Australian Government
Department of Health and Aged Care

2023 · Volume 47

Communicable Diseases Intelligence

Lessons from the re-emergence of imported measles cases following the COVID-19 pandemic in Victoria, Australia

Madeleine J Marsland, Janet Strachan, Rebecca F Gang, Miriam O'Hara, Nicole M Hughes, Anna Glynn-Robinson

https://doi.org/10.33321/cdi.2023.47.54
Electronic publication date: 21/09/2023
http://health.gov.au/cdi

Communicable Diseases Intelligence
ISSN: 2209-6051 Online

This journal is indexed by Index Medicus and Medline.

Communicable Diseases Network Australia

Communicable Diseases Intelligence contributes to the work of the Communicable Diseases Network Australia.
http://www.health.gov.au/cdna

Communicable Diseases Intelligence (CDI) is a peer-reviewed scientific journal published by the Office of Health Protection, Department of Health and Aged Care. The journal aims to disseminate information on the epidemiology, surveillance, prevention and control of communicable diseases of relevance to Australia.

Website
http://www.health.gov.au/cdi

Contacts
CDI is produced by the Office of Health Protection, Australian Government Department of Health and Aged Care, GPO Box 9848, (MDP 6) CANBERRA ACT 2601

Email:
cdi.editor@health.gov.au

Submit an Article
You are invited to submit your next communicable disease related article to the Communicable Diseases Intelligence (CDI) for consideration. More information regarding CDI can be found at: http://health.gov.au/cdi.

Further enquiries should be directed to: cdi.editor@health.gov.au.

Original article

Lessons from the re-emergence of imported measles cases following the COVID-19 pandemic in Victoria, Australia

Madeleine J Marsland, Janet Strachan, Rebecca F Gang, Miriam O'Hara, Nicole M Hughes, Anna Glynn-Robinson

Abstract

Introduction

Australia was declared to have eliminated endemic measles in 2014; however, imported cases continue to pose a threat of outbreaks. International travel restrictions during the coronavirus disease 2019 (COVID-19) pandemic led to a rapid decline in measles cases. The re-opening of the Australian international border to measles endemic regions returns the threat of outbreaks, which may be further compounded by disruptions in routine vaccinations during the COVID-19 pandemic. We consider lessons learned from the public health response to recent measles cases.

Methods

This case series includes all confirmed measles cases meeting the national case definition reported to the Victorian Government Department of Health (the Department) between 1 January and 31 December 2022. The Department conducted active case finding and contact tracing of all cases in line with national guidelines. Cases were descriptively analysed.

Results

In 2022, six of the seven measles cases reported in Australia occurred in Victoria, all of whom resided in Australia and acquired their infection overseas. Three cases were unlinked, and three formed an epidemiologically-linked household cluster. One case was partially vaccinated, one was not eligible for vaccination, one had unknown vaccination status, and three were unvaccinated, one of whom was under 12 months old but would have been eligible for vaccination prior to travel to endemic regions. None of the cases led to secondary transmission within Australia.

Discussion

Following the COVID-19 pandemic, measles importations have re-commenced in Victoria. Although few measles cases occurred in 2022 and none resulted in onwards transmission, imported measles cases remain complex and require substantial public health follow-up. Delays in case diagnosis and flight contact tracing pose a significant risk for outbreaks of measles. Public health interventions are needed to maintain high vaccination rates, improve contact tracing, and ensure public health authorities and healthcare providers can rapidly identify and respond to imported measles cases.

Keywords: measles; communicable diseases, imported; communicable disease control; epidemiology

Introduction

Measles is a highly contagious viral infection with the potential to cause severe complications including death, though this is uncommon in Australia.[1,2] The incubation period for measles is 10 days (ranging from 7 to 18 days),[3] and has rarely been reported up to 23 days.[1,4] Measles has one of the highest reproductive numbers for a directly transmitted pathogen, ranging from 12 to 18 in susceptible populations.[1,2] Humans are the only known reservoir.[2]

In Australia, two doses of measles-containing vaccine are recommended for all children aged ≥ 12 months, with children aged ≥ 6 months able to receive one dose when travelling to regions with high endemic transmission or outbreaks.[5] Vaccination against measles is freely available under the National Immunisation Program (NIP), with the two-dose schedule conferring 99% protection.[5]

