Lessons from a system-wide response to a measles outbreak, Canterbury, February–April 2019

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Measles is a highly contagious airborne virus which affects both children and adults and can be life-threatening. Furthermore, measles infection can cause immune memory loss, increasing susceptibility to other infections for up to three years and contributing significantly to childhood non-measles infectious disease mortality.\(^1,2\) In New Zealand, people born before 1969, when vaccination was introduced, are likely to be immune due to past measles infection. The measles, mumps and rubella (MMR) vaccine is effective at preventing measles in 95% of people after one dose, and 96% of people after two doses.\(^3\) Reports of previous New Zealand outbreaks have identified important gaps in community immunity.\(^4,5\)

New Zealand achieved measles elimination in October 2017.\(^6\) However, cases continue to be introduced to New Zealand from overseas. Canterbury experienced measles outbreaks in 2009 (126 confirmed and 43 probable cases), 2011 (three cases), 2017 (one case) and 2018 (February, three cases; April, nine cases plus seven linked cases elsewhere in the South Island). There are currently large measles outbreaks in a number of overseas countries. From mid-2019 a large Auckland-centred outbreak grew rapidly and resulted in cases in many other parts of New Zealand and in neighbouring Pacific countries.

The purpose of this paper is to help inform measles control in New Zealand and elsewhere by describing a contained measles outbreak in Canterbury in early 2019 and reflecting on lessons learnt from our system-wide response.
Methods

The Health Act 1956 requires health practitioners to notify confirmed or suspected cases of measles to the medical officer of health. Canterbury Community Health-Pathways provides a generic electronic notification form or a measles-specific fax form, as well as advice on laboratory testing. Staff at Canterbury District Health Board (DHB)'s public health unit, Community and Public Health (CPH) follow up notifications using Ministry of Health case and contact definitions and laboratory confirmation criteria, and obtain further information from cases and contacts.

At the National Measles and Rubella Laboratory (CHL Christchurch), nucleic acids were extracted from nasopharyngeal swab samples and analysed via a CDC-developed screening real-time PCR. A second measles genotype A-specific real-time PCR developed by the Regional Measles and Rubella Laboratory at VIDRL/Melbourne was used to identify the measles vaccine strain in people who had recently been vaccinated and developed measles symptoms. Further genotyping of positive measles cases was done via a conventional RT-PCR targeting the N gene and sequencing of the terminal 450 nucleotides. Serum samples were analysed for Measles IgM via a manual ELISA using a WHO-recommended Siemens Enzygnost kit. Measles IgG were detected using a Euroimmun kit on an automated Triturus platform.

Outbreak description

In the last week of February 2019, CPH was notified of five unrelated confirmed cases of measles. One case had been an inpatient at Christchurch Hospital before and during the incubation period. The other four cases were from Rangiora, a town just north of Christchurch. Cases had been in contact with large numbers of people, including in schools and healthcare facilities. A further 33 confirmed cases were notified during March (see Figure 1), bringing the total number of cases meeting our operational case definition to 38 (one additional case had been in Thailand during their incubation and initial symptomatic period and so was not included in the outbreak total). Sixteen cases were hospitalised and one case was admitted to ICU. No cases died. Cases ranged in age from four months to 54 years, with a median age of 23 years (see Table 1). Thirty-one cases (81.6%) were European, six (15.8%) were Māori, and one (2.6%) was Asian. Although most lived in Christchurch, cases came from as far north

<table>
<thead>
<tr>
<th>Age group</th>
<th>&lt;15 months</th>
<th>15 months–4 years</th>
<th>5–28 years</th>
<th>29–50 years</th>
<th>50+ years</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>5 (13.2%)</td>
<td>2 (5.3%)</td>
<td>16 (42.1%)</td>
<td>13 (34.2%)</td>
<td>2 (5.3%)</td>
</tr>
</tbody>
</table>
as Waiau (see Figure 2). Identified exposure settings included households, education settings (pre-school, primary and secondary school, and university), a hospital and two medical centres (see Figure 3). However, half of the cases (19 cases) did not have any identified exposure to measles. Nineteen cases (50%) were unimmunised, 11 (29%) had only received MMR1, four (10.5%) had received MMR1 and MMR2, and four (10.5%) were of unknown vaccination status. One case was a general practitioner and six cases were hospital staff members. Two of the infected healthcare workers had received MMR1 and MMR2, two had received only MMR1 (both vaccinated overseas), two were unvaccinated and one's vaccination status was unknown.

