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Descriptive Analysis of Measles Transmission Among Travelers During Domestic and Inbound US International Air Travel, 2018–2019

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Abstract

Measles is highly transmissible and can lead to severe complications and mortality risk. Cases of measles are reportable to the US Centers for Disease Control and Prevention (CDC). This study describes characteristics of travelers who flew while infectious with measles and their contacts. We analyzed data from domestic and US inbound international flights reported between January 1, 2018, and December 31, 2019. To identify contacts potentially exposed to measles during air

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travel we used the CDC-defined measles contact zone and crossmatched with the CDC measles database. We conducted a descriptive analysis of travelers with measles and their aircraft contacts and determined average time from flight exposure to contact interview. During the analysis period, CDC received reports of 83 air travelers infectious with measles resulting in 5,186 potential aircraft exposures. Health departments provided data to CDC for 39% (n=2,037) of the exposures/contacts. On average, 9.8 days elapsed between flight exposure and initial interview attempt. Of the 2,037 contacts interviewed, 82% (n=1,680) reported a history of vaccination or prior disease. Seven secondary cases were identified. Five were exposed on US inbound international flights, 5 had no history of vaccination, and 4 were seated outside the contact zone. Most contacts who developed measles were unvaccinated and shared a US inbound international flight with an infected traveler. Over half of secondary cases were outside the contact zone. The average first contact interview attempt occurred beyond the 3-day window for effective prophylaxis. Continued emphasis on measles vaccination, evaluation of the contact zone definition, and timely contact investigation of exposed travelers may prevent secondary cases and outbreaks in the United States.

Keywords

Measles; Disease transmission; Air travel; Contact investigations

Background

Despite the official declaration of measles elimination in the United States in 2000,¹ cases continue to be reported to the US Centers for Disease Control and Prevention (CDC) each year. Measles is a highly contagious virus that spreads through respiratory droplets; it is vaccine preventable, a nationally notifiable disease, and cases are reported to CDC through the National Notifiable Diseases Surveillance System.^{2,3} State, tribal, local, and territorial (STLT) health departments and foreign ministries of health notify CDC of persons diagnosed with measles who traveled by air while infectious. Visitors to the United States and unvaccinated returning passengers and crew (hereafter referred to as “travelers”) account for many reported primary cases that can result in secondary cases and outbreaks.^{3,4} Additionally, transmission of measles has been documented on commercial flights. From 2004 to 2011, 77 travelers who flew while infectious with measles resulted in 12 secondary cases in the United States.^{5,6}

In 2005, CDC developed the first measles aircraft contact investigation (CI) protocol, which defined the contact zone as an area containing all passengers seated within 1 row of the infected traveler. All infants-in-arms onboard the flight, regardless of their seat location, were also considered contacts due to the high probability that parents may be walking up and down the aisles during the flight with the child. The contact zone was expanded in 2008 to include all passengers seated in within the 2 rows in front and behind the infected traveler and all infants-in-arms and flight crew serving the infected traveler. Additionally, given different airflow patterns and proximity of the passenger seats on smaller planes, the 2008 updated protocol took into consideration the aircraft size defining the contact zone as the entire flight for aircraft with a passenger capacity of up to 30.⁹ In 2013, this was

expanded to include flights with a passenger capacity of up to 50 (personal communication with CDC).

CDC's aircraft CI outcome data are periodically analyzed and published to assess the effectiveness of current aircraft CI protocols and to evaluate the extent of flight-associated disease transmission. The last measles aircraft CI review prior to 2020 (which examined the period 2008–2011) did not result in a protocol change.⁷ All secondary cases reported to CDC during that period (n=9) occurred in persons located within the contact zone defined at that time (unpublished data).