People can be vulnerable to infection if unvaccinated or partially vaccinated according to Australian standards, or due to inadequate immune response or waning immunity.[6–8] Individuals born pre-1966 are considered to have natural immunity due to likely infection in childhood, and are not eligible for free vaccination within Victoria, though some may not be immune.[6–8] Individuals born in the 1970s may also not have natural immunity as a result of reduced measles exposure, and may be susceptible due to single-dose schedules during this period.[9]

The World Health Organization (WHO) declared Australia to have eliminated endemic measles transmission in 2014.[10] Almost all cases now reported in Australia are either imported or related to an imported case.[7,8] Imported measles has occasionally resulted in tertiary spread of the disease, most recently in 2019,[11] demonstrating a continued threat of the re-introduction of measles into Australia if high vaccination coverage levels are not maintained. Globally, measles eradication efforts are ongoing, with cases declining between 2000 and 2016.[1,12] However, between 2017 and 2019 a worldwide resurgence of measles occurred, with outbreaks in regions where measles had previously been declared eliminated.[1,12–14]

The coronavirus disease 2019 (COVID-19) pandemic resulted in Australia closing its international borders in 2020,[15] leading to measles cases rapidly declining. In Victoria, 57 measles cases were reported in 2019, compared to only five in 2020 prior to travel restrictions, and there were no measles cases in Australia in 2021.[16] With the reopening of international borders in February 2022,[15] measles importations have recommenced, with seven measles cases reported nationally in 2022, six of which occurred in Victoria.[17] The risk of outbreaks may be increased due to globally-disrupted vaccinations during the pandemic,[1,18] although childhood vaccination rates have remained high among most population groups in Victoria.[1,19]

Imported measles cases can lead to localised outbreaks and ongoing transmission, which may ultimately result in re-establishment of endemic transmission if there are immunity gaps.[6,8,11,12] We consider lessons learned from the re-emergence of imported measles in Victoria following the COVID-19 pandemic.

Methods

Case series analysis

This case series included all confirmed measles cases reported to the Victorian Government Department of Health (the Department), from 1 January 2022 to 31 December 2022, which met the Australian national notifiable diseases case definition.[21] Cases were descriptively analysed.

Epidemiological investigation

Measles is an urgent notifiable condition in Victoria, with a statutory requirement that all suspected, probable and confirmed cases are notified to the Department.[22]

The Department conducted enhanced surveillance, active case-finding and contact tracing for all confirmed cases in line with the Communicable Diseases Network Australia (CDNA) Measles National Guidelines for Public Health Units (CDNA guideline).[3] For each case, interviews were conducted with the case, healthcare provider, and/or next-of-kin as appropriate, to identify all potential contacts and exposure sites. All associated case and contact data were stored in Victoria's Public Health Event Surveillance System (PHESS).

The likely source of acquisition for each case was identified based on the case's risk history including any overseas travel, with the support of genomic testing as appropriate. Cases were considered epidemiologically linked if there was evidence of contact involving plausible transmission,[3] and were classified as clustered if there was more than one case within a household group. Cases were considered infectious from one day prior to prodromal onset, until four days after onset of their rash, and were isolated in their home or a healthcare setting from initial suspicion of measles diagnosis until the infectious period was complete. Monitoring of the event concluded two incubation periods (upper limit: 36 days) after the case (or last case in a cluster) was released from isolation.

Vaccination status of cases and of identified contacts was confirmed via the Australian Immunisation Register (AIR), or via records provided by cases and contacts or their next-of-kin. The vaccination status of cases was classified as 'unknown' if the case was unable to provide evidence of prior vaccination, and 'not eligible' if the case was born prior to 1966.

The Department notified all face-to-face contacts (those identified by the case or next-of-kin) of their potential exposure via telephone. Where evidence of measles vaccination was not available, contacts were encouraged to undergo serological testing to confirm their immune status (i.e., immunoglobulin G [IgG] antibodies for measles), and, if applicable, were offered appropriate post-exposure prophylaxis (PEP) (i.e. measles-containing vaccination within three days, or normal human immunoglobulin within six days of first exposure).[3,5] Contacts were regularly monitored via text message or telephone call (usually every 2–4 days) until 18 days after last contact with the case. Healthcare facilities conducted contact tracing and coordinated PEP for exposures that occurred on healthcare grounds (e.g. emergency departments or primary healthcare facilities). Chief Health Officer (CHO) alerts were issued where public exposure sites were identified and premises were provided with advice; however, contacts at these sites were not individually followed up.

