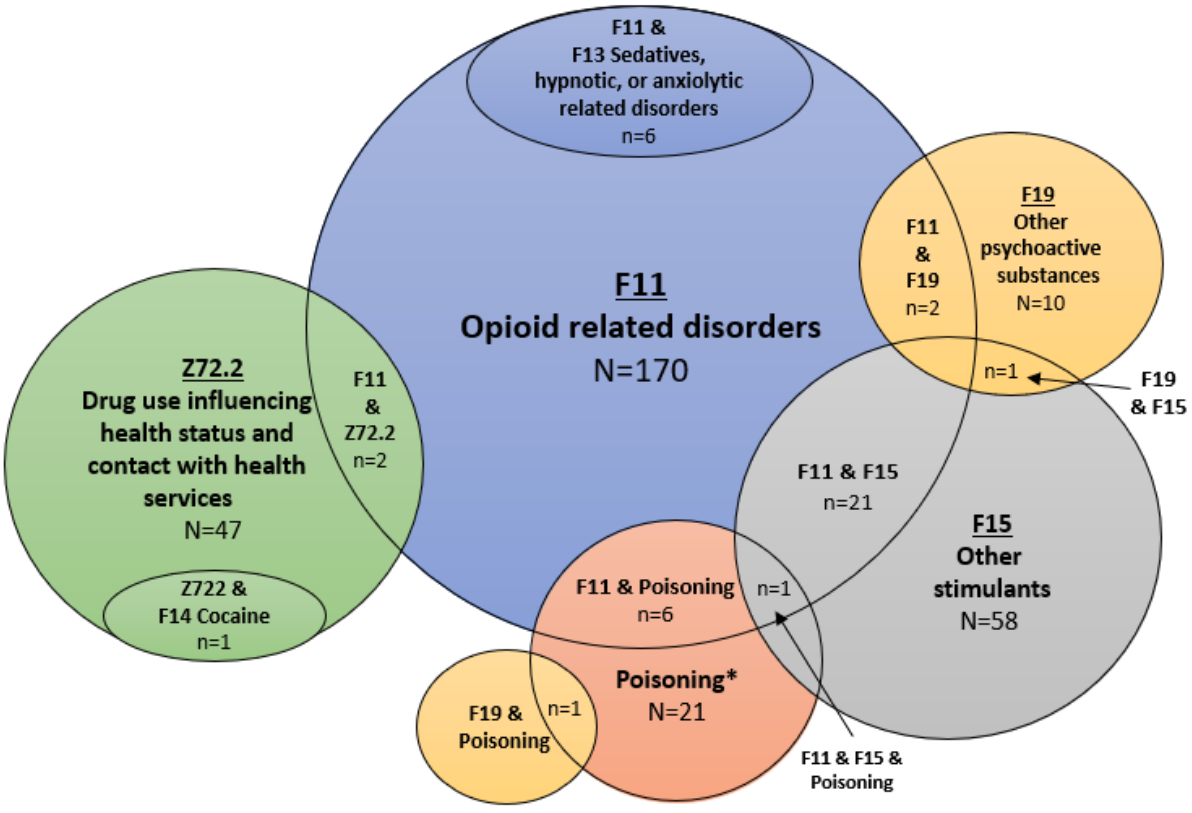
Cohort identified from manual review

From 574 manually reviewed hospital admissions that included ICD-10-AM codes suggestive of injecting drug use with an IRI, the injecting status according to manual chart review was current for 47.1% (270/574), previous for 7.8% (45/574) and never for 45.1% (259/574). Among admissions with current injecting drug use coded, 83.7% (226/270) had an IRI.

Among the 270 admitted episodes confirmed by chart review to involve a patient with current injecting drug use, 14.8% (40/270) contained ICD-10-AM codes from two groups used to identify injecting drug use and 0.7% (2/270) contained codes from three groups. Co-occurrence of the various combinations of ICD-10-AM codes indicating current injecting drug use are presented in Figure 1. All hospital admission episodes with a code from the

sedative, hypnotic, or anxiolytic related disorders (F13) group also had a diagnostic code from opioid related disorders (F11). All hospital admission episodes with a diagnostic code from the cocaine (F14) group were also coded with the drug use influencing health status and contact with health services (Z72.2) diagnostic code from the factors influencing health status and contact with health services group.

Figure 1. Venn diagram of International Classification of Diseases, Tenth Revision, Australian Modification diagnostic code groups used for admitted episodes relating to patients with confirmed current injecting drug use at the Alfred Hospital from 1 January 2017 to 30 April 2019.



*Poisoning: T40.0, T40.1, T40.2, T40.3,T40.4, T40.5, T40.6, T40.8, T40.9, T41.1, T41.2, T42.3,T42.4,T43.6,T43.8,T43.9,X42, X62

N=Total ICD-10-AM codes in the group. n=Total ICD-10-AM codes with co-occurrence

ICD code performance for predicting injecting drug use

Table 1 presents the PPV across ICD-10-AM code groups, and by individual code. Other stimulant related disorders (F15) had the highest overall PPV, at 82% (95%CI: 70%, 90%), followed by opioid related disorders (F11) with 80% (95%CI: 74%, 85%) and the drug use

influencing health status and contact with health services (Z72.2) code with 75% (95%CI: 62%, 84%). The codes relating to poisoning had a PPV of 64% (95%CI: 45, 79), with five of nine codes individually scoring ≥70%. Cocaine (F14) and hallucinogens (F16) were only present for one admission in the manually reviewed dataset. Of the F1X code complication subcategories (i.e., F1X.3), withdrawal state for opioid-related disorders (F11.3) and other stimulant related disorders (F15.3) had a high PPV and larger sample size, relative to other subcategories. Dependence syndrome for opioid related disorders (F11.2) also performed well across F1X codes and had the highest number of 'previous' intravenous drug users.

Table 1. Positive predictive value (PPV) of International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM) codes to identify injecting drug use, using manual chart review as reference standard.