A 2012 review of the literature by Edelson examining a broader time range found that, for cases identified from 1946 to 2012, 10 (50%), excluding 5 infants-in-arms, of the 20 secondary cases occurring on large planes (more than 30 passengers) were seated outside of a 5-row contact zone.⁸ A 2015 review of cases and contacts identified from 2001 to 2011 by Jost found that at least 18 (45%) of 40 secondary cases occurred outside of a 5-row contact zone.⁹ Given the improved airflow dynamics on modern aircraft, along with the increasing number of measles cases in recent years, additional investigation into measles transmission risk on modern aircraft would be helpful to inform updates to current measles aircraft contact investigation protocols.⁷

At the end of 2019, the 39 measles outbreaks that occurred in 2018–2019 comprised the largest number of cases in the United States in a 2-year period since 1992–1993.^{10,11} Due to the increase in cases and the evidence in the earlier literature of secondary cases occurring outside the contact zone, an analysis of 2018–2019 aircraft CI outcome data was undertaken to evaluate the contact zone definition and examine its effectiveness in accurately identifying persons who acquire measles following exposure on an aircraft.

Methods

Demographic, clinical, laboratory, and flight itinerary information for an infectious traveler is reported to CDC by STLT health departments^{4,5} and entered and stored in CDC's Port Health Activity Reporting System (PHARS), a secure database for managing CDC's border public health activities.¹² In accordance with federal regulations, CDC requests flight manifests from the airline to obtain contact information of passengers and flight crew meeting the criteria for exposure risk. Traveler information is securely provided to the STLT health department in which the traveler resides for contact investigation and public health follow-up. Health departments investigate exposed travelers, identify secondary cases, and voluntarily provide outcome data from these investigations to CDC.

Primary case data were cross-referenced with CDC's National Center for Immunization and Respiratory Diseases (NCIRD) measles case data to identify any secondary cases not recorded in PHARS that may have occurred among travelers on the primary case flight. CDC PHARS primary case data from 2018 to 2019 were compared with NCIRD case surveillance data from the same period to identify measles cases with an illness onset within one incubation period (21 days) of the primary measles case's flight to determine if any unreported traveler on the flight developed measles. Additionally, PHARS contact data from

2018 to 2019 were compared to NCIRD measles case data by flight arrival year, date of birth, and state, and all observations appearing in both datasets were reviewed to determine if any contacts had developed measles. All personally identifiable information was deleted, and only a unique identifier maintained, to ensure confidentiality for the main analysis. For the crossmatch, an encrypted and password-protected file additionally containing date of birth was shared between the 2 authors who conducted data analysis. Data were analyzed using Excel and R. A descriptive analysis of all reported primary and secondary cases was completed. This analysis examined primary measles cases by year reported, age, sex, clinical history, measles vaccination and disease history, flight duration, and flight departure location, and secondary cases by age, sex, clinical history, measles vaccination and disease history, location, and eligibility for and receipt of postexposure prophylaxis (PEP) based on the established time window for effective PEP of 3 to 6 days after exposure.^{13,14}

A notification time point analysis was also conducted using the dates and times calculated between each time point. For primary cases these dates and times included the dates of flight arrival, rash onset, specimen collection, and when the case was reported to CDC; and for traveler contacts dates and times included the date the STLT health department was notified and the interview attempt. Data for travelers missing 1 or more time point entries and data entry errors were excluded from the analysis. Data analyzed for this report were collected during routine public health operational work carried out by CDC. This activity was reviewed by CDC, deemed not research, and was conducted consistent with applicable federal law and CDC policy.