Where a case travelled on an international flight during the infectious period,[3] details of flight contacts were sourced via the National Incident Centre (NIC), based at the Australian Government Department of Health and Aged Care. The NIC provided incoming passenger cards (IPCs) for passengers with a Victorian address, with interstate flight contacts followed up by their respective residential states and territories. The IPCs of Victorian residents were manually transcribed, and all passengers were sent information on their exposure and available PEP via email and/or text message. Exposure sites and international contacts were notified to relevant country National Focal Points by the NIC.

Laboratory investigation

Laboratory testing was conducted at the Victorian Infectious Diseases Reference Laboratory (VIDRL), the national measles reference laboratory for Australia and a WHO measles regional reference laboratory.[23,24] All cases were confirmed to have measles via polymerase chain reaction (PCR) testing. Genotyping was performed by nucleic acid sequencing with phylogenetic analysis conducted after PCR testing,[23,24] to support epidemiological investigation.

Ethics

Case investigations were conducted under the *Victorian Public Health and Wellbeing Act 2008* with an ethics waiver from the Australian National University Human Research Ethics Committee (2017/909).

Results

Six confirmed measles cases were reported in Victoria in 2022, all occurring between June and December (Table 1). Three cases were single imported cases, and three cases formed part of an epidemiologically-linked household cluster. All cases acquired their infection overseas. Key findings of the outbreak investigation are reported below.

Case one

Case one presented to a health clinic five days after entering Australia from Europe after receiving notification from a European Health Department of exposure to a confirmed measles case on a flight entering Europe. She reported a four-day history of headache, dry cough, sore neck, and sore eyes and a one-day history of maculopapular rash commencing on her face and progressing to her torso. PCR testing confirmed a measles diagnosis.

Genomic sequencing confirmed the case's strain (genotype B3) was identical to the European case, and matched strains identified in Europe in January and May of 2022. She had a prolonged incubation period of 20 days between contact with the known measles case and onset of the rash. The case had evidence of prior measles-containing vaccination in her country of birth, receiving one dose at six months of age, and a

Table 1: Summary of demographics and epidemiological data for confirmed measles cases in Victoria, 2022

<table>
<tr><th>Case designation</th><th>Linked</th><th>Sex</th><th>Age group (years)</th><th>Born in Australia</th><th>Resides in Australia</th><th>Genotype</th><th>Source (likely place of acquisition)</th><th>Vaccination status</th><th>Estimated number of contacts[a]</th></tr>
<tr><td>One</td><td>No</td><td>Female</td><td>30–34</td><td>No</td><td>Yes</td><td>B3</td><td>Imported (Europe)</td><td>Partially vaccinated</td><td>157</td></tr>
<tr><td>Two</td><td>No</td><td>Female</td><td>40–44</td><td>No</td><td>Yes</td><td>D8</td><td>Imported (South Asia)</td><td>Unknown[b]</td><td>54</td></tr>
<tr><td>Three</td><td>No</td><td>Male</td><td>55–59</td><td>Yes</td><td>Yes</td><td>D8</td><td>Imported (Southeast Asia)</td><td>Not eligible[c]</td><td>14</td></tr>
<tr><td>Four</td><td rowspan="3">Household cluster</td><td>Male</td><td>1–4</td><td>Yes</td><td>Yes</td><td>D8</td><td>Imported (Middle East)</td><td>Not vaccinated</td><td rowspan="3">6</td></tr>
<tr><td>Five</td><td>Female</td><td>5–9</td><td>Yes</td><td>Yes</td><td>D8</td><td>Imported (Southeast Asia)</td><td>Not vaccinated</td></tr>
<tr><td>Six</td><td>Female</td><td>< 1</td><td>Yes</td><td>Yes</td><td>D8</td><td>Imported (Southeast Asia)</td><td>Not vaccinated[d]</td></tr>
</table>

a Includes close contacts, contacts identified by healthcare facilities, and contacts from public exposure sites where this was estimated. Excludes flight contacts and contacts from public exposure sites where it was not possible to estimate these numbers.

b Vaccination status was classified as unknown when the case reported having a measles vaccination but was not able to provide evidence.

c Vaccination status was classed as not eligible when the case was born prior to 1966.

d The case was considered not vaccinated as they were ≥ 6 months of age when they travelled to a measles endemic region, and therefore was eligible to receive a recommended measles-containing vaccine.

second dose at 15 months of age. However, as she had received her first dose under the recommended age of 12 months, to be considered fully vaccinated under current Australian guidelines, the case should have received a third dose of measles-containing vaccine.[5] This case was therefore considered to be partially vaccinated.