One case was exported to Dunedin and subsequently infected one other person there, and another case was exported to Auckland. Both exported cases were linked to this outbreak with a 100% identical B3 sequence but have not been included in the outbreak total as they did not meet our operational case definition. Case 11 was overseas during his incubation period and was subsequently confirmed as having a non-outbreak measles strain (D8). However, as he became symptomatic in Christchurch he met our operational case definition and was followed up as part of the outbreak.

Of the 38 cases of this outbreak, the genotypes of 13 cases were determined at the National Measles and Rubella Laboratory at Canterbury Health Labs (CHL) in Christchurch and for eight cases genotyping was done at the Regional Measles and Rubella Reference Lab at VIDRL, Melbourne. The genotype of this outbreak (OB-19-108048-CH) was B3, but the strain of this outbreak was not previously reported in New Zealand. It shows 100% sequence identity to a measles B3 sample from the Philippines from epidemiological week 17 in 2018 (MV/San Juan City.PHL/47.18/) and no exact matches to MeaNS named strains. A phylogenetic comparison with genotyped measles samples from 2018 and 2019 also shows a close relationship of the Canterbury B3 strain to other B3 importations from the Philippines (see phylogenetic tree in Figure 4).
During the period of the outbreak from 21 February (date of first sample) until 31 March (date of last sample) the measles vaccine strain (genotype A) was detected in 16 additional suspected cases from Canterbury. In the same time period, four more importations of different B3 strains (from Afghanistan, Philippines, China [originally from the Philippines] and an unknown source) as well as two more D8 importations (from the UK and Thailand) have occurred in New Zealand (see Figure 4).

Outbreak control
Community and public health

Initially all community cases and contacts were followed up by CPH staff according to in-house protocols. Cases were asked to stay away from early childhood services, school, work and close contact with unexposed people for five days after the appearance of the rash, with airborne precautions recommended in healthcare facilities for the same period. Susceptible contacts who met the contact definition were asked to avoid attending school, early childhood services or community gatherings, and to avoid contact with other susceptible individuals, including in higher-risk work settings, from seven days after first exposure until 14 days after last exposure to the infectious case. However, contacts who had previously received one documented dose of MMR and then received their second dose of MMR within 72 hours after first exposure and contacts who received IG within seven days after first exposure were considered safe to
Figure 4: Phylogenetic tree of genotyped measles samples 2018–April 2019.
return to school or work. All contacts were advised to seek early medical attention (telephoning ahead) if symptoms developed. Institutions and families were provided information on the disease risk and advised that all unimmunised children should receive MMR. The use of Health Act directions to individuals, requiring exclusion, was considered, but was not required.

Due to the large number of cases and contacts during the second week of the outbreak CPH staff moved to “focused public health management”, continuing to follow up household contacts but asking the case, institution or healthcare setting to provide a tailored “contact letter” to other contacts. Full follow-up by CPH staff resumed later in the outbreak as case numbers fell. A total of 799 contacts were recorded as followed up by CPH staff. Many more contacts were identified but not formally recorded. Seventeen contacts were referred for MMR vaccination within 72 hours of their exposure.

A Coordinated Incident Management System (CIMS) structure ran from 22 February until the outbreak was declared over on 16 May, and included up to 30 staff from multiple CPH teams and other organisations as the outbreak progressed. Daily situation reports and regularly updated incident action plans were shared with all stakeholders.

Christchurch Hospital

The response to DHB patients and staff who had been exposed to measles at Christchurch Hospital and/or who developed measles was overseen by the Canterbury DHB Infection Prevention and Control Executive Committee. The committee included infection control nurse specialists, infectious disease physicians, laboratory and communications staff, and senior hospital management. Its focus remained on the hospital, the key objectives being to contain measles infection and spread, and to minimise impact on business as usual activities. Over 200 staff who had been exposed to measles cases in hospital were followed up using CPH protocols. Staff members who had been exposed to measles but whose immune status was uncertain were offered serological testing to guide advice about quarantine. In addition, vaccination records for all staff working in areas designated as “high risk” (including cleaning staff employed by a contractor) were reviewed, and if there was no record they were contacted and offered vaccination. Over 130 staff were vaccinated by the Occupational Health Service.

