Risk of measles transmission on aeroplanes: Australian experience 2007–2011

Veronica C Hoad
MB BS, MPH,
Public Health Registrar[1]

Bridget A O'Connor
BAppSc, MPH, MAppEpid,
Lecturer[2]

Andrew J Langley
MB BS, FAFOEM, FAFPHM,
Public Health Physician[3]

Gary K Dowse
MB BS, MScEpid, FAFPHM,
Medical Epidemiologist[4]

1 Public Health and Ambulatory Care, North Metropolitan Health Service, Perth, WA.

2 National Centre for Epidemiology and Population Health, Australian National University, Canberra, ACT.

3 Sunshine Coast Public Health Unit, Queensland Health, Maroochydoore, QLD.

4 Communicable Disease Control Directorate, Department of Health Western Australia, Perth, WA.

Veronica.hoad@health.wa.gov.au

MJA 2013; 198: 320–323
doi: 10.5694/mja12.11752

Online first 20/03/13

Abstract

Objective: To quantify the risk of transmission of measles associated with infectious people who travelled on aeroplane flights to or within Australia.

Design, setting and subjects: Data were obtained from state and territory health authorities on all measles notifications from January 2007 to June 2011 for people who were likely to have been infectious or infected while travelling on aeroplanes in Australia.

Results: Forty-five infectious people travelled on aeroplanes. Twenty secondary infections occurred in people on seven of 49 flights (14%; 95% CI, 6%–29%), comprising 19% (95% CI, 8%–40%) of the 36 international flights and none of 13 (95% CI, 0–28%) domestic flights that carried infectious people. Secondary infections occurred in nine people who were seated within two rows of the index case and in 11 people who were seated outside of two rows. Secondary transmission was more likely to occur with younger index cases ($P = 0.025$) and when there were multiple infectious people travelling ($P = 0.018$). About a third (15/49) of flight manifests were available to health authorities within 5 days of travel.

Conclusion: Despite secondary measles transmission occurring on 19% of international flights carrying infectious people, risk was not clearly related to seating proximity, and contact tracing was ineffective, especially given delays in diagnosis, notification and accessing flight manifests. We recommend that direct contact tracing to identify susceptible people exposed to people infected with measles on aeroplane flights should not be undertaken routinely, and other strategies should be considered.

Experience with severe acute respiratory syndrome[1] and pandemic (H1N1) 2009 influenza[2] has clearly shown the potential for air travel to result in the spread of emerging respiratory diseases. Similarly, countries (like Australia) that have successfully interrupted local transmission of measles virus face repeated importation of measles by travellers who are infected overseas.[3] Australian residents made a record eight million short-term trips overseas in the 2011–12 financial year.[4] In addition, around 6 million visitors from overseas arrive in Australia each year,[4] many from countries with endemic measles transmission.

There is little published information on the risk of transmission from infectious measles cases during aeroplane travel, or the effectiveness of contact tracing in this setting. Current Australian guidelines recommend direct follow-up of contacts of all people with measles who are considered to be infectious during a flight. Contacts are defined as people seated in the same row, two rows in front of and two rows behind an infectious person.[5] There were no reports of measles transmission on aeroplanes in Australia in the decade before development of these guidelines,[5] which were informed by evidence from the United States that secondary transmission on aeroplanes was rare and probably related to seating proximity.[6] However, since the guidelines were published, there have been multiple reports of measles transmission to passengers sitting further than two rows from the index case.[3,7-9]

In response to the increasing number of published reports and anecdotal evidence of measles transmission on aeroplanes, we aimed to quantify the risk of transmission of measles associated with infectious people who travelled on flights to or within Australia, to inform contact-tracing guidelines. We reviewed all cases of measles notified from January 2007 to June 2011 and known to have travelled on aeroplanes in Australia while infectious. We also collected information about any secondary cases identified among aeroplane travellers.

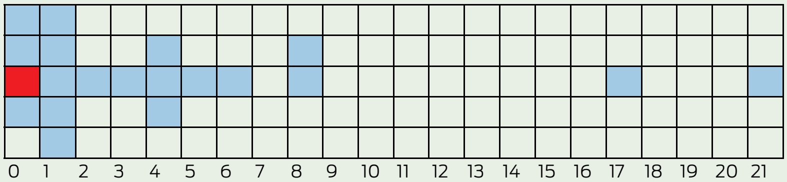
Methods

Measles is a notifiable disease in all Australian states and territories under local legislation, and all cases are subject to follow-up by public health authorities. Our study was undertaken under the auspices of the Communicable Diseases Network Australia (CDNA), which oversees communicable disease surveillance in Australia. The CDNA asked each jurisdiction to provide de-identified data for people who travelled on an aeroplane to or within Australia while infectious with measles. People were considered to have been infectious on the flight if they travelled during the 4 days before and the 4 days after the onset of the measles rash.