The Department identified 38 close contacts, and the health clinic she attended identified seven contacts who were offered PEP. A CHO alert was issued identifying public exposure sites. The case had travelled extensively across Victoria, as well as into New South Wales, requiring collaboration with interstate counterparts. Approximately 112 individuals were estimated to have had contact with the case at public exposure sites. The Department notified people who were on the flight with the case entering Australia. No further cases were identified.

Case two

Case two presented to a healthcare facility four days after entering Australia from South Asia with a five-day history of cough, coryza and conjunctivitis, and a two-day history of a maculopapular blanching painful rash. She was not assessed for measles at the time and re-presented to the hospital two days later due to worsening symptoms. Measles diagnosis was confirmed via PCR.

The case spent her entire incubation period in South Asia, and whilst a particular source could not be identified, genotyping confirmed the likely origin of the strain (genotype D8) was exposure in South Asia, with the last detection of this strain occurring in 2018. The Department identified ten close contacts and notified flight contacts; however, PEP was not offered due to the delayed diagnosis of this case beyond six days from the time of the flight. Healthcare clinics identified and provided advice to a further 44 contacts. Several public exposure sites were identified, including large shopping centres, and a CHO alert was issued. The number of contacts at these locations was unable to be estimated. No further cases were identified.

Case three

Case three was admitted to a hospital ten days after entering Australia from Southeast Asia. He had an eight-day history of cough, coryza and ongoing fever, and had been diagnosed with COVID-19 from a Rapid Antigen Test (RAT) on the first day of his illness. He also had a two-day history of cranio-caudal exanthem rash. PCR testing confirmed a measles diagnosis. The case was considered not eligible for vaccination as he was born prior to 1966.

This is the first known case of measles and COVID-19 co-infection in Australia. Given the overlap of symptoms, the infectious period for measles was based on the emergence of the rash,[3] and flight contact tracing was subsequently not required. The Department identified 14 close contacts; however, PEP was not offered due to delayed diagnosis beyond six days from time of exposure. There were no public exposure sites associated with this case as he had been isolating due to COVID-19. No further cases were identified.

Household cluster: cases four, five and six

Three young siblings presented to a health clinic one day after returning to Australia from Southeast Asia. All the children were unvaccinated. The youngest child was aged < 12 months but had been ≥ 6 months old at the time of travelling to a measles endemic region.

Case four had experienced a measles-like illness in Southeast Asia after travelling from the Middle East, with a five-day history of runny nose and sore throat followed by the development of a rash. The family had sought care in Southeast Asia and been advised the child probably had measles, although laboratory testing was inconclusive. The family remained in isolation until four days after symptom resolution before returning to Australia.

The family presented in Australia after case five and six experienced subjective fevers. All three cases tested PCR-positive for measles. Case four was considered the likely index case for cases five and six. Based on the incubation period, the index case likely acquired measles in the Middle East, with onwards transmission to their siblings within Southeast Asia. All cases were classified as imported.

The Department identified six close contacts, and eligible contacts were offered PEP. There were no healthcare contacts associated with these cases. Flight contacts were notified of exposure and a CHO alert was issued, given the airport was a public exposure site. No further cases were identified.

Discussion

There remains significant complexity in rapidly identifying and responding to measles cases, even in a low-incidence environment. Australia experienced a reprieve from measles incursions during the COVID-19 pandemic. However, there may now be an increased risk of resurgence.[1] Within this context ongoing prevention strategies, high immunisation coverage and strong surveillance systems are required to prevent outbreaks of measles within Australia.[6,8,11,12]

There were fewer measles cases reported in Victoria in 2022 compared with the years before the pandemic,[16] and no onwards transmission was identified within Australia. This may be associated with high levels of immunity due to ongoing high vaccination coverage in the community.[5,25] Four cases (cases three to six) also isolated themselves during their infectious period due to COVID-19 illness or prior awareness of likely measles infection and possible spread. Community health behaviours, such as mask wearing within healthcare clinics, may have also reduced the risk of transmission. There is no guarantee future cases will comply with public health measures, noting people are infectious before the onset of rash, and health literacy is generally an underestimated global health problem.[26–28] In early 2023, measles cases have been detected in other Australian states and territories,[29] so it is timely for public health agencies to be aware of the ongoing risk of outbreaks.