Contacts from the emergency department waiting room who had been discharged home were followed up by CPH staff.

Primary care

The Canterbury Primary Response Group (CPRG) is tasked by the Canterbury DHB with leading the region’s primary care emergency planning, response and recovery. It includes general practice, nursing, pharmacy, and emergency planning expertise, and can call on a wider group of health sector representatives to provide a whole-of-health response to health emergencies. CPRG became involved when a measles vaccination campaign was proposed as part of the response, and contributed to the campaign’s planning and implementation, including providing co-ordination and communication with primary care.

Planning and funding

Canterbury DHB’s Planning and Funding division became involved as vaccine supply issues arose due to increased demand, and led modelling of priority group volumes and expected demand and co-ordinated vaccine supply for the remainder of the outbreak.

Vaccination campaign

It was quickly clear that the early cases had exposed large numbers of people to measles and that further spread was likely. Canterbury has relatively high recent measles, mumps and rubella vaccine (MMR) coverage, with 93% of both two and four year-olds fully vaccinated for their age. However, there was concern about those in the community who were susceptible to measles because they:

- were too young for their first MMR (given at 15 months)
- were too young for their second MMR (given at four years)
- had declined or not sought MMR in the past
- were aged between 29–50 years old and may have only had one MMR based on the vaccination schedule when they were young.
as well as concern about health or education professionals who worked with vulnerable populations.

Initial public communications emphasised the importance of all people born after 1969 having two MMR vaccinations. The resulting public demand placed considerable pressure on general practices and on the vaccine supply. An Immunisation Programme Team was formed by representatives from CPH, Ministry of Health, and Canterbury DHB Planning and Funding, who worked closely with PHARMAC and the Canterbury Primary Response Group, and on 13 March identified the following priorities for vaccination:

- **Priority 1**: Children aged 12 months to 13 years who have never been vaccinated
- **Priority 2**: Children and adults aged 14 years to 28 years who have never been vaccinated
- **Priority 3**: Caregivers and close contacts of children aged less than 12 months or those who cannot be vaccinated.
- **Priority 4**: Continue with the routine immunisation programme (15 months and 4 years)
- **Priority 5**: Occupational groups who have frequent contact with children, such as EEC, primary, and secondary school teachers, residential care and healthcare workers, who have never been vaccinated.

Planning and Funding estimated vaccine requirements for each priority group (a total of 20,000 vaccines for the five priority groups), produced daily uptake reports based on National Immunisation Register (NIR) data, and in conjunction with the immunisation co-ordinators managed vaccine supply to practices. The Immunisation Programme Team met regularly, and liaised with CPRG.

Between 4 March and 24 March, 13,578 MMR doses were recorded on NIR, with greatest uptake in under-five-year-olds. Another 4,500 MMR doses were administered to 14–50-year-olds but could not be linked to NIR. As more vaccine had become available, the vaccination strategy was reviewed, and a “phase two” four-week campaign agreed from 28 March to 26 April, delaying the start of the seasonal influenza vaccination campaign, and targeting first or second MMR for:

- all those aged 12 months to 28 years
- caregivers of infants aged up to 12 months
- those between 29 and 50 who work with children (teachers or healthcare workers)

In total, over 31,000 vaccines were distributed to general practice during the response, and over 22,000 vaccination events were recorded on the NIR. At its peak, general practices vaccinated over 1,950 people in one day, with individual practices vaccinating up to 850 people each over the six weeks of the outbreak. Fifty-three percent of vaccines were delivered to under-five-year-olds. Two thirds of these were MMR2 delivered early to 1–3-year-olds. Five to 29-year-olds received 14% of vaccines. The remaining third of vaccines were delivered to people aged 30 and over. Almost all of the vaccines delivered to people aged five and over were MMR1 (see Figure 5). The recorded ethnicity of those vaccinated was European 67%, MELAA 15%, Maori 8%, Pacific 3% and Other 7%.

**Liaison**

A CPH medical officer of health undertook liaison with hospital, primary care and Ministry of Health groups, to help coordinate activities and ensure good communication.