Each jurisdiction was provided with a Microsoft Excel spreadsheet on which to record details of the index case (age, vaccination history, dates of flight departure and arrival, flight number, flight duration, seat number, number of days from arrival to diagnosis and notification of the illness, and the date the flight manifest became available to public health authorities) and logistical information for contact tracing (total number of passengers and cabin crew, the numbers of passengers and staff contacted and uncontactable, and any secondary measles cases identified among the passenger cohort). For each secondary case identified, information on seating and other potential sources of measles exposure was requested. The study period was from 1 January 2007 to 30 June 2011 for all jurisdictions except Western Australia and Victoria, which provided data for longer periods (to 19 September 2011 and 30 October 2011, respectively).

All data were cleaned and collated using Microsoft Excel and analysed using SPSS, version 20 (SPSS Inc). Differences between flights on which transmission did and did not occur were compared using the independent samples *t* test (age in years), independent samples Mann–Whitney *U* test (flight times) or Fisher exact test (categorical data). Confidence intervals for transmission occurrences

1 Aeroplane seating of secondary measles cases, by rows distant (fore or aft) from index cases, Australia 2007–2011



The red square represents index cases on flights where transmission occurred; blue squares represent seating of secondary cases according to the number of rows away (fore or aft) from index cases, not actual seating position. One secondary case in a cabin crew member is not represented. ◆

2 Selected characteristics for aeroplane flights with documented secondary transmission of measles, Australia 2007–2011

Flight	Postexposure prophylaxis* recommended or given†	Number of cases within two rows	Number of cases outside of two rows
1‡	Yes	0	1
2	Yes	0	2
3	Yes	5	1
4§	No	1	2
5	No	1	0
6	No	1	2
7	No	1	3
Total	**3/7 with intervention**	**9**	**11**

* MMR (measles–mumps–rubella) vaccine or NHIG (normal human immunoglobulin). † To susceptible contacts within two rows in front of or behind the index case; not all secondary cases received MMR or NHIG. ‡ Carried two siblings who were infectious. § Carried three siblings who were infectious. ◆

were calculated using the Byar approximation to the Poisson distribution.[10] The level of significance was considered to be $P < 0.05$.

Ethics approval was not required, as our study evaluated surveillance practice using de-identified data collected during the routine public health response to measles as a notifiable disease.

Results

A total of 327 measles cases were notified in Australia during the study period. Forty-five people (14%; 95% CI, 10%–18%) flew on a total of 49 flights while infectious, of which 13 flights were domestic and 36 were international. Where known, most index cases were Australians who acquired their infection while travelling overseas, with a minority being overseas visitors who acquired their infection before travelling to or within Australia.

Twenty secondary cases occurred among people on seven (14%; 95% CI, 6%–29%) of the 49 flights, comprising 7 of 36 international flights (19%; 95% CI, 8%–40%) and none of the 13 (0; 95% CI, 0–28%) domestic flights that carried infectious people. Nine people identified as secondary cases were seated in the same row or within two rows fore and aft of the index case; 11 were outside these rows, one of whom was a member of the cabin crew (Box 1). After index cases were diagnosed and their contacts were traced, immunoprophylaxis (measles–mumps–rubella [MMR] vaccine or normal human immunoglobulin [NHIG]) was offered to identified susceptible contacts seated within two rows fore and aft of the index case[11] on three of the seven flights on which documented secondary transmission occurred (Box 2). On two of these three flights there were no secondary cases within two rows of the index case; on the third, there were five secondary cases within two rows, but none received immunoprophylaxis: three declined, one gave a verbal history of vaccination in another country and the fifth was missed during the initial contact tracing.

Secondary transmission was more likely to occur if the index case was younger ($P = 0.025$) or there were multiple infectious cases on board ($P = 0.018$) (Box 3). Two family groups with multiple infectious cases — two siblings aged 3 and 7 years, and three siblings aged 12–17 years — were associated with one and three secondary cases, respectively, on two flights. While there was a suggested association between transmission and flights of longer duration, this was not significant and transmission did occur on three flights shorter than 8 hours (4.5, 7.5 and 7.8 hours) (Box 3).