Several cases experienced delays in diagnosis. This can occur due to delays in people presenting with illness, or due to delays in testing, with samples from primary laboratories requiring transport to and confirmation by reference laboratories. Notably, case two attended a hospital twice before being diagnosed. Measles is often missed in clinical settings as many Victorian medical practitioners have little first-hand experience of measles.[30] Delayed diagnosis can hinder contact tracing efforts, leading to contacts missing out on PEP.[30] Furthermore, transmission can occur within healthcare settings, particularly if cases are not rapidly identified and isolated.[31] Healthcare workers must be constantly vigilant for potential measles cases, with CHO advisories for doctors warning of travel-related infectious diseases and alerts associated with imported cases providing opportunities for regular reminders.[30,31] The way people access and consume news is changing, shifting from traditional media (e.g. newspapers) to social media, so CHO alerts which typically use traditional media may no longer be the best way of reaching all populations and social media should be used to disseminate alerts.

Most measles cases that occur within Australia are unvaccinated,[7] with only one case in this series having evidence of immunisation. The partially vaccinated case had a prolonged incubation period, suggesting a modified measles infection.[32,33] Attenuated measles presentations are increasing in Victoria, and can be challenging to diagnose, demonstrating further the benefit of having two valid measles-containing vaccinations administered, and the need for clinicians to be alert for modified measles infections.[32,33] Several factors are thought to increase the risk of individuals being unvaccinated or having incomplete vaccinations; these include being from a larger family not using formal childcare services, being from a single parent household, poor social supports, being overseas-born, receiving immunisations from general practitioners, and being a late starter to immunisation.[25,34] Two adult cases (one and two) and the parents of the three children (cases four to six) were overseas-born. Within the household cluster, all children were unvaccinated despite recommendations and readily available measles vaccination in Australia. Preventing measles transmission should focus on maintaining high vaccination rates across Australia, including in populations who may have missed routine childhood vaccinations, such as migrant populations, and who may require additional education and support to be aware of available immunisation services.[7]

Flight contact tracing was required for five of six cases in this series. Measles cases on flights pose a heightened risk of transmission, with cases potentially able to widely transmit within a confined space, and contact tracing often ineffective, incomplete and delayed, as passenger lists and IPCs can be difficult to access.[35–37] Transmission can also occur within airport settings during the pre-flight or post-flight period.[37,38] Flight contact tracing was a critical control measure during the early months of the COVID-19 pandemic,[39] leading to the introduction of digital passenger declarations to support large-scale contact tracing.[40] However, this pathway in Australia is no longer available. Among the six cases in this series, there were often delays in acquiring and manually transcribing IPCs, as they came in batches over days and weeks. Timeliness is critical for measles public health actions, and for some cases the window to offer PEP for flight contacts expired.[38] Delays in contact tracing can also lead to contacts being missed and delayed diagnosis of secondary cases, potentially contributing to onwards transmission. Further work is needed to improve processes to support flight contact tracing, including digitisation of passenger cards, and working with airlines and airports to facilitate more timely access to flight manifests.

This case series was limited by the small number of cases that occurred in 2022, and may not be representative of cases that occur in the future. The findings and lessons may also not be applicable to all Australian states and territories, as the public health systems, infrastructure and resources vary, affecting jurisdictions' ability to implement public health actions. None of the cases led to transmission within Australia, so it was not possible to test the public health response to secondary cases or to consider the impact of the COVID-19 pandemic on local transmission of measles.

Despite these limitations, this case series provides a useful overview of lessons learned from responding to the first measles cases to occur in Victoria following a pause in cases during the COVID-19 pandemic. Measles contact tracing is resource-intensive, with one international study noting that the response cost for even a single case that does not result in transmission can be as high as $142,000 USD.[41] Public health follow up requires considerable time and effort,[38] highly skilled and trained personnel, and close collaboration with local, interstate, national and international health agencies. It is timely to consider the lessons from the re-emergence of imported measles and opportunities to improve Victoria's response to prevent potential outbreaks in the future. This case series is also of use to other Australian states and territories where measles is also re-emerging after the COVID-19 pandemic.