ICD-10-AM codes	Intravenous drug use				
	Current	Previous	Never	Total	PPV for current use, % (95% CI)
	N				
F11 Opioid related disorders	**170**	**34**	**9**	**213**	**80 (74, 85)**
F11.0 Acute intoxication	2	0	1	3	67 (13, 98)
F11.1 Harmful use	22	0	1	23	96 (76, 100)
F11.2 Dependence syndrome	133	32	5	170	78 (71, 84)
F11.3 Withdrawal state	44	4	3	51	86 (73, 94)
F11.4 Withdrawal state with delirium	3	0	0	3	100 (31, 100)
F11.5 Psychotic disorder	1	0	0	1	100 (5, 100)
F13 Sedative, hypnotic, or anxiolytic related disorders	**6**	**2**	**8**	**16**	**38 (16, 64)**
F13.0 Acute intoxication	0	0	1	1	0 (0, 95)
F13.1 Harmful use	3	0	2	5	60 (17,93)
F13.2 Dependence syndrome	3	1	4	8	38 (10,74)
F13.3 Withdrawal state	0	1	1	2	0 (0, 80)
F13.4 Withdrawal state with delirium	0	0	1	1	0 (0, 95)
F14 Cocaine					
F14.1 Harmful use	1	0	0	1	100 (5, 100)
F15 Other stimulant related disorders	**58**	**4**	**9**	**71**	**82 (70, 90)**
F15.1 Acute intoxication	31	2	5	38	82 (65, 92)
F15.2 Harmful use	8	1	1	10	80 (44, 96)
F15.3 Withdrawal state	15	1	2	18	83 (58, 96)
F15.5 Psychotic disorder	3	0	1	4	75 (22, 99)

F15.9 Unspecified mental and behavioural disorder	4	0	0	4	100 (40, 100)
F16 Hallucinogens					
F16.2 Harmful use	0	1	0	1	0 (0, 95)
F19 Other psychoactive substance related disorders	**10**	**0**	**9**	**19**	**53 (29, 75)**
F19.1 Harmful use	6	0	2	8	75 (36, 96)
F19.2 Dependence syndrome	2	0	3	5	40 (7, 83)
F19.3 Withdrawal state	1	0	0	1	100 (5, 100)
F19.4 Withdrawal state with delirium	0	0	4	4	0 (0, 60)
F19.5 Psychotic disorder	1	0	1	2	50 (9, 91)
Poisoning by drugs	**21**	**3**	**9**	**33**	**64 (45, 79)**
T40.1 Heroin	12	0	0	12	100 (70, 100)
T40.2 Other opioids (Codeine, Morphine)	1	0	6	7	14 (1, 58)
T40.4 Other synthetic narcotics (Pethidine)	2	0	1	3	67 (13, 98)
T40.5 Cocaine	2	0	0	2	100 (20, 100)
T40.6 Other and unspecified narcotics	1	0	0	1	100 (5,100)
T42.4 Benzodiazepines	3	3	5	11	27 (7, 61)
T43.6 Psychostimulants with abuse potential	3	0	1	4	75 (22, 99)
X42 Narcotics and psychodysleptics (accidental)	10	0	3	13	77 (46, 94
X62 Narcotics and psychodysleptics (intentional)	4	0	3	7	57 (20, 88)
Factors influencing health status and contact with health services					
Z72.2 Drug use	47	11	5	63	75 (62, 84)
CI= Confidence Interval.					

ICD code performance for predicting injection-related infections

Overall, ICD-10-AM code groups performed well for identifying their respective IRI condition, and for identifying any IRI condition (Table 2). Codes predicting osteomyelitis or septic arthritis performed best with a PPV of 82% (95%CI: 67, 92), followed by SSTI, 75% (95%CI: 68, 81), and central nervous system IRIs, 75% (95%CI: 36, 96). There was a PPV of ≥70% for detecting specific IRI conditions, except for deep abscess, 67% (95%CI: 24, 94). All IRI groups had a PPV ≥84% for detecting any IRI. The 'other' IRI group were commonly coded in admissions (99/270, 36.7%), of which 99% (98/99) were also coded with a specific IRI condition.

Table 2. Positive predictive value (PPV) of International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM) codes to identify injection-related infections.

ICD-10-AM code	Specific injection-related infection				Any injection-related infection			
	Yes	No	Total	PPV	Yes	No	Total	PPV
	N			% (95% CI)	N			% (95% CI)
Skin or soft tissue infections	130	43	173	75 (68, 81)	149	24	173	86 (80, 91)
L01 Impetigo	2	0	2	100 (20, 100)	2	0	2	100 (20, 100)
L02 Cutaneous abscess, furuncle and carbuncle	62	9	71	87 (77, 94)	67	4	71	94 (85, 98)
L03 Cellulitis	94	18	112	84 (76, 90)	101	11	112	90 (83, 95)
L08 Other local infections of skin and subcutaneous tissue	1	0	1	100 (5, 100)	1	0	1	100 (5, 100)
I80 Phlebitis and thrombophlebitis	5	16	21	24 (9, 48)	8	13	21	38 (19, 61)
M600 Infective myositis	1	7	8	12 (1, 53)	8	0	8	100 (60, 100)
M651 Other infective (teno)synovitis	2	1	3	67 (13, 98)	3	0	3	100 (31, 100)
M726 Necrotizing fasciitis	1	0	1	100 (5, 100)	1	0	1	100 (5, 100)
Bloodstream infections or sepsis*	21	9	30	70 (50, 85)	80	15	95	84 (75, 91)
A40 Streptococcal sepsis	-	-	-	-	6	1	7	86 (42, 99)
A41 Other sepsis	-	-	-	-	47	12	59	80 (67, 89)
A49 Bacterial infection of unspecified site	21	9	30	70 (50, 85)	28	2	30	93 (76, 99)
B377 Candidal sepsis	-	-	-	-	1	0	1	100 (5, 100)
R572 Septic shock	-	-	-	-	8	1	9	89 (51, 99)
Infective endocarditis	26	9	35	74 (56, 87)	32	3	35	91 (76, 98)
I33 Acute and subacute endocarditis	23	8	31	74 (55, 87)	29	2	31	94 (77, 99)

I35 Nonrheumatic aortic valve disorders	3	1	4	75 (22, 99)	3	1	4	75 (22, 99)
Osteomyelitis or septic arthritis	33	7	40	82 (67, 92)	38	2	40	95 (82, 99)
G061 Intraspinal abscess and granuloma	10	0	10	100 (66, 100)	10	0	10	100 (66, 100)
G08 Intracranial and intraspinal phlebitis and thrombophlebitis	0	1	1	0 (0, 95)	0	1	1	0 (0, 95)
M00 Pyogenic arthritis	15	2	17	88 (62, 98)	17	0	17	100 (77, 100)
M462 Osteomyelitis of vertebra	8	0	8	100 (60, 100)	8	0	8	100 (60, 100)
M465 Other infective spondylopathies	3	1	4	75 (22, 99)	4	0	4	100 (40, 100)
M86 Osteomyelitis	8	3	11	73 (39, 93)	10	1	11	91 (57, 100)
Deep abscess	4	2	6	67 (24, 94)	6	0	6	100 (52, 100)
J85 Abscess of lung and mediastinum	4	2	6	67 (24, 94)	6	0	6	100 (52, 100)
Central nervous system infections	6	2	8	75 (36, 96)	7	1	8	88 (47, 99)
G060 Intracranial abscess and granuloma	0	1	1	0 (0, 95)	1	0	1	100 (5, 100)
G062 Extradural and subdural abscess, unspecified	2	1	3	67 (13-98)	2	1	3	67 (13, 98)
H440 Purulent endophthalmitis	1	0	1	100 (5, 100)	1	0	1	100 (5, 100)
H441 Other endophthalmitis	3	0	3	100 (31, 100)	3	0	3	100 (31, 100)
Other*	-	-	-	-	94	5	99	95 (88, 98)
A488 Other specified bacterial diseases	-	-	-	-	1	0	1	100 (5, 100)
B95 Streptococcus and staphylococcus as the cause of	-	-	-	-	83	3	86	97 (89, 99)

diseases classified to other chapters								
B96 Other specified bacterial agents as the cause of diseases classified to other chapters	-	-	-	-	17	4	21	81 (57, 94)

*The manual chart review only assessed bloodstream infection, not sepsis, and did not include an 'other infection' category.