Among the 20 secondary cases, three people had been fully vaccinated (ie, had received two documented MMR vaccinations), two had one documented MMR vaccination, nine were unvaccinated and vaccination status was unknown for six. Mean age was 25 years (range, 11–47 years). Most secondary cases (11/20) were identified independently and in-flight exposure was determined after notification. The remaining cases (9/20) were identified during the contact-tracing process, with subsequent onset of illness and notification.

Fifteen of the 49 flight manifests were available to public health authorities within 5 days of the flight, 14 were available within 6–7 days and 20 after 8 or more days. The mean time to notification of public health authorities of an infectious measles case on an aeroplane was 6.5 days from the date of the flight, with an additional mean of 1.4 days (median, 1; range, 0–5 days) to obtain flight manifests and contact details for passengers. Provision of postexposure immunoprophylaxis to contacts was possible in less than one in five flights (Box 4).

Data on the number of passenger contacts followed up were available for 40 flights, for which attempts were made to contact 1082 passengers (mean, 27 per flight). Applying this mean to the 49 flights, which yielded nine secondary cases, the risk of acquiring measles if seated within the two-plus-two row range recommended by contact-tracing guidelines was estimated as 0.0068; hence, an estimated 147 (95% CI, 77–322) passengers were contacted to identify each "future" secondary case. Similarly, the risk of acquiring measles in rows 3–8 distant from an index case, assuming a wide-bodied jet with 10

3 Selected characteristics of aeroplane flights with and without secondary measles transmission, Australia 2007–2011

	Secondary transmission (n = 7 flights)	No transmission (n = 42 flights)	P
International flight	7 flights	29 flights	0.167*
Mean (range) age of index case in years†	13.7 (3–25)	20.5 (0–46)	0.025‡
Mean (range) flight time in hours	8.4 (4.5–12)	5.7 (1.0–13.5)	0.091§
More than one infectious case present	2 flights	0 flights	0.018*
Prophylaxis offered to susceptible contacts	3 flights	5/37¶ flights	0.10*

* Fisher exact test. † Includes all infectious index cases (10). ‡ Independent samples t-test. § Mann–Whitney U test. ¶ Denominator excludes five flights for which it was unknown whether prophylaxis was specifically offered. ◆

4 Number of flights according to the length of time taken for the flight manifest to be made available to public health authorities and the type of intervention undertaken, Australia, 2007–2011

Time (days)	Number of flights	No contact tracing	Information only*	Postexposure immunoprophylaxis†	Unknown‡
< 3	3	0	0	2	1
3–5	12	0	3	4	5
⩾ 6	34	5	26	2	1
Total	**49**	**5**	**29**	**8**	**7**

* Advice on the risk, signs and symptoms of measles infection and restriction advice if non-immune or symptoms develop. † Measles–mumps–rubella vaccine or normal human immunoglobulin offered to identified susceptible contacts. ‡ Unknown whether information only or postexposure prophylaxis was given to contacts. ◆

passengers per row, was 0.0014, with an average of 720 (95% CI, 368–1471) passenger contacts requiring follow-up per secondary case identified.

Discussion

Our analysis of people notified with measles who were likely to have been infectious or infected while travelling on aeroplanes in Australia showed that just over half of the people identified as secondary cases were seated outside the two-plus-two row distance recommended by contact-tracing guidelines in Australia[5] and elsewhere.[12,13] This result is consistent with other recently published literature reporting the occurrence of measles transmission on aeroplanes. Eleven reports[3,6-9,14-19] (two of which refer to cases included in this study; see Appendix online at mja.com.au) listed a total of 36 secondary cases associated with transmission in aeroplanes, with only six cases having documented seating within two rows of the index case. However, the literature is limited by publication bias favouring reporting of flights on which secondary transmission occurs, and probably of flights where cases occur outside contact-tracing guidelines. By including all people notified with measles within a defined 4.5-year period, who travelled on aeroplanes while infectious, our study overcomes the disadvantage of publication bias, and provides valuable information on the incidence of and factors associated with secondary transmission of measles on aircraft.

Aircraft cabin design is thought to limit the transmission of infectious diseases spread by droplets or aerosols, such that the greatest risk is to those seated in rows adjacent to an infected individual. Air circulation patterns are side to side, with little front to back airflow, and air exits the cabin near the floor. Recirculated air passes through high efficiency particulate (HEPA) filters which are effective against microorganisms, including viruses, before cabin redelivery.[20,21] However, coughing may spread respiratory droplets in an aeroplane environment,[22] and risk assessments based on seating proximity do not take into account passenger movements before (eg, at check-in), during (eg, toilet visits) and after (eg, baggage collection) the flight. Despite the designed airflow environment, transmission of measles during international aeroplane travel is not rare if there is an infectious case on board, nor is it limited to the current two-plus-two row contact-tracing recommendations, as we have shown.