Acknowledgements

We thank all individuals who were involved in the public health response to these measles cases. In particular, from the Victorian Department of Health, we thank Liv Lowe, Natalie Shepherd, Sarah Lewis, Aicha Brahmi, Grace King, Rebekkah White and Samara Griffin who were involved in the investigation and follow up of these cases.

Madeleine Marsland is a Master of Philosophy in Applied Epidemiology (MAE) Scholar with the Australian National University and is supported by a MAE scholarship funded by the Department of Health, Victoria.

Author details

Dr Madeleine J Marsland,[1,2]

Ms Janet Strachan,[1]

Dr Rebecca F Gang,[1]

Ms Miriam O'Hara,[1]

Ms Nicole M Hughes,[1]

Ms Anna Glynn-Robinson[2]

1. Public Health Division, Department of Health, Victoria.

2. National Centre for Epidemiology & Population Health, Australian National University.

Corresponding author

Dr Madeleine J Marsland

Address: Victoria Department of Health, 50 Lonsdale Street, Melbourne, Victoria, 3000

Phone: 03 8850 7484

Email: madeleine.marsland@health.vic.gov.au; madeleine.marsland@anu.edu.au

References

1. Hübschen JM, Gouandjika-Vasilache I, Dina J. Measles. *Lancet*. 2022;399(10325):678–90. doi: https://doi.org/10.1016/S0140-6736(21)02004-3.

2. Misin A, Antonello RM, Di Bella S, Campisciano G, Zanotta N, Giacobbe DR et al. Measles: an overview of a re-emerging disease in children and immunocompromised patients. *Microorganisms*. 2020;8(2):276. doi: https://doi.org/10.3390/microorganisms8020276.

3. Australian Government Department of Health and Aged Care, Communicable Diseases Network Australia (CDNA). *Measles: CDNA National Guidelines for Public Health Units*. Canberra: Australian Government Department of Health and Aged Care, CDNA; 7 May 2019. [Accessed on 28 March 2023.] Available from: https://www.health.gov.au/sites/default/files/documents/2020/02/measles-cdna-national-guidelines-for-public-health-units.pdf.

4. Fitzgerald TL, Durrheim DN, Merritt TD, Birch C, Tran T. Measles with a possible 23 day incubation period. *Commun Dis Intell Q Rep*. 2012;36(3):E277–80.

5. Australian Government Department of Health and Aged Care, Australian Immunisation Handbook. Measles. [Webpage.] Canberra: Australian Government Department of Health and Aged Care; 19 May 2022. [Accessed on 29 March 2023.] Available from: https://immunisationhandbook.health.gov.au/contents/vaccine-preventable-diseases/measles.

6. Williamson KM, Merritt T, Durrheim DN. Australia: an island in a sea of measles. *Med J Aust*. 2020;213(3):101–3.e1. doi: https://doi.org/10.5694/mja2.50650.

7. Winkler NE, Dey A, Quinn HE, Pourmarzi D, Lambert S, McIntyre P et al. Australian vaccine preventable disease epidemiological review series: measles, 2012–2019. *Commun Dis Intell (2018)*. 2022;46. doi: https://doi.org/10.33321/cdi.2022.46.38.

8. MacIntyre CR, Karki S, Sheikh M, Zwar N, Heywood AE. The role of travel in measles outbreaks in Australia – an enhanced surveillance study. *Vaccine*. 2016;34(37):4386–91. doi: https://doi.org/10.1016/j.vaccine.2016.07.023.

9. Gidding HF. The impact of Australia's measles control programme over the past decade. *Epidemiol Infect*. 2005;133(1):99–105. doi: https://doi.org/10.1017/s0950268804003073.

10. World Health Organization (WHO). Four Western Pacific countries and areas are the first in their Region to be measles-free. [Internet.] Geneva: WHO; 20 March 2014. [Accessed on 26 April 2023.] Available from: https://www.who.int/westernpacific/news/item/20-03-2014-four-western-pacific-countries-and-areas-are-the-first-in-their-region-to-be-measles-free.

11. Alexander K, Wickens M, Fletcher-Lartey S. Measles elimination in Australia: hard won, easily lost. *Aust J Gen Pract*. 2020;49:112–4. doi: https://doi.org/10.31128/AJGP-11-19-5147.