Cohort characteristics

Having evaluated the performance of the ICD codes, we used the final derived algorithm (Supplementary Material Tables 1 and 2) to analyse trends at our health service over the period from 2008 to 2020. In this period, 0.2% (1,751/910,495) of all hospital admission episodes were identified as people who inject drugs with an IRI. Most patients had one admission (1,062/1,311 81.0%), 11.6% (152/1,311) had two admissions, 7.4% (97/1,311) had three or more admissions. The median age at admission was 40 years [Interquartile range (IQR): 33, 48] and 66.7% (875/1,311) were male. Participant characteristics are presented in Table 3.

Table 3. Demographics of hospital admission episodes for people who inject drugs with an injection-related infection at the Alfred Hospital from 1 January 2008 to 31 December 2020.

Characteristic	**N (%)**
Hospital admission episodes	1,751
Unique patients	1,311
Male sex	875 (66.7)
Age (years)*	40 [33, 48]
Emergency Department admission	1,531 (87.4)
Surgery during admission	838 (47.9)
Intensive Care Unit stay	150 (8.6)
Age-adjusted Charlson Comorbidity Index*	1 [0, 2]
**Median [interquartile range]*	

Burden of injection-related infections

People who inject drugs with IRIs accounted for 192 per 100,000 hospital admissions between 2008 and 2020. Over half of patients had an 'other' infection (922/1,751, 52.7%), of which, 59.4% (548/922) also had a specific IRI condition. Nearly half of admissions involved a SSTI (45.5%, 797/1,751), of which most were uncomplicated (689/797, 86.5%). LOS was shortest for uncomplicated SSTI, 4 days [IQR: 2, 8], and longest for infective endocarditis, 20 days [IQR: 9, 42]. A total 6.1% (107/1,751) of patients with an IRI died during their admission, and mortality was highest for patients with infective endocarditis (21/170, 12.4%). Central nervous system and deep abscess infections were rare, (9/1,751, 0.6%) and (8/1,751, 0.5%), respectively. The burden of IRIs is presented in Table 4.

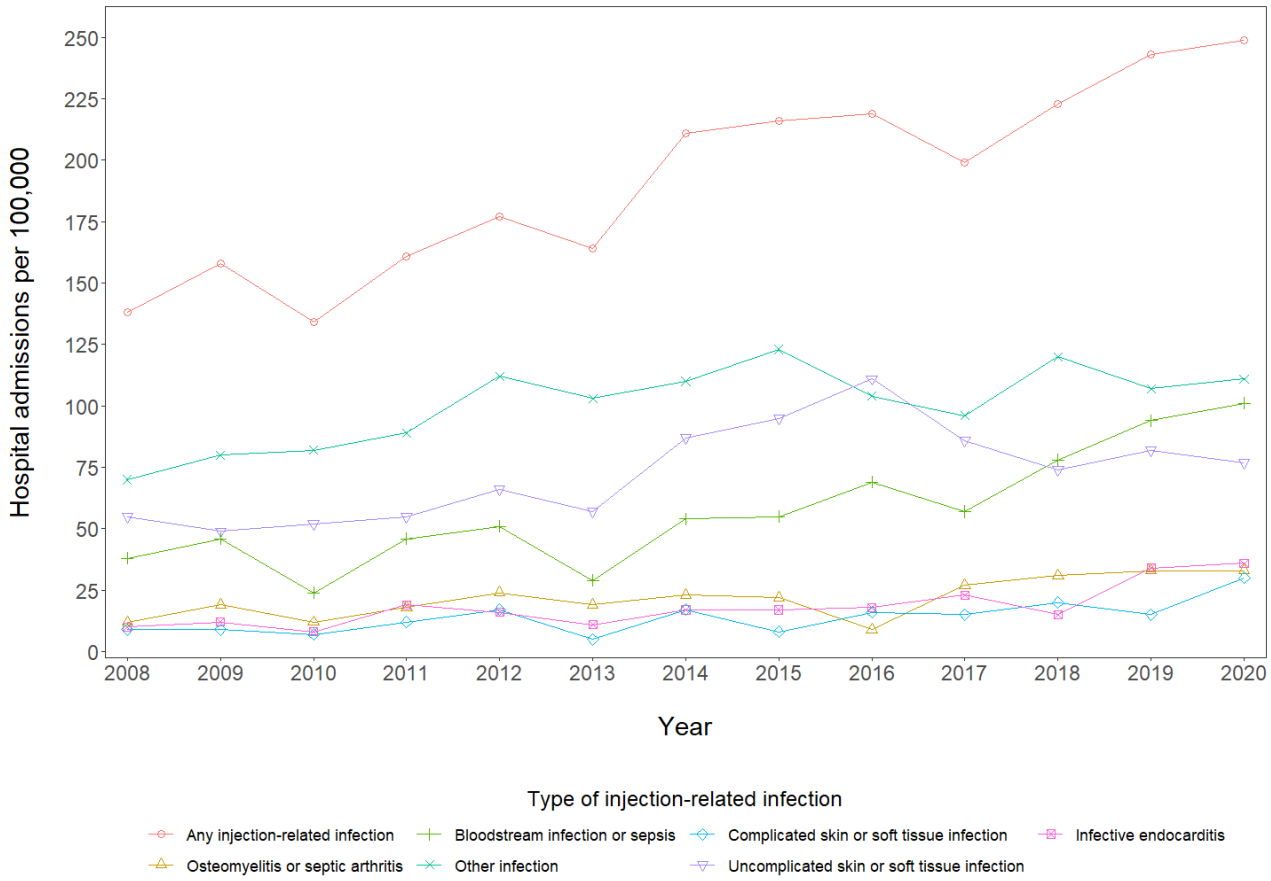
Table 4. Burden and outcome of injection-related infections (IRI) at the Alfred Hospital from 1 January 2008 to 31 December 2020.