Results

Eighty-three persons traveling by air on domestic or US inbound international flights while infectious with measles were reported to CDC between January 1, 2018 and December 31, 2019, resulting in the identification of 5,186 travelers potentially exposed during air travel. Health departments returned outcomes data to CDC for 2,037 (39.3%), of whom 2,002 (38.6%) were interviewed (Figure 1). After the contact's potential exposure to measles during the flight, on average, 6.25 days (median 6, IQR 3–8) elapsed before notification of the primary case to CDC, 9.1 days (median 8, IQR 5.5–12) elapsed before notification to the contact's jurisdiction health department, and 9.8 days (median 9, IQR 6.5–12.5) elapsed before the initial interview attempt (Figure 2). Of the 2,037 traveler contacts, 1,369 (67.2%) were reported to be between the ages of 2 and 65 years and eligible to receive at least 1 vaccine dose in the United States.¹³ Of the 2,002 interviewed contacts, 1,615 (79.3%) were reported as having a self-reported or documented history of measles immunization or disease, 286 (14.3%) had unknown status, and 71 (3.5%) were unvaccinated (Table 1). No history of immunization, prior disease, or date of birth before 1957 (thus no presumed immunity) was recorded for 357 (17.5%). Of the 65 people born before 1957, 38.5% (n=25) received PEP, 12.3% (n=8) had PEP recommended and were within the time window for effective PEP but declined, 64.4% (n=230) received no PEP because they were outside the time window,^{13,14} and 26.3% (n=94) had no information reported regarding PEP. Among the 2,002 people interviewed, 1,898 (94.8%) did not receive PEP.

Two secondary cases were identified in the initial PHARS data search, and another 5 were identified through cross-reference with the NCIRD database, for a total of 7 secondary measles cases among contacts (Figure 1). Of these secondary cases, 5 (71.4%) were exposed on US inbound international flights, 5 (71.4%) were unvaccinated or had unknown vaccination status, and 4 (57.1%) were identified as located outside the defined contact zone (Table 2).

The 7 identified primary cases led to 7 secondary cases. One of 7 primary cases (14.3%) and 1 of 7 secondary cases (14.3%) were 6 years old or younger. Five of 6 primary cases (83.3%) eligible for vaccination were not vaccinated. All secondary cases were exposed to imported primary cases¹³ (see Supplemental Table). Of the 7 secondary cases, 2 (28.5%) were vaccinated with at least 1 dose of measles vaccine, 2 (28.5%) were not vaccinated, and 3 (42.9%) provided no information regarding immunization or disease history. For 6 of 7 secondary cases (85.7%), STLT public health received notification of their exposure more than 6 days after the exposure flight arrival date, which was outside the window for PEP (Table 2). Two secondary cases were exposed on 2 different domestic flights, each lasting less than 4 hours. The other 5 secondary cases (71.4%) were exposed on 3 different US inbound international flights lasting more than 8 hours. Three secondary cases (42.8%) (including 1 infant-in-arms) were located within the defined contact zone, and 4 secondary cases (57.1%) were located outside the defined contact zone. One secondary case traveled on a flight with 3 primary cases. (Figure 3).

Discussion

In 2018 and 2019, CDC received reports of 83 air travelers infectious with measles resulting in 5,186 potential aircraft exposures. Seven secondary cases were identified. Of these 7, 2 (28.6%) were vaccinated with at least 1 dose of measles vaccine, 2 (28.6%) were unvaccinated, and 3 (42.9%) provided no information regarding immunization or disease history, highlighting the increased risk among nonimmune travelers.

The 7 identified secondary measles cases are a small fraction of potentially exposed air travelers, which suggests measles transmission on commercial aircraft is a rare event. However, there is still a risk, especially among nonimmune travelers, emphasizing the importance of PEP to provide protection against measles infection in this population. To be effective, PEP must be administered within 3 to 6 days of initial exposure^{13,14}; however, among contacts, the time elapsed between flight exposure and the first contact interview attempt was 6 days or less for only 25% of contacts, thus for 75% of contacts the first interview attempt occurred beyond the PEP time window. Resource limitations are a likely barrier to STLT health department reporting to CDC. The inability to reach measles contacts within the PEP time window limits the effectiveness of flight-related contact investigations.