CPH’s Māori Relationships Manager liaised with and provided information to local rūnanga, Mana Whenua ki Waitaha, and local Māori providers.

One of the Ministry of Health’s Deputy Directors of Public Health was based at Community and Public Health for much of the outbreak, facilitating linkages to the Communicable Diseases Team in the Ministry as well as to PHARMAC, who were responsible for vaccine supply.

**Communications**

The Canterbury DHB Communications Team were engaged early in the outbreak to ensure consistent and accurate information was relayed through the DHB, other health sector organisations and the community. Media interest remained high for much of the outbreak, often requiring daily media briefings which were live-streamed via Facebook, and interpreted by a sign language interpreter. The footage from daily media briefings was also uploaded to the Ministry of Health website for wider dissemination.
briefings was posted on the Canterbury DHB's Facebook page, and elicited large volumes of comments, shares and likes. Throughout the outbreak, the Communications Team received a large number of private messages via Facebook from concerned members of the public requesting updates on the latest priority groups for vaccinations, vaccine availability, whether it was safe for parents to take unvaccinated young children and babies out in public, and latest updates on case numbers. The medical officers of health fronted media briefings and were consulted on any clinical queries from members of the public.

The initial focus for communications was to advise the public on the risks and actions they should take, and keep them updated as the situation evolved. Communications staff were also involved with communications to primary care and the wider health system, and with liaison with the Ministry of Health.

Community information was provided through print media, radio, television and Canterbury DHB's website and social media. Press releases were produced daily during the height of the outbreak and fact sheets and FAQs were translated into multiple languages (te reo Māori, Samoan, Farsi, Tongan, Tagalog, Hindi, Simplified and Traditional Chinese) and circulated through community channels.

Education settings were identified as priority audiences for communication and information. Updated measles information was distributed to all Canterbury early childhood centres and schools. Information was also distributed to affected workplaces, community organisations and Christchurch International Airport.

**Discussion**

**Source**

As the index case of this outbreak could not be identified, no information about importation was directly available. The measles strain of this outbreak had been previously identified in The Philippines but had not been previously reported in New Zealand.

The Philippines were experiencing a very large measles outbreak that started in December 2017, with mainly B3 genotypes circulating. Canterbury's Filipino population at the 2013 census was 4,887 (approximately 1% of the then Canterbury population, 516,360). Between January and March 2019, 2,471 passengers arrived at Christchurch Airport carrying Philippine passports.

The cases with the earliest onset of symptoms and rash onset in this outbreak were the first Dunedin case, an 18-year-old, and case 7, a 42-year-old from Christchurch, who both developed their first symptoms on 14 February and a rash on 16 February. The Dunedin case was likely to have been infected while staying in Rangiora. Most other cases early in the outbreak appeared in Rangiora or had been inpatients at Christchurch Hospital. On this basis, it was hypothesised that the unknown index case had visited Christchurch Hospital as well as moving around the community in Rangiora while infectious.
Ongoing risk of importation

Globally, analyses of 2012 and 2013 data suggested that measles incidence is typically highest in less-developed nations. WHO preliminary global data in August 2019 showed that reported cases of measles rose by 300 percent in the first six months of 2019, compared to the same period in 2018. Many countries were in the midst of sizeable measles outbreaks, with all regions of the world experiencing sustained rises in cases.

Travel to New Zealand by non-New Zealanders is dominated by Australia, followed by China, UK, Japan and the US. Australia is also the most common travel destination for New Zealanders. However, outbreaks in other countries with strong links to New Zealand or significant immigrant or resident populations here may pose a particular risk.

Vaccination

Despite New Zealand’s immunisation programme having achieved endemic measles elimination in 2017, outbreaks continue to occur in response to imported cases. The World Health Organization estimates that interruption of measles transmission can be achieved by herd immunity when approximately 95% of the population is homogeneously immune to measles. In New Zealand, not only is overall population immunity lower than 95%, but significant pockets of susceptible, non-immune population remain. As a result, New Zealand outbreaks still largely affect school-aged children, young adults and children under two years of age. Modelling suggests that supplementary measles immunisation would be economically beneficial in the New Zealand population.