Type of IRI	**Admission episodes,** N (%)	**Incidence per 100,000**	**In-hospital mortality,** N (%)	**Total bed days,** N	**Length of stay,** median [IQR]
Any IRI	1,751	192	107 (6.1)	26,478	8 [3, 18]
Other	992 (59.4)	101	50 (5.0)	15,104	9 [3, 19]
Any skin or soft tissue infection	797 (45.5)	88	31 (3.9)	8,338	4 [2, 9]
Uncomplicated skin or soft tissue infection	689 (39.4)	76	23 (3.3)	5,275	4 [2, 8]
Complicated skin or soft tissue infection	108 (6.2)	12	8 (7.4)	3,063	15 [6, 32]
Bloodstream infections/sepsis	524 (29.9)	58	45 (8.6)	12,723	17 [7, 33]
Osteomyelitis or septic arthritis	203 (11.6)	22	10 (4.9)	5,139	19 [9, 36]
Infective endocarditis	170 (9.7)	19	21 (12.4)	4,695	20 [9, 42]
Central nervous system infection	9 (0.6)	1	0	185	8 [4, 19]
Deep abscess	8 (0.5)	0.9	0	398	18 [8, 43]

Trends in hospital admissions

From 2008-2020, the incidence of hospital admissions with any IRI increased from 138 per 100,000 to 249 per 100,000. Hospital admissions with 'other' infections also increased from 70 per 100,000 in 2008 to 111 per 100,000 in 2020. Hospital admissions with BSI/sepsis remained steady from 2008 to 2014, before gradually increasing from 54 per 100,000 in 2014 to a peak of 101 per 100,000 hospital admissions in 2020. Hospital admissions with uncomplicated SSTIs increased between 2009 and 2016 from 49 per 100,000 to 111 per 100,000, before declining in 2018 to 74 per 100,000 and then plateauing. There were no clear trends in admissions for other IRIs (Figure 2).

Figure 2. Annual incidence of hospital admissions per 100,000 of people who inject drugs with an injection-related infection at the Alfred Hospital from 1 January 2008 to 31 December 2020, by type of infection.



Discussion

We described the performance of ICD-10-AM codes validated against chart review to estimate hospitalisations for people who inject drugs with IRIs and explored 12-year trends of IRIs at a tertiary care hospital in Melbourne. PPV of ICD-10-AM codes varied, with opioid related disorders (F11) and other stimulant related disorders (F15) best predicting current injecting drug use. In our health service, the overall incidence of hospitalisations with an IRI increased between 2008 to 2020, mostly attributable to an increase in uncomplicated SSTIs, BSI/sepsis and other bacterial infections.

We report that nearly half of hospitalisations involved a SSTI, consistent with existing literature suggesting that SSTIs are the most common IRI (2, 3, 7). Most SSTIs in our cohort were not accompanied by an invasive internal or systemic IRI, however, the fact that hospital admission was required for management is indicative of the SSTI severity (although we note that the SSTI was the primary reason for admission in only 51% of these cases). This may represent delayed access to primary health care, which is a common issue for people who inject drugs (16, 17). The findings of our study are also consistent with existing literature that hospitalisation with IRIs is increasing (3, 4, 18). Of note, we did not observe an increase in infective endocarditis as previously reported in Victoria, Australia, despite similar cohort demographics and our service being a large cardiac and cardiothoracic referral centre (19, 20).

In our study, opioid related disorders (F11) and other stimulant related disorders (F15) performed best for identifying current injecting drug use. Other studies have grouped all mental and behavioural disorders ‘F’ codes together rather than assess individual codes, and their subgroups, which makes our study unique, but limits comparison (6-9). We found that sedative, hypnotic, or anxiolytic related disorders (F13) and other psychoactive substance related disorders (F19) poorly predicted current injecting drug use, which highlights the need to reconsider the use of these codes in estimations. Additionally, the use of the drug use influencing health status and contact with health services (Z72.2) code to identify current injecting drug use has not been commonly reported, however our study and a Canadian evaluation of a range of algorithms, both report this code as having the highest

PPV (5). Most ICD-10-AM codes used to identify IRIs performed well in our study, akin to the results of a previous validation study of serious infections in the United States (21). We also report that the 'other' infection group (Table 2) had a high PPV for identifying any IRI and were commonly coded with a specific IRI condition, which could be a useful addition in future estimations. Overall, our algorithm can be used by combining all the high performing current injecting drug use codes (F11, F14, F15, T40.1, T40.5, T40.6, X42, Z72.2) with all the high performing codes for each specific IRI condition to identify any IRI or specific IRI conditions at a health service.

Our study has some limitations. First, we were unable to calculate sensitivity, specificity, or negative predictive values of ICD-10-AM codes because manual chart review was only performed for admissions where one or more codes indicating current drugs and IRI were present. Second, although ICD codes should have good inter-rater reliability from standardised guidelines, administrative data can be limited by domestic and international variations in coding standards practices. Third, reference standard of retrospective chart review was reliant on disclosure and documentation of injecting drug use and is likely to underrepresent people who inject drugs; undisclosed drug use may improve the PPV of these codes. However, our use of ICD-10-AM codes based upon a manual chart review to identify current injecting use, combined with ICD-10-AM codes for infection conditions, is likely to reduce false positives and increase accuracy, as demonstrated elsewhere (5, 8). Four, there is no defined 'acceptable' PPV threshold, therefore our selection of 70% was necessarily arbitrary, and a lower PPV may be acceptable for severe disease (22). Finally, this study was performed at a single site at a major inner-city state-funded tertiary care hospital that may limit generalisability to settings that are distinct geographically, with different patterns of injecting drug use, or alternative funding arrangements; nevertheless, the temporal trends within our health service show an almost doubling of IRI burden over the last decade.

The limitations of this study highlight the importance of further research in this area. Further work is needed to validate accuracy of ICD-10-AM codes in regions with similar coding standards and identify opportunities for establishing passive surveillance of people who inject drugs with IRIs. Additionally, Australia has not experienced the opioid crisis

described overseas which calls for further investigation into understanding the causes of rising hospitalisation with IRIs. Finally, all strategies should be supported by early intervention and prevention including improved access to public health and primary care services to reduce the health and economic burden of hospitalisations.

Conclusion

We have identified a set of ICD-10-AM codes for detecting hospitalisations for people who currently inject drugs with an IRI. Hospital administrative data may be able to act as a passive surveillance system in absence of other local and national level data. Given the increasing burden over time, strategies to reduce hospitalisation with IRIs may need to be supported by early intervention and prevention, particularly for SSTIs, which have increased over time at our health service, indicate severity and represent potential delayed access to care.

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Supplementary material

Table S1. International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM) codes used to identify hospital admission episodes for people who inject drugs.