Contact investigations also provide the opportunity to identify exposed contacts and allow public health authorities to share critical prevention information. However, in this analysis, over half of the secondary cases were not within the defined contact zone and, thus, not included in the aircraft contact investigations. Crew accounted for 2 of the 7 identified secondary cases, but they were not included in the contact investigations for flights on

which they were exposed because they did not serve the primary case. Crew names may not be included on requested manifests. Additionally, crew are likely to be exposed to passengers outside the section in which they are assigned to work. A broader inclusion of all flight crew may better identify those exposed. Finally, a third secondary case traveled on a flight with 3 infectious measles cases but was seated outside the defined contact zone and not included in the contact investigation. Current protocols do not address situations with more than 1 primary case on a flight. Multiple cases traveling on the same flight may increase transmission risk and expanding the defined contact zone may better identify exposed travelers.

Two secondary cases were reported vaccinated for measles with at least 1 dose of measles-containing vaccine: 1 crew and 1 passenger seated within the contact zone. Documented proof of measles vaccination is often not available to contact investigators, and self-reported measles vaccination by a contact may not confirm immunity in that contact. Lack of functional immunity among 2 secondary cases who were reported vaccinated suggests a need to share comprehensive prevention information with all exposed contacts.

CDC did not receive outcomes data for 61% of measles air traveler contacts. Return of contact investigation outcome data to CDC is voluntary, and reporting mechanisms are not yet automated. Preliminary findings indicate that the majority of these data are lost when outcome reports are not returned to CDC. Limited availability of traveler outcome data reduced the robustness of the analysis.

Our findings suggest the exploration of potential changes to CDC's current protocols for measles aircraft contact investigations: First, continue efforts to fully automate contact investigation outcome data reporting. Second, provide the same information to all contacts identified as potentially exposed, regardless of vaccination status. Third, initiate full plane contact investigation for all flights where multiple (2 or more) infectious measles cases are identified. Fourth, include all crew in the list of contacts. Finally, given that reaching passengers postflight is difficult, encourage or require airlines to issue notification to all passengers on an aircraft upon identification of an infectious measles case on the flight.

Limitations

The low number of secondary cases makes it challenging to draw significant conclusions. Second, limited reporting of exposed traveler outcome data to CDC reduced the ability to make data-driven decisions. Third, it was not possible to collect vaccination and immunity history information for the complete population of exposed travelers, thus measles susceptibility and risk cannot be quantified nor calculated for this group. Fourth, given not all identified contacts were able to be interviewed, and some travelers may change seats or move around the aircraft, it is challenging to always accurately determine such factors as proximity of secondary cases to index cases. Finally, the volume of manual data entry required to document aircraft CIs introduced the possibility of data entry errors.

Conclusions

Measles is one of the most contagious infectious diseases to affect humans.^{13,15} Transmission on aircraft is rare, especially among vaccinated individuals, but does occur, and represents an increased risk to travelers who lack immunity. Measles can be prevented in those lacking immunity by prophylaxis after exposure, but the window of time for administering PEP is narrow. Continued emphasis on measles vaccination, better definition of the contact zone, broader notification mechanisms, and efficient location and evaluation of exposed traveler contacts may prevent secondary measles cases and outbreaks in the United States.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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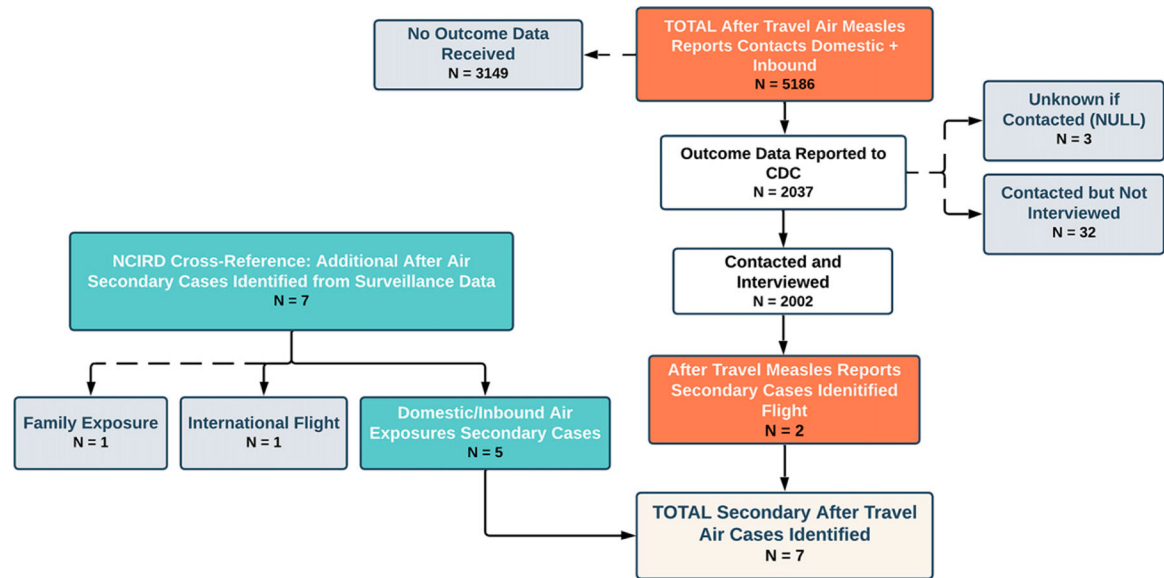