The risk of measles acquisition depends on exposure to respiratory droplets, which can become aerosolised. Speculatively, younger-aged cases may have been more likely to transmit infection because children are less able to contain their respiratory secretions. Not surprisingly, risk of transmission was also increased by multiple infectious cases on board. In addition to being associated with three secondary cases in Australia, the three siblings on one flight who were infectious were associated with a further five secondary cases on a subsequent flight to New Zealand.[8]

European risk assessment guidelines state that no documented cases of measles transmission have occurred on flights shorter than 8 hours.[12] However, transmission has been reported on short duration flights.[8,9] In addition, although not stated, it could be assumed that flights from the Netherlands to England,[14] Venezuela to Miami, USA,[17] within Brazil[7] and within the US[16] would be less than 8 hours. A recent literature review[13] concluded that "flight duration is not an important factor". Our study showed transmission risk may be greater on longer duration international flights, although transmission also occurred on three flights shorter than 8 hours.

Measles contact tracing aims to provide contacts with education, counselling and, where appropriate, with immunoprophylaxis to prevent illness. Recommended prophylaxis includes MMR vaccination within 72 hours of exposure or NHIG within 144 hours after exposure.[11] In our study, contact tracing generally occurred too late for provision of immunoprophylaxis, primarily because of lengthy delays in diagnosis and notification of the index case — delays in obtaining flight manifests were relatively less important. This highlights the need for medical practitioners to consider a diagnosis of measles in overseas travellers who have a clinically compatible illness, and to notify such cases to public health authorities promptly, on clinical suspicion. Unless these times can be reduced significantly, immunoprophylaxis to prevent secondary cases will rarely be feasible, let alone effective, calling into question the value of committing significant human resources to performing direct contact tracing of aeroplane contacts.

Our study has some limitations. Our methods relied on all Australian jurisdictions providing data, and it is possible there were inconsistencies in the completeness and accuracy of those data. However, all jurisdictions use national guidelines for response to and documentation of measles cases.[11] Moreover, it is unlikely that identified cases (either primary or secondary) would not have been notified to public health authorities, as all cases require an urgent public health response. During the study period, endemic measles transmission had been eliminated in Australia and practically all notified cases were identified as imported cases or were linked to known imported cases, indicating that very few cases are unidentified.

While it is not possible with the data available to determine whether transmission occurred in-flight, the clustering within eight rows fore and aft of index cases suggests that in-flight transmission associated with seating proximity was the likely mechanism in most instances.

The combined delays in diagnosis, notification and acquisition of flight manifests shown in this study resulted in contact tracing being ineffective for identifying susceptible people for timely immunoprophylaxis. In addition, while 17/19 passengers who were identified as secondary cases were seated within eight rows fore and aft of the index case, these 17 rows accommodate around 170 passengers on any wide-bodied jet. This number would require the use of significant human resources to perform direct contact tracing, which is unlikely to be feasible. There are also high levels of herd immunity in Australia and transmission events are relatively infrequent.[23] Therefore, we recommend that public health authorities no longer routinely perform contact tracing for infectious measles cases on aeroplanes. Other strategies, such as general media alerts that identify affected flights, and direct email or SMS text messaging of passengers (if airlines can provide such contact information), may be more timely and effective. Circumstances in which contact tracing might be justified include those where diagnosis and notification have been prompt, where flight manifests are readily available, and where there are multiple infectious people, especially children, on a flight. Authorities should also continue to document cases of measles associated with air travel, in order to provide a sounder evidence base for public health guidelines.

Ensuring measles vaccination coverage remains high, promoting predeparture measles vaccination to travellers without a documented vaccination history, and raising awareness among health practitioners of the need to consider the diagnosis of measles in returning travellers and overseas visitors with clinically compatible fever and rash illnesses will decrease the risk of measles importation and secondary transmission in Australia.

Acknowledgements: We gratefully acknowledge our colleagues in individual state and territory health departments who provided data and undertook the initial public health responses to measles cases. We also thank Alex Xiao for his advice on statistical analysis. The conclusions are those of the authors and do not necessarily represent those of the CDNA.

Competing interests: Andrew Langley previously owned stock in CSL, which manufactures NHIG.

Received 29 Nov 2012, accepted 14 Feb 2013.

1 Olsen SJ, Chang HL, Cheung TY, et al. Transmission of the severe acute respiratory distress syndrome on aircraft. *N Engl J Med* 2003; 349: 2416-2422.