Diagnosis group	ICD-10-AM codes included in the audit	Used in descriptive analysis
Mental and behavioural disorders due to psychoactive substance use	F11* Opioid related disorders	Yes
	F13* Sedative, hypnotic, or anxiolytic related disorders	No
	F14* Cocaine	Yes
	F15* Other stimulant related disorders	Yes
	F16* Hallucinogens	No
	F19* Other psychoactive substance related disorders	No
Poisoning by drugs	T40.0 Opium	No
	T40.1 Heroin	Yes
	T40.2 Other opioids (Codeine, Morphine)	No
	T40.3 Methadone	No
	T40.4 Other synthetic narcotics (Pethidine)	No
	T40.5 Cocaine	Yes
	T40.6 Other and unspecified narcotics	Yes
	T40.8 Lysergide [LSD]	No
	T40.9 Other and unspecified psychodysleptics [hallucinogens]	No
	T41.1 Intravenous anaesthetics (Thiobarbiturates)	No
	T41.2 Other and unspecified general anaesthetics	No
	T42.3 Barbiturates	No
	T42.4 Benzodiazepines	No
	T43.6 Psychostimulants with abuse potential	No
	T43.8 Other psychotropic drugs, not elsewhere classified	No
	T43.9 Psychotropic drug, unspecified	No
	X42 Accidental poisoning by and exposure to narcotics and psychodysleptics [hallucinogens]	Yes
	X62 Intentional self-poisoning by and exposure to narcotics and psychodysleptics [hallucinogens]	No
Findings of drugs and other substances, not normally found in blood	R78.1 Finding of opiate drug in blood	No
	R78.2 Finding of cocaine in blood	No
Factors influencing health status and	Z50.3 Drug rehabilitation	No
	Z71.5 Drug abuse counselling and surveillance	No

contact with health services	Z72.2 Drug use	Yes

** ICD-10-AM codes starting with.*

Table S2. International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM) codes used to identify hospital admission episodes with injection-related infections (IRI).

Infection group	ICD-10-AM codes included in the audit	Used in the descriptive analysis	
		Specific IRI condition	**Any IRI**
Skin or soft tissue infections	A46 Erysipelas	Yes	Yes
	A48.0* Gas gangrene	Yes	Yes
	B43.2 Subcutaneous phaeomycotic abscess and cyst	Yes	Yes
	I80* Phlebitis and thrombophlebitis	No	No
	L01* Impetigo	Yes	Yes
	L02* Cutaneous abscess, furuncle and carbuncle	Yes	Yes
	L03* Cellulitis	Yes	Yes
	L04* Acute lymphadenitis	Yes	Yes
	L08* Other local infections of skin and subcutaneous tissue	Yes	Yes
	M60.0 Infective myositis	No	Yes
	M65.0 Abscess of tendon sheath	Yes	Yes
	M65.1 Other infective (teno)synovitis	No	Yes
	M72.6 Necrotizing fasciitis	Yes	Yes
Bloodstream infections or sepsis^	A27 Actinomycotic sepsis	Yes	Yes
	A40* Streptococcal sepsis	Yes	Yes
	A41* Other sepsis	Yes	Yes
	A49* Bacterial infection of unspecified site	Yes	Yes
	B37.7 Candidal sepsis	Yes	Yes
	I26.01 Septic pulmonary embolism with acute cor pulmonale	Yes	Yes
	I26.90 Septic pulmonary embolism without acute cor pulmonale	Yes	Yes
	R57.2 Septic shock	Yes	Yes
	R65.1 Severe sepsis	Yes	Yes
Infective endocarditis	B37.6 Candidal endocarditis	Yes	Yes
	I33* Acute and subacute endocarditis	Yes	Yes
	I34* Nonrheumatic mitral valve disorders	Yes	Yes
	I35* Nonrheumatic aortic valve disorders	Yes	Yes
	I36* Nonrheumatic tricuspid valve disorders	Yes	Yes

	I37* Pulmonary valve disorders	Yes	Yes
	I38 Endocarditis, valve unspecified	Yes	Yes
	I39* Endocarditis and heart valve disorders in diseases classified elsewhere	Yes	Yes
Osteomyelitis or septic arthritis	G06.1 Intraspinal abscess and granuloma	Yes	Yes
	G08 Intracranial and intraspinal phlebitis and thrombophlebitis	No	No
	M00* Pyogenic arthritis	Yes	Yes
	M86* Osteomyelitis	Yes	Yes
	M46.2 Osteomyelitis of vertebra	Yes	Yes
	M46.3 Infection of intervertebral disc (pyogenic)	Yes	Yes
	M46.5 Other infective spondylopathies	Yes	Yes
Deep abscess	D73.3 Abscess of spleen	Yes	Yes
	E32.1 Abscess of thymus	Yes	Yes
	J85* Abscess of lung and mediastinum	No	No
	K63.0 Abscess of intestine	Yes	Yes
	K65.1 Peritoneal abscess	Yes	Yes
	K68.1 Retroperitoneal abscess	Yes	Yes
	K75.0 Abscess of liver	Yes	Yes
	M71.0 Abscess of bursa	Yes	Yes
	N15.1 Renal and perinephric abscess	Yes	Yes
Central nervous system infections	B43.1 Phaeomycotic brain abscess	Yes	Yes
	G06.0 Intracranial abscess and granuloma	No	Yes
	G06.2 Extradural and subdural abscess, unspecified	No	No
	H44.0 Purulent endophthalmitis	Yes	Yes
	H44.1 Other endophthalmitis	Yes	Yes
	H45.1 Endophthalmitis in diseases classified elsewhere	Yes	Yes
Other	A48.8 Other specified bacterial diseases	No	Yes
	B95 Streptococcus and staphylococcus as the cause of diseases classified to other chapters	No	Yes
	B96 Other specified bacterial agents as the cause of diseases classified to other chapters	No	Yes

**ICD-10-AM codes starting with.*

^There is no specific ICD-10-AM code for bloodstream infection, rather a range of sepsis codes and 'other bacterial infection/disease' codes are used in Australia.

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Chapter 6: Teaching experience

Prologue

A requirement of the MAE is to teach field epidemiology, specifically through a presentation on a public health topic or case study to first year MAE scholars and the delivery of a 'Lessons from the field' (LFF) problem-solving exercise to a nominated group of peers in the MAE cohort. This chapter outlines my contribution to these activities, and collaboration with others in the cohort to achieve the teaching competency. Both sections introduce the relevant teaching task and topic, learning objectives and lessons learned.

For the teaching to the first year MAE scholars, I teamed up with two members of the MAE2020 cohort, Chris Bailie and Fran Sheehan, to present a lesson on 'An introduction to antimicrobial resistance and hospital-acquired infections.' This teaching is usually delivered face-to-face during the first course block of first year scholars, and the third course block of second year scholars, however due to the COVID-19 pandemic and travel restrictions within Australia, the lesson was taught by Zoom teleconference. For the LFF, I teamed up with another member of the MAE2020 cohort, Troy Laidlaw, to prepare a two-part series on the importance of workflow and file management when using statistical software. The LFF was delivered to a group of peers in our MAE cohort by Zoom teleconference.