Figure 1.

Flow chart showing outcomes of contact investigations done for travelers reported to CDC as having flown while infectious with measles from January 2018 to December 2019.

Abbreviations: CDC, Centers of Disease Control and Prevention; NCIRD, CDC National Center for Immunization and Respiratory Diseases.

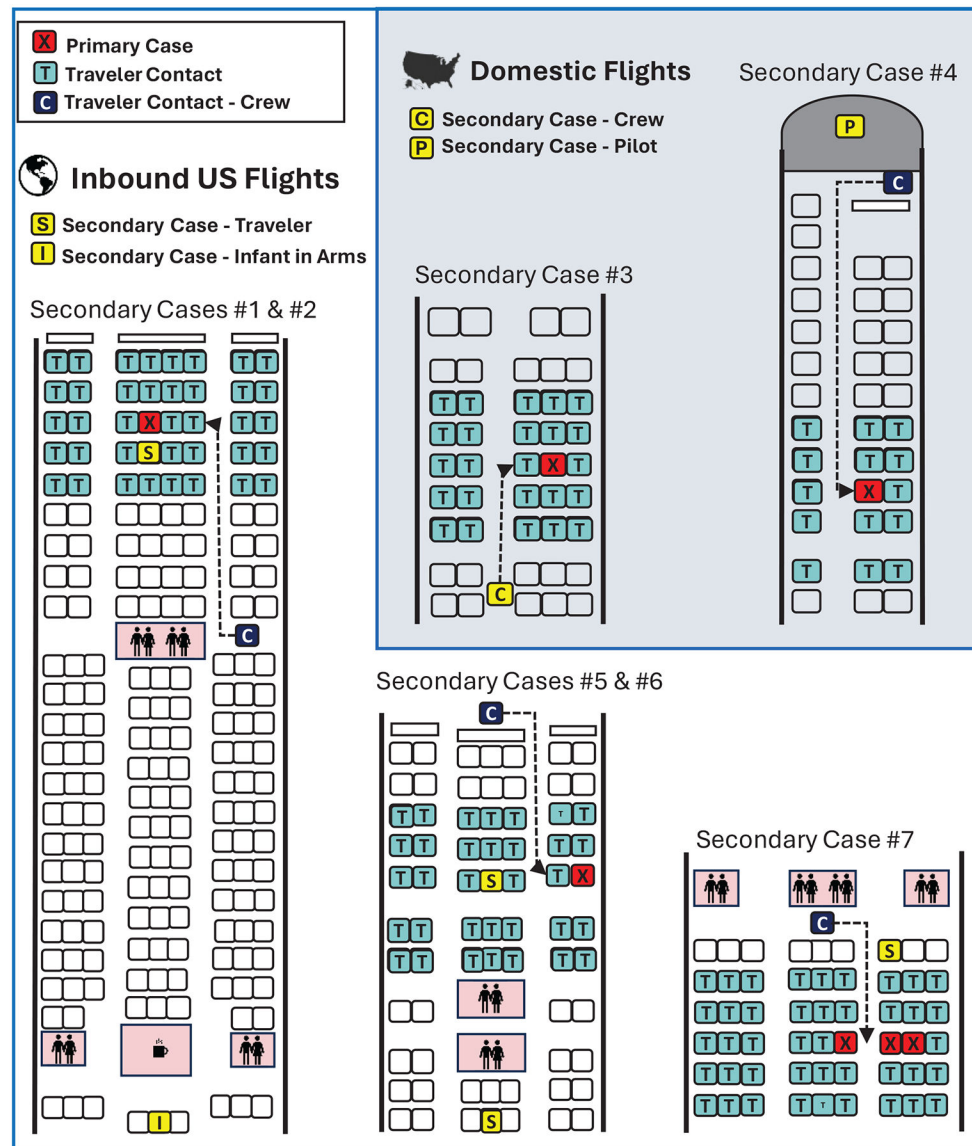


Figure 2. Contact definitions and zones used during aircraft contact investigations to identify travelers who were exposed to an individual who flew while infectious with measles on domestic and inbound US international flights from January 2018 to December 2019.