2 Khan K, Arino J, Hu W, et al. Spread of a novel influenza A (H1N1) virus via global airline transportation. *N Engl J Med* 2009; 361: 212-214.

3 Beard F, Franklin L, Donohue S, et al. Contact tracing of in-flight measles exposures: lessons from an outbreak investigation and case series, Australia, 2010. *West Pac Surveill Response J* 2011; 2: 25-33.

4 Australian Bureau of Statistics. Overseas arrivals and departures, Australia, Jun 2012. Canberra: ABS, 2012. (ABS Cat. No. 3401.0.) http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/3401.0Feature%20Article1Jun%202012?opendocument&tabname=Summary&prodno=3401.0&issue=Jun%202012&num=&view= (accessed Sep 2012).

5 Communicable Diseases Network Australia. Revised guidelines for the follow-up of communicable diseases reported among travellers on aeroplanes. Canberra: Department of Health and Ageing, 2006. http://www.health.gov.au/internet/main/publishing.nsf/Content/cda-cdna-gl-airtravlers.htm (accessed Nov 2012).

6 Centers for Disease Control and Prevention. Measles — United States, 2004. *MMWR Morb Mortal Wkly Rep* 2005; 54: 1229-1231.

7 de Barros FR, Danovaro-Holliday MC, Toscano C, et al. Measles transmission during commercial air travel in Brazil. *J Clin Virol* 2006; 36: 235-236.

8 Centers for Disease Control and Prevention. Notes from the field: multiple cases of measles after exposure during air travel — Australia and New Zealand, January 2011. *MMWR Morb Mortal Wkly Rep* 2011; 60: 851.

9 Coleman KP, Markey PG. Measles transmission in immunized and partially immunized air travellers. *Epidemiol Infect* 2010; 138: 1012-1015.

10 Rothman KJ, Boice JD. Epidemiologic analysis with a programmable calculator. Washington, DC: Department of Health Education and Welfare, Public Health Service, National Institutes of Health, 1979.

11 Communicable Diseases Network Australia. Measles: national guidelines for public health units. Canberra: Australian Government Department of Health, 2009. http://www.health.gov.au/internet/main/publishing.nsf/Content/55AD336B864C7203CA25755F000307B6/$File/measles-song.pdf (accessed Nov 2012).

12 European Centre for Disease Prevention and Control. Technical report. Risk assessment guidelines for infectious diseases transmitted on aircraft. Stockholm: ECDPC, 2009. http://ecdc.europa.eu/en/publications/Publications/0906_TER_Risk_Assessment_Guidelines_for_Infectious_Diseases_Transmitted_on_Aircraft.pdf (accessed Feb 2013).

13 Edelson PJ. Patterns of measles transmission among airplane travellers. *Travel Med Infect Dis* 2012; 10: 230-235.

14 van Binnendijk RS, Hahne S, Timen A, et al. Air travel as a risk factor for introduction of measles in a highly vaccinated population. *Vaccine* 2008; 26: 5775-5777.

15 Centers for Disease Control and Prevention. Notes from the field: measles transmission associated with international air travel — Massachusetts and New York, July-August 2010. *MMWR Morb Mortal Wkly Rep* 2010; 59: 1073.

16 Centers for Disease Control. Epidemiologic notes and reports: interstate importation of measles following transmission in an airport — California, Washington 1982. *MMWR Morb Mortal Wkly Rep* 1983; 32: 215-216.

17 Amler RW, Bloch AB, Orenstein WA, et al. Imported measles in the United States. *JAMA* 1982; 248: 2129-2133.

18 Slater P, Anis E, Bashary A. An outbreak of measles associated with a New York/Tel Aviv flight. *Travel Med Int* 1995; 13: 92-95.

19 Centers for Disease Control and Prevention. Notes from the field: measles among US-bound refugees from Malaysia — California, Maryland, North Carolina, and Wisconsin, August–September 2011. *MMWR Morb Mortal Wkly Rep* 2011; 60: 1281-1282.

20 Mangili A, Gendreau MA. Transmission of infectious diseases during commercial air travel. *Lancet* 2005; 365: 989-996.

21 Leder K, Newman D. Respiratory infections during air travel. *Intern Med J* 2005; 35: 50-55.

22 Gupta JK, Lin CH, Chen Q. Inhalation of respiratory droplets in aircraft cabins. *Indoor Air* 2011; 21: 341-350.

23 Gidding HF, Wood J, MacIntyre CR, et al. Sustained measles elimination in Australia and priorities for long term maintenance. *Vaccine* 2007; 25: 3574-3580. ❑