Teaching to first year MAE scholars

The purpose of this teaching activity was to introduce the concepts of AMR and HAI and their relevance to field epidemiology. The topic of our teaching session was selected due to relevant experience and special interest in the topic by each member of our team. Our team collaborated efficiently to develop the lesson plan, presentation structure and content, and to rehearse the presentation. This teaching was delivered as a PowerPoint on Zoom, with live questions and answers, group discussion and concluded with a formal evaluation. Table 1 presents the lesson plan, and the key learning objectives of this activity were:

1. To define and understand the global burden of AMR/HAI.
2. To understand the importance of AMR/HAI in the context of field epidemiology.
3. To collaboratively work through case studies and quizzes to ensure the teaching content is well understood by the audience.
4. To identify additional resources about AMR/HAI for further learning after the teaching session.
5. To build relationships with other MAE scholars, that will benefit future public health and field epidemiology responses.

Table 1. Structure of the teaching session on antimicrobial resistance and healthcare associated infections to the first year MAE scholars on 26 March 2021.

Time	Presenter	Content
11:00–11:15	Steph	• Teaching team introductions. • Summarise the purpose and objectives of the teaching session. • Virtual whiteboard for baseline 'what comes to mind when you hear this topic'. • Virtual whiteboard to show the classes professional backgrounds.
11:15–11:25	Chris	• Overview of AMR. • Global burden of AMR.
11:25–11:35	Fran	• Overview of HAI. • Intersection of AMR/HAI.
11:35–11:37	Fran	• AMR/HAI as a public health issue and its relevance to field epidemiology.
11:38–11:50	Fran	• Case study: establish or evaluate a HAI/AMR surveillance system in Zoom breakout rooms.

11:50–12:00	Steph	• Group discussion of each surveillance system explored in the case study. • Repeat virtual whiteboard for baseline 'what comes to mind when you hear this topic.'
12:00–12:10	Chris	• Open group discussion: questions, comments and exploration of individual experience in AMR/HAI in field epidemiology. • Discus further learning resources. • Teaching evaluation.

Lessons learnt and evaluation

Preparing for the teaching session offered an opportunity to develop a structured lesson plan, which highlighted the importance of carefully considering the objectives of a teaching session to provide structure to the lesson. For this activity, it was beneficial to collaborate in a team with a multidisciplinary background, i.e., Fran is a Registered Nurse, Chris is a Medical Doctor, and I have a background in research. Our combined experience in different areas of AMR/HAI prior to the MAE enabled the teaching session to cater to a broad audience from different professional backgrounds and equipped us well to answer questions during the teaching session.

Our topic and delivery method were well received with high levels of engagement and questions, as reflected in the evaluation results. The teaching evaluation included a series of statements that were answered using a Likert scale (strongly disagree, disagree, neither agree or disagree, agree, strongly agree). The evaluation statements were:

- The facilitators were prepared and organised.
- The learning objectives were outlined at the beginning of the session.
- The content presented was relevant to my knowledge and understanding of epidemiology and public health.
- I feel motivated to learn more about this subject area after the session.
- The facilitator's teaching methods and aids were appropriate and effective to my learning.
- The facilitators provided opportunities to ask questions and participate in further discussion.
- At the end of the session, the learning objectives were met.

- Overall, I am very satisfied with the session.

For each of these statements, 95% (19/20) of respondents reported that they agree or strongly agree. The other respondent reported neutral feedback for all the statements, however it was noticed that this respondent repeatedly provided the same neutral or negative feedback to all teaching groups. In response to the open-ended question “what was done well?”, there was a common theme that the teaching session was interactive, fun and engaging. In response to the open-ended question “what could have been improved?”, many respondents reported the ability to be together on campus rather than online, and technology issues. Unfortunately, these two limitations were unavoidable consequences of the setting in which the teaching occurred, online during a pandemic. Overall, our team delivered the teaching to the best of our capability within the constraints of teleconference technology, and the experience built on my teaching skills which I hope to continually develop in my field epidemiology career.

Lessons from the field

The purpose of my LFF was to introduce the importance of workflow and file management in statistical software. This lesson idea came to mind when Troy and I were assisting others in the MAE2020 with using RStudio and working in large collaborative projects in our field placements. During these experiences, we noticed a lack of efficient workflow, which commonly resulted in unnecessary additional time being spent on coding in statistical software. Therefore, we produced a two part-LFF, across a two-hour session. For my part, 'Part 1: Organising your workflow in RStudio with scripts', the key learning objectives were:

1. Create, save and open an RStudio script.
2. Create comments in an RStudio script.
3. Use snippets to create a script header in RStudio.
4. Run select lines of a script, or the entire script, in RStudio.
5. Find and replace in an RStudio script.
6. Define the role and benefits of packages in RStudio.
7. Install, load, remove and update packages in RStudio.

The LFF was reviewed by my academic supervisor Professor Lau and sent to the cohort two weeks before the teleconference session to allow participants time to review the theory before the practical session. During the LFF teleconference, I revisited the theory by asking each person to explain a component that was addressed in the activity. Subsequently, we worked through the practical, reviewed examples from the group and explored further tips, tricks, and potential questions relating to scripts and packages. The LFF also included further recommended reading and activities to continue learning after the session if interested.

Lessons learnt

My participation in the LFF presentations by other scholars and the opportunity to prepare my own LFF were learning opportunities to share experiences across field placements. The LFF is not typically performed in groups, and Troy and I presented separate components of our LFF, however the cohort expressed the benefits of having a longer and more comprehensive LFF through combining two presentations. It was also a great opportunity to collaborate with another MAE2020 Scholar and share our unique experiences in RStudio.

Although no formal evaluation was performed, I believe the sessions were well received, as there was extensive discussion on the day and several of the attendees followed up with additional LFF related questions. This experience provided the opportunity to create class content from scratch, which was more time consuming than anticipated especially with coding activities, as it requires very clear instructions for the cohort, many of whom were beginners in RStudio. Overall, I was happy with how the presentation went, and believe attendees were too.

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Chapter 7: Additional field experience

The Victorian Department of Health

Background

After a busy three-month secondment to the Victorian DHHS, I joined the COVID-19 team as an Outbreaks Epidemiologist on a casual contract, external to the MAE. This provided the opportunity to gain additional field experience across 2020 and 2021, through all phases of the epidemic in Victoria, from outbreak 'waves' to 'ripples' to zero cases and to 'opening up' after the vaccine rollout and over a year of lockdown in Victoria.