12. Hayman DTS. Measles vaccination in an increasingly immunized and developed world. *Hum Vaccin Immunother*. 2019;15(1):28–33. doi: https://doi.org/10.1080/21645515.2018.1517074.

13. New Zealand Government Ministry of Health – Manatū Hauora. Measles. [Webpage.] Wel-

lington: New Zealand Government Ministry of Health; 20 December 2022. [Accessed on 12 May 2023.] Available from: https://www.health.govt.nz/your-health/conditions-and-treatments/diseases-and-illnesses/measles.

14. Durrheim DN, Crowcroft NS, Blumberg LH. Is the global measles resurgence a "public health emergency of international concern"? *Int J Infect Dis*. 2019;83:95–7. doi: https://doi.org/10.1016/j.ijid.2019.04.016.

15. Parliament of Australia. Senate Select Committee on COVID-19. Appendix 2: Timeline of key decisions and milestones. [Webpage.] Canberra: Parliament of Australia; 2022. [Accessed on 29 March 2023.] Available from: https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/COVID-19/COVID19/Report/section?id=committees%2Freportsen%2F024920%2F79485.

16. Victoria State Government Department of Health. Victoria, local public health areas and local government areas surveillance summary report. [Internet.] Melbourne: Victoria State Government Department of Health; 2 March 2023. [Accessed on 28 March 2023.] Available from: https://www.health.vic.gov.au/infectious-diseases/local-government-areas-surveillance-report.

17. Australian Government Department of Health and Aged Care, National Notifiable Disease Surveillance System (NNDSS). National Communicable Disease Surveillance Dashboard. [Website.] Canberra: Australian Government Department of Health and Aged Care, NNDSS; 2023. [Accessed on 30 March 2023.] Available from: https://nindss.health.gov.au/pbi-dashboard/.

18. Iacobucci G. Measles is now "an imminent threat" globally, WHO and CDC warn. *BMJ*. 2022;379:o2844. doi: https://doi.org/10.1136/bmj.o2844.

19. Hull BP, Hendry AJ, Dey A, Bryant K, Radkowski C, Pellissier S et al. The impact of the COVID-19 pandemic on routine vaccinations in Victoria. *Med J Aust*. 2021;215(2):83–4. doi: https://doi.org/10.5694/mja2.51145.

20. Victoria State Government Department of Health. Local Public Health Units. [Webpage.] Melbourne: Victoria State Government Department of Health; 4 November 2022. [Accessed on 4 April 2023.] Available from: https://www.health.vic.gov.au/local-public-health-units.

21. CDNA. *Measles: Australian national notifiable diseases case definition*. Canberra: Australian Government Department of Health; 1 July 2019. [Accessed on 28 March 2023.] Available from: https://www.health.gov.au/sites/default/files/documents/2022/06/measles-surveillance-case-definition.pdf.

22. Victoria State Government Department of Health. Measles. [Internet.] Melbourne: Victoria State Government Department of Health; 8 October 2015. [Accessed on 28 March 2023.] Available from: https://www.health.vic.gov.au/infectious-diseases/measles.

23. Victorian Infectious Diseases Reference Laboratory (VIDRL). Measles. [Webpage.] Melbourne: The Doherty Institute, VIDRL; 2023. [Accessed on 12 May 2023.] Available from: https://www.vidrl.org.au/surveillance/measles/.

24. VIDRL. *Measles and Rubella Molecular Epidemiology: Australia 2020. Victorian Infectious Diseases Reference Laboratory Summary Report*. Melbourne: The Doherty Institute, VIDRL; 2020.

[Accessed on 12 May 2023.] Available from: https://www.vidrl.org.au/app/uploads/2022/03/Measles-and-Rubella-Molecular-Epidemiology-in-Australia-2020.pdf.

25. Pearce A, Marshall H, Bedford H, Lynch J. Barriers to childhood immunisation: findings from the Longitudinal Study of Australian Children. *Vaccine*. 2015;33(29):3377–83. doi: https://doi.org/10.1016/j.vaccine.2015.04.089.

26. Ishikawa H, Kato M. Health literacy and COVID-19-related beliefs and behaviors: a longitudinal study of the Japanese general population. *Health Promot Int*. 2023;38(2):daac196. doi: https://doi.org/10.1093/heapro/daac196.