Heightened media and public interest in measles during this outbreak provided a potential opportunity to promote vaccination widely, in order to improve community immunity, and reduce measles spread during the current and future outbreaks. However, the limited amount of vaccine available at short notice necessitated identification of priority groups for vaccination.

Canterbury DHB Planning and Funding led the vaccine prioritisation process, working with CPH, Ministry of Health, PHARMAC and primary care. At the start of the outbreak Canterbury DHB had been achieving MMR coverage of 92–95% at ages two and five for the previous five years, so was confident that children aged 2–10 years were well protected. Unfortunately, vaccination coverage data for the years before introduction of the NIR in 2005 are incomplete. Based on local experience, adults born between 1969 and 2005 were assumed to have mostly had one dose of measles vaccine (and some would have also received a second dose in their teenage years). Coverage may have been lower for current secondary school-aged children, whose vaccination ages coincided with public discussion of the now-discredited “Wakefield” paper. However, a substantial measles outbreak in Canterbury in 2009 had also raised awareness of measles, and widespread publicity of the recommendation for early MMR1 and MMR2 for Canterbury children may have increased vaccination uptake at that time.

Challenges for the vaccination campaign included uncertainty about vaccine supplies, general practice capacity to deliver large numbers of additional vaccinations within a short time frame, and difficulty accessing prior vaccination history for people vaccinated before the introduction of the National Immunisation Register. Unfortunately, adults who would otherwise have been eligible for a second MMR who sought vaccination during the outbreak had to be turned away if they did not belong to a priority group.

Over one third of the vaccinations administered during the outbreak were MMR2 delivered early (to 1–3-year-olds). While these vaccinations improved protection for an important vulnerable group during the outbreak, they will not improve population immunity in the longer term. The number of people in Canterbury born since 1969 who have not received full vaccination against measles is unknown. Many of these people are not aware that they have not been fully immunised. A systematic campaign offering vaccination to all these people through recall and/or opportunistic vaccination in general practice could substantially reduce the future risk of measles outbreaks in Canterbury.
Isolation and quarantine

Isolation of measles cases while infectious is universally recommended. Recommendations for quarantining of susceptible contacts vary between jurisdictions, but while there is limited evidence for its effectiveness, there are good arguments for its use in elimination settings, particularly in the very early stages of an outbreak.\(^\text{13}\)

Although the Health Act (1956) provides for medical officers of health to require compliance with isolation or quarantine restrictions by issuing a direction or by applying for a public health order, in practice these provisions are time-consuming and difficult to enforce. The use of directions was discussed by the response team in this outbreak, but was not considered necessary. Cases and contacts generally appeared receptive to public health advice, and appeared willing to comply with isolation and quarantine requests.

Nevertheless, the burden on individuals and families of staying away from work or study, or keeping children away from school or early education for extended quarantine periods can be substantial. CPH is continuing to develop relationships with other agencies which can provide support to households affected by isolation or quarantine advice, including primary healthcare providers and non-government organisations in our region.

Equity, hauora Māori, and culturally and linguistically diverse groups

Current “fully vaccinated’ rates for Māori in Canterbury are 91% for two-year-olds and 89% for five-year-olds, and for Pacific people in Canterbury are 97% for two-year-olds and 98% for five-year-olds (CDHB 2018/19 Q4 data). The ethnicity of measles cases in this outbreak was recorded and did not suggest a disproportionate burden in any one ethnic group. Although the outbreak measles strain suggested the current Philippines measles outbreak as the most likely source of this outbreak, no cases were identified in Filipino people.

No specific cultural or support needs were identified for the six Māori cases. The response team maintained links with and provided advice to local rūnanga (tribal councils), Mana Whenua ki Waitaha (the representative body of the local tribe Ngāi Tahu in Canterbury for health issues) and local providers.

The potential for isolation and exclusion advice to place a disproportionate burden on poorer families was noted, and plans were made to engage social support for households requiring it. However, the extent to which households were willing or able to comply with isolation and exclusion advice is not known, as the response team had limited capacity to follow up individual households once advice had been provided, and the team did not become aware of any households where social support was required.

More recent Canterbury measles cases have highlighted the importance of isolation and exclusion advice that matches the expectations and needs of the households and families involved, and CPH is pursuing closer working relationships with Māori and Pacific health and social service providers to ensure that public health advice is accompanied by appropriate support.