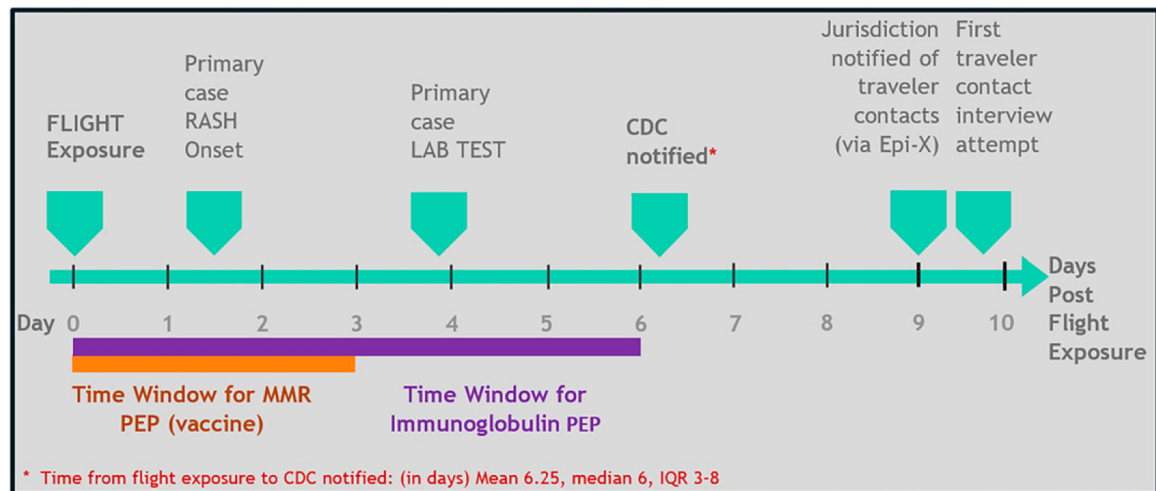


Figure 3. Average times from date of exposure on an aircraft to CDC notification to health department traveler interview, for aircraft contact investigations done for travelers reported to CDC who flew while infectious with measles from January 2018 to December 2019. Abbreviations: CDC, Centers for Disease Control and Prevention; Epi-X, Epidemic Information Exchange; MMR, measles, mumps, and rubella; PEP, postexposure prophylaxis.