27. Paakkari L, Okan O. COVID-19: health literacy is an underestimated problem. *Lancet Public Health*. 2020;5(5):e249–50. doi: https://doi.org/10.1016/S2468-2667(20)30086-4.

28. Murphy K, Williamson H, Sargeant E, McCarthy M. Why people comply with COVID-19 social distancing restrictions: self-interest or duty? *Aust N Z J Criminol*. 2020;53(4):477–96. doi: https://doi.org/10.1177/0004865820954484.

29. Gibney K, Cheng A. Measles has been identified in NSW, Qld and SA. 5 things to know about the virus. [Webpage.] Melbourne: The Conversation Australia and New Zealand; 30 March 2023. Available from: https://theconversation.com/measles-has-been-identified-in-nsw-qld-and-sa-5-things-to-know-about-the-virus-202945.

30. Gibney KB, Brahmi A, O'Hara M, Morey R, Franklin L. Challenges in managing a school-based measles outbreak in Melbourne, Australia, 2014. *Aust N Z J Public Health*. 2017;41(1):80–4. doi: https://doi.org/10.1111/1753-6405.12620.

31. Hope K, Boyd R, Conaty S, Maywood P. Measles transmission in health care waiting rooms: implications for public health response. *Western Pac Surveill Response J*. 2012;3(4):33–8. doi: https://doi.org/10.5365/WPSAR.2012.3.3.009.

32. Uren AM, Vasant BR, Judd D, Looke DFM, Henderson AJ, Jarvinen KAJ. Modified measles with an atypical presentation. *Commun Dis Intell (2018)*. 2019;43. doi: https://doi.org/10.33321/cdi.2019.43.26.

33. Gibney KB, Attwood LO, Nicholson S, Tran T, Druce J, Healy et al. Emergence of attenuated measles illness among IgG-positive/IgM-negative measles cases: Victoria, Australia, 2008-2017. *Clin Infect Dis*. 2020;70(6):1060–7. doi: https://doi.org/10.1093/cid/ciz363.

34. Hull BP, Mclntyre PB, Sayer GP. Factors associated with low uptake of measles and pertussis vaccines — an ecologic study based on the Australian Childhood Immunisation Register. *Aust N Z J Public Health*. 2001;25(5):405–10.

35. Hoad VC, O'Connor BA, Langley AJ, Dowse GK. Risk of measles transmission on aeroplanes: Australian experience 2007–2011. *Med J Aust*. 2013;198(6):320–3. doi: https://doi.org/10.5694/mja12.11752.

36. Beard F, Franklin L, Donohue S, Moran R, Lambert S, Maloney M et al. Contact tracing of in-flight measles exposures: lessons from an outbreak investigation and case series, Australia,

2010. *Western Pac Surveill Response J*. 2011;2(3):25–33. doi: https://doi.org/10.5365/WPSAR.2011.2.2.010.

37. Rafferty AC, Bofkin K, Hughes W, Souter S, Hosegood I, Hall RN et al. Does 2x2 airplane passenger contact tracing for infectious respiratory pathogens work? A systematic review of the evidence. *PLoS One*. 2023;18(2):e0264294. doi: https://doi.org/10.1371/journal.pone.0264294.

38. Nic Lochlainn L, Ruijs WLM, Swaan C, de Melker H, Hahné S. Response to Lim et al regarding "In-flight transmission of measles: Time to update the guidelines?". *Am J Infect Control*. 2017;45(1):95–6. doi: https://doi.org/10.1016/j.ajic.2016.08.023.

39. Draper AD, Dempsey KE, Boyd RH, Childs EM, Black HM, Francis LA et al. The first 2 months of COVID-19 contact tracing in the Northern Territory of Australia, March-April 2020. *Commun Dis Intell (2018)*. 2020;44. doi: https://doi.org/10.33321/cdi.2020.44.53.

40. Australian National Audit Office (ANAO). *Human Biosecurity for International Air Travellers during COVID-19*. [Performance audit report.] Canberra: ANAO; 24 March 2022. [Accessed on 4 April 2023.] Available from: https://www.anao.gov.au/work/performance-audit/human-biosecurity-international-air-travellers-during-covid-19.

41. Sundaram ME, Guterman LB, Omer SB. The true cost of measles outbreaks during the postelimination era. *JAMA*. 2019;321(12):1155–6. doi: https://doi.org/10.1001/jama.2019.1506.