Prioritising public health resources

Public health follow-up of measles cases is labour-intensive, and capacity for individual contact follow-up by public health staff is quickly overwhelmed in a large outbreak. In this outbreak, planning for “focused public health management” commenced early, based on strategies developed and generously shared by Auckland Regional Public Health Service. The “focused management” phase recognises that household contacts are at highest risk, and they continue to be followed up by public health staff. For other contacts, public health staff provide a tailored letter to the case, and to any institution or health care setting where exposure has occurred, with a request for the letter to be passed on to any identified contacts. The effectiveness of this approach compared to individual contact follow-up by public health staff is unknown.

Follow-up of waiting-room contacts is labour-intensive for healthcare settings, and can be at least partially avoided by clearly instructing possible measles patients to phone ahead for advice.

In this outbreak only 17 contacts were advised to receive post-exposure MMR within 72 hours of their contact with a measles case. Post-exposure prophylaxis
is a proven control measure in measles outbreaks. However, measles cases are commonly notified too late for post-exposure MMR to be effective. Encouraging health practitioners to notify measles cases on suspicion is an important component of outbreak communications.

Recent research has suggested that “breakthrough” measles infections in vaccinated patients produce a lower viral load, and are associated with a reduced risk of onward transmission. In this outbreak, 11 of 38 cases had previously received MMR1 and four of 38 cases had previously received both MMR1 and MMR2. None of the seven instances of identified transmission from one case to another in this outbreak resulted from fully vaccinated cases. Further discussion of the extent of follow-up required for breakthrough cases could support prioritisation of limited public health resources in large measles outbreaks.

Healthcare workers
Exposure of healthcare workers to measles is inevitable in any outbreak. In this outbreak there was substantial measles transmission in the hospital environment. Nosocomial transmission of measles by healthcare workers is costly and preventable, as is quarantine of susceptible healthcare staff after workplace exposure to measles. All staff in healthcare settings should have their vaccination history recorded, and susceptible staff should be offered measles vaccination.

Communications
A substantial measles outbreak response is a complex event involving many players, with inevitable public and media interest. In the early stages of this outbreak variations in messaging, particularly concerning priority groups for vaccination, provided challenges for the public and for primary care staff delivering MMR. Early collaboration between public health, primary care, the Ministry of Health and PHARMAC on vaccination strategy development is recommended to avoid confusion. Alignment of key messages across all agencies is essential, and can be facilitated by early establishment of regular interagency meetings, early development and adoption of a formal communications plan, and by including an on-the-spot communications advisor in the public health response team.

Impact of mosque murders
The 15 March Christchurch mosque murders occurred in the middle of this outbreak. Potential implications for the outbreak considered by the response team included reduced capacity at Christchurch Hospital, the potential for re-importation of measles by people travelling to New Zealand in response to the event, and the potential for measles spread at mass gatherings and among the communities affected by and responding to the event. Public communications in the aftermath of the event emphasised that anyone who was unwell should stay away from others, and particularly from mass gatherings or community events. Media coverage of the outbreak, which had been intense, decreased markedly following the event. In retrospect, no effect of the event on measles transmission could be detected.

Lessons learnt
Despite New Zealand’s “measles elimination” status, measles continues to pose a risk to New Zealanders due to ongoing importation and sub-optimal immunisation coverage, including specific sub-populations with higher proportions of susceptible people. This outbreak, which involved substantial spread before it was detected, and in which the index case was never identified, highlighted that risk, which the subsequent much larger 2019 Auckland-centred outbreak has reinforced.

Canterbury mounted a substantial whole-of-health-system response to the outbreak, and along with apparently relatively high background population measles immunity, this appears to have limited its size. Important features of a measles outbreak response in an “elimination” context include cross-system liaison, co-ordination of communications, careful prioritisation of use of available resources, and support for households affected by isolation and/or quarantine requests.

In view of the ongoing risk of measles outbreaks, review and prioritisation of strategies for measles prevention and control is important at both national and local levels. Maintaining high childhood vaccination rates, vaccination of healthcare workers, and immunisation advice for travellers to countries with outbreaks are obvious strategies to
Competing interests:
Nil.

Acknowledgements:
We acknowledge with gratitude the many staff from across our health system and people from across our community whose efforts helped control this outbreak.

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