Table 1.
 Characteristics of Travelers Exposed to Measles Identified During Aircraft Contact Investigations Initiated From January 2018 to December 2019^a (N = 2,037)

Characteristic	n (%)
Sex	
Male	911 (44.7)
Female	816 (40.0)
Unknown/not reported	310 (15.2)
Age, years	
0–1	57 (2.8)
2–6	46 (2.6)
7–17	71 (3.5)
18–65	1,252 (61.5)
66 and older	165 (8.1)
Unknown (null)	446 (21.9)
Immunity history	
Born before 1957	65 (3.2)
History of disease	200 (9.8)
Immune by serology	118 (5.8)
Immunized for measles with MMR (or other measles-containing vaccine)	1,297 (63.7)
Unknown/not reported/null	286 (14.0)
Not vaccinated	71 (3.5)
PEP received (among those interviewed, n=2,002) ^b	
No	1,898 (94.8)
Yes	50 (2.5)
Null	54 (2.7)
Of the 2,002 interviewed, PEP received among those with no reported history of vaccination or disease (n=357) ^b	
PEP received	25 (7.0)
PEP recommended and within time window, but declined	8 (2.2)
No PEP received because outside time window	230 (64.4)
Null/other	94 (26.3)
Secondary measles cases	7 (.3)

^aFor travelers who were infectious with measles and reported to CDC.

^bPercentages in this characteristic calculated using the subpopulation denominator.

Note: For those questions not answered by all interviewees, the number of people who answered the question is noted after the characteristic and the percentages given within that category is based on that population.

Abbreviations: MMR, measles, mumps, and rubella; PEP, postexposure prophylaxis.

Table 2.

Characteristics of Primary and Secondary Cases of Measles Who Flew While Infectious on Domestic and US Inbound Flights From January 2018 to December 2019 and Were Reported to CDC

Characteristic	Primary Cases (n = 7) n (%)	Secondary Cases (n = 7) n (%)
Sex		
Male	6 (86)	4 (57)
Female	1 (14)	3 (43)
Age, years		
0–1	0 (0)	1 (14)
2–6	1 (14)	0 (0)
7–17	3 (43)	0 (0)
18–65	3 (43)	6 (86)
Vaccination status?		
Unvaccinated (UnVx)	6 (86)	2 (29)
UnVx age <18	4 (57)	1 (20)
UnVx age >18	2 (29)	–
Unknown (Unkn)	–	3 (43)
UnVx/Unkn age >18	–	4 (80)
Vaccinated	1 (14)	2 (29)
Exposure (country)		
International (imported)	7 (100)	–
Domestic (United States)	0 (0)	–
Exposure (flight)		
Inbound international flight (>8 hrs)	–	5 (71)
Domestic flight (<4 hrs)	–	2 (29)
Located within defined contact zone		
Yes	–	3 (43)
No	–	4 (57)
Symptoms (at time of interview) ^a		
Rash	7 (100)	7 (100)
Fever or feeling feverish/having chills	5 (71)	3 (43)
Cough	3 (43)	1 (14)
Sore throat	2 (29)	0 (0)
Coryza	2 (29)	0 (0)
Koplik spots	2 (29)	1 (14)
Conjunctivitis	1 (14)	0 (0)
Vomiting/diarrhea	1 (14)	0 (0)
Rash onset (in relation to flight)		
Onset at least 1 day before flight	1 (14)	–
Onset day of flight	2 (29)	–
Onset at least 1 day after flight	4 (57)	–

Characteristic	Primary Cases (n = 7) n (%)	Secondary Cases (n = 7) n (%)
Time to rash onset (days after exposure)		
Range	–	12–16
Mean	–	13.6
Median	–	14
Nonrash symptom onset (in relation to flight)		
Onset at least 1 day before flight	4 (57)	–
Onset day of flight	2 (29)	–
Onset at least 1 day after flight	1 (14)	–

^aNo symptoms besides rash were reported for 4 of 7 secondary cases; however, both vaccinated secondary cases reported multiple symptoms.