My role in the DHHS was similar to that described in Chapter 2, however I also gained leadership experience after I became a Pod Lead (Senior Epidemiologist) in October 2020. In this role, I oversaw a team of Epidemiologists, Surveillance Officers and Data Managers, and contributed to developing strategies for the response, including the integration of newly formed Local Public Health Units. In late 2020, I also completed the Public Health Association of Australia-Australasian Epidemiological Association mentoring program for those engaged in front line Victorian response to the COVID-19 pandemic. In this program I was matched with Professor Raina MacIntyre who provided excellent mentorship. Subsequently, I also felt confident to provide mentorship to other members of the outbreak team, which included discussion of career options and upskilling the team in a range of activities from data analysis to research projects, whilst sharing my experience in public health.

Lessons learnt

- Good time management was essential to being able to complete the MAE whilst also working in COVID-19 response. I thrive in busy, challenging environments, and good time management ensured I was able to achieve the expectations of study, the MAE field placement and external employment. As they say, give a task to a busy person and they will get it done.

- There are unique benefits to different types of jobs in public health. For example, at the DHHS I enjoyed the ability to perform discrete tasks that could be achieved in a short period and provide an immediate sense of accomplishment. The discrete work is different to a research role, where each milestone takes a longer period to complete, and tasks (i.e., writing a protocol and ethics or data analysis) are often completed as an individual rather than a large interactive team.
- Finally, I was able to experience how the pandemic response in Victoria developed overtime; from being one of the first people involved in the response in March 2020, to being one of the few 'original' team members in October 2021. Working in the COVID-19 team was difficult and stressful, however there were many great accomplishments, thanks to the contribution of many.

Fieldwork at Howard Springs

Background

The Howard Springs International Quarantine Facility (HSIQF) at the Centre for National Resilience (CNR), in the Northern Territory was implemented by the National Critical Care and Trauma Response Centre (NCCTRC) through the Australian Medical Assistance Team with support of the Australian Government. The operation's mandate was to manage quarantine for internationally repatriated Australians, and the facility become known as the 'Howard Springs' quarantine model that other jurisdictions explored replicating.

I was invited by NCCTRC to carry out fieldwork to document the operations of HSIQF at the CNR, with a focus on IPC. This documentation was essential to the public health community, due to the achievement of no leakage of COVID-19 to the community through residents or staff, which was an issue in other hotel quarantine facilities. I was invited to perform this fieldwork because of relevant experience in research, IPC surveillance, COVID-19 outbreak response and emergency response.

I arrived in Darwin on 21 March 2021, spent 10 days working onsite at HSIQF at the CNR, and stayed in one of the staff demountable cabins (also known as a 'donga'). Whilst onsite, I witnessed and took part in the impressive operations of HSIQF at CNR, including daily PPE training, health screening and COVID-19 testing by polymerase chain reaction and rapid antigen diagnostics. Whilst onsite, I spent time meeting staff, learning about the 'Why' behind each strategically implemented policy and procedure, and collating data sources on the operations. I witnessed these policies and procedures in action, asked questions about them to ensure I had an accurate understanding, and supported by learning with written manuals. On return to Melbourne, I spent additional time to write a peer-reviewed journal article about the operation of HSIQF at the CNR which was submitted to Emerging Infectious Diseases in September 2021.

Lessons learnt

- I am thankful to the NCCTRC for hosting me at HSIQF at the CNR. On the ground I was able to grasp the comprehensiveness of the operation, including the influence

and importance of a variety of emergency responders, from Police to Fire services. The multidisciplinary team was essential to creating a safe and effective operation, that went beyond a public health approach, to incorporate expert advice from a variety of industries. This was the type of multidisciplinary on-the-ground team I love to work in, and I hope to have the opportunity to work with NCCTRC again.

- There is a need to think beyond a traditional healthcare setting for IPC, to consider how emergency settings, different climates and outdoor environments may affect IPC procedures. For example, I always saw single-use gloves as adequate for COVID-19 IPC in my work in Melbourne, however the heat climate of Darwin resulted in heavy sweat soilage by staff, and therefore required the need for a double-gloving policy. There are dozens of these examples I learnt during my field experience, which are invaluable to future field epidemiology work across the globe.
- Finally, I learnt there is a real need for face-to-face stakeholder engagement in emergency response. It is essential to establish in-person rapport, and those involved in emergency operations are likely to spend little to no time on computers, therefore strong engagement would not have been feasible via emails or teleconferencing alone.

The CRISPER project

Background

Throughout the MAE, Professor Lau provided the opportunity to be part of 'CRISPER: COVID-19 Real-time Information System for Preparedness and Epidemic Response', a project funded by the Australian Partnership for Preparedness Research on Infectious Disease Emergencies (APPRISE), a National Health and Medical Research Council Centre of Research Excellence. This provided opportunities to network with additional researchers and public health professionals, whilst contributing to the project where possible.

The aim of the CRISPER system was to provide accurate, reliable and trustworthy information for public health practitioners, clinicians, and the public to support a unified national response to COVID-19. A core element of the project was to work with government to collect data and provide data visualisation through an interactive mapping tool of cases, testing and contact tracing alerts by location, summary dashboards detailing cases, deaths and testing and an automatic alert system providing registered users with daily or weekly email alerts on new cases, exposure site alerts and/or testing rates based on user-defined geographical areas of interest.

My involvement in CRIPSER spanned across both years of the MAE, and included:

- Simulate data on Queensland cases and outbreaks using publicly available data on postcodes, Local Government Areas, Hospital and Health Services, and COVID-19 to facilitate the pilot dashboards for data visualisation and reporting.
- Review the CRISPER website (www.crisper.net.au), dashboards and alerts system prospectively as changes were made, and make suggestions for usability, particularly from a public health perspective.
- Contribute to data analysis plans for the CRISPER project, including conceptualisation of areas to explore from a public health perspective.
- Co-authored two peer-reviewed journal articles; 'Development of the COVID-19 Real-time Information System for Preparedness and Epidemic Response (CRISPER), Australia' in Frontiers in Public Health and 'Differential privacy for public health data:

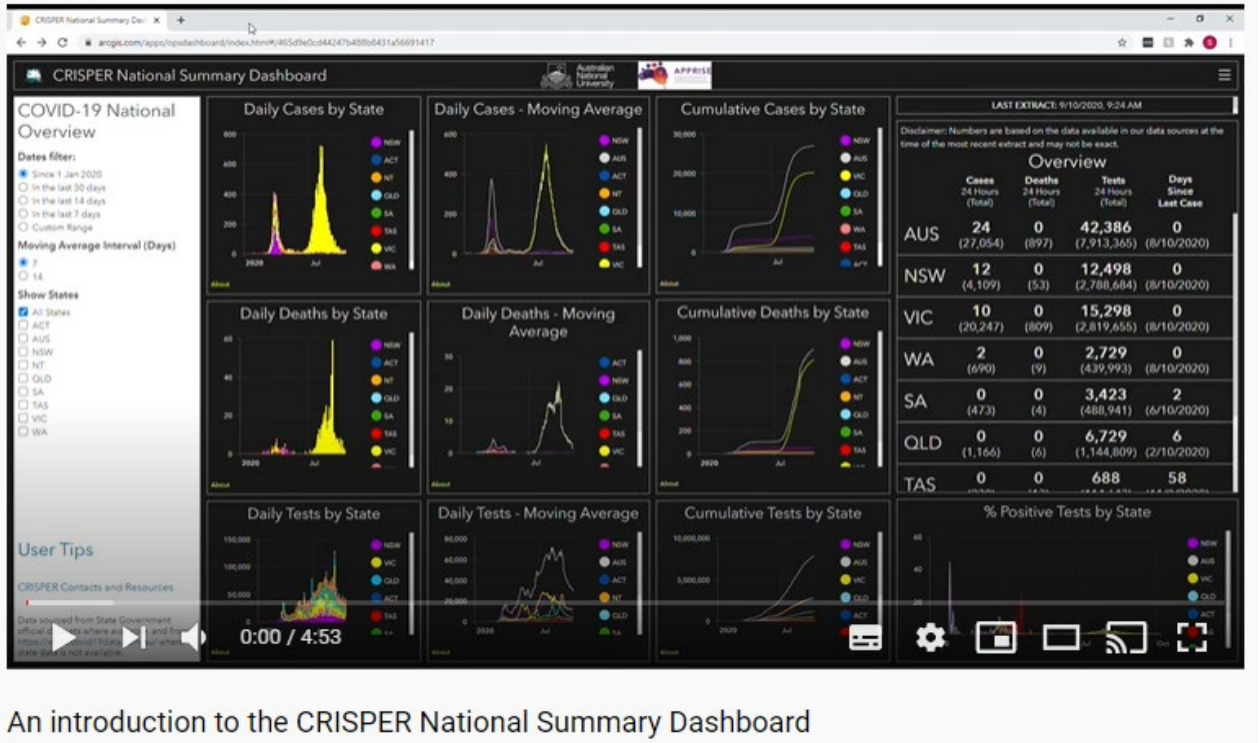
An innovative tool to optimize information sharing while protecting data confidentiality' published in Patterns.

- Prepare a summary of public health information for a lay audience through recording a Video on the use of the CRISPER National Summary Dashboard.

Lay audience competency

The competency of preparing a summary of public health information for a lay audience was done in a unique way for CRISPER, that was not the typical 'poster' presentation to disseminate information. Rather, the CRISPER team identified the need for the website to include a 'how to use this page' videos for each component of the dashboard. Therefore, I wrote a presentation script and recorded a video to be embedded into the CRISPER dashboard website, available on YouTube as "An introduction to the CRISPER National Summary Dashboard". The video explores dashboard tips, including exploring controls and navigation, for a lay audience to best derive utility from the tool. A snapshot of this video on YouTube is provided in Image 1.

Image 1. A YouTube snapshot of the CRISPER National Summary Dashboard presentation for a lay audience



Lessons learnt

- My involvement reiterated the lessons learnt from Chapter 4, about the benefits of multidisciplinary collaboration, this time, in collaborating with the Software Innovations Institute, College of Engineering and Computer Science at the Australian National University and National Centre for Geographic Resources & Analysis in Primary Health Care at the Australian National University. The collaboration enabled the development of useful tools and alerts for public health professionals, that are not within the capacity of most public health professional's skill set to create. Again, this presented the opportunity to learn from other facilities technical backgrounds, which lead me to complete training in ArcGIS software to further develop my own mapping skills.
- Collaboration with health departments can be complex, and for CRISPER, this resulted in no jurisdiction sharing line list data requested. Rather, the CRISPER system relied on publicly available data. This limitation in data sharing can be a major impediment to completing operational response and research projects.
- Finally, I learnt new ways to communicate to lay audiences. I had not considered how this competency could be completed through use of verbal communication, however with prompting by Dr Emma Field, I was reminded that communication can come in many forms, each of which are important for delivering public health messaging.

The Optimise Study

Background

As part of my field placement at the Burnet Institute, I joined the project team for the Optimise Study, 'Optimising Isolation, Quarantine and Distancing for COVID-19.' The project aimed to find out how Victorians were experiencing COVID-19 and responding to the measures introduced to stop the spread of the virus to inform national policy and practice. The project included regular reporting to the State and Federal Government on strategic information collected from the study.

My involvement in the Optimise Study included:

- Contribute to the development of all data collection tools and pilot the tools in the data collection platform.
- Write SOPs for the Data Collection and Data Analysis team, and contribute to those of the Data Management team, to successfully define processes for the project.
- Be a Data Analyst, to write code in statistical software that cleaned, analysed and reported on the strategic information. Initially, this focussed on setting up script that would automate repeatable analysis. Subsequently, it focussed on responding to ad-hoc analytics requests and brainstorming reporting topics based upon available data.
- Work with Dr Anna Wilkinson to write, edit and run code in statistical software to automate participant reimbursements, based upon the surveys complete in the previous period.
- Work with the Victorian DHHS to arrange participant recruitment flows into the Optimise Study.
- Prepare a summary of public health information for a lay audience through co-authoring the initial report on the study. Freya Saich was the lead author, whilst Dr Katie Heath and I were second authors and lead analysts.

Lay audience competency

Throughout the MAE, I prepared several summaries of public health information for a lay audience, and here I share a second example through my work in the Optimise Study. This

communication was through the production of a short report that detailed the first round of study results. This activity required collaborating with the Knowledge Translation team, whilst exploring the data, to scope useful and valid information from the initial study sample. The purpose was to communicate to project partners, including government and participants, to provide real-time and rapid advice. The report focused on participants demographics, perceptions of government response, vaccine preparedness and adoption of risk reduction behaviours. The report is available on the Burnet Website: 'The Optimise Study: Optimising Isolation, Quarantine and Distancing for COVID-19 Report 1 November 2020 '.

Lessons learnt

- The fast launch of this project, including establishment of a team at the Burnet, was impressive. Within a few weeks the project had established a series of teams including Data Collection, Data Analysis, Data Management and Knowledge Translation to achieve the projects goals. Whilst research projects often move slowly, this was not the case for the Optimise Study.
- I was reminded that most coding will not be simple, despite how simple it may sound, or how simple others promise it to be. There will always be new challenges in data cleaning, linkage, analysis and/or reporting, and this should be factored into all project commitments. As a longitudinal study, the Optimise Study collected thousands of data points, across multiple surveys per day, week and month, therefore the collation and cleaning of this data was difficult. In this project, I found it difficult to communicate the complexities of data manipulation to those not involved with the data analysis.
- Finally, the lay audience piece required a lot of collaboration with the Knowledge Translation team. In the creation of the first report, the topic was initially unclear, however through a back-and-forth collaboration and questioning, and rapid data review, we were able to pull together important information. Subsequent reporting became easier as each report produced lead to further questions being asked by stakeholders.

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