Health Care–Associated Measles Outbreak in the United States After an Importation: Challenges and Economic Impact

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(See the editorial commentary by Ostroff, on pages 1507–9.)

Background. On 12 February 2008, an infected Swiss traveler visited hospital A in Tucson, Arizona, and initiated a predominantly health care–associated measles outbreak involving 14 cases. We investigated risk factors that might have contributed to health care–associated transmission and assessed outbreak-associated hospital costs.

Methods. Epidemiologic data were obtained by case interviews and review of medical records. Health care personnel (HCP) immunization records were reviewed to identify non–measles-immune HCP. Outbreak-associated costs were estimated from 2 hospitals.

Results. Of 14 patients with confirmed cases, 7 (50%) were aged ≥18 years, 4 (29%) were hospitalized, 7 (50%) acquired measles in health care settings, and all (100%) were unvaccinated or had unknown vaccination status. Of the 11 patients (79%) who had accessed health care services while infectious, 1 (9%) was masked and isolated promptly after rash onset. HCP measles immunity data from 2 hospitals confirmed that 1776 (25%) of 7195 HCP lacked evidence of measles immunity. Among these HCPs, 139 (9%) of 1583 tested seronegative for measles immunoglobulin G, including 1 person who acquired measles. The 2 hospitals spent US$799,136 responding to and containing 7 cases in these facilities.

Conclusions. Suspecting measles as a diagnosis, instituting immediate airborne isolation, and ensuring rapidly retrievable measles immunity records for HCPs are paramount in preventing health care–associated spread and in minimizing hospital outbreak–response costs.

Measles is a highly infectious viral disease spread by airborne transmission. During the late 1950s, an estimated 3–4 million measles cases occurred annually in the United States, with 48,000 reported hospitalizations and 450 reported deaths [1, 2]. After implementation of a 1-dose measles vaccine program in 1963, measles cases decreased [1]. In 1989, administration of a second dose of measles, mumps, and rubella (MMR) vaccine was recommended routinely for school children, health care personnel (HCP), students attending post–high school institutions, and international travelers without acceptable evidence of immunity [3]. Elimination of endemic measles transmission was declared in the United States in 2000 [1]. During 2001–2008, a median of 56 cases (range, 37–140 cases) were reported annually, with importations causing outbreaks among unvaccinated populations in certain community settings [4].

Because of measles severity, patients often seek care in health care settings, posing a high risk for transmission to other patients and HCP [5, 6]. Studies conducted during the 1980s documented that HCP have a 2–19-fold higher risk of acquiring measles than the general population [6, 7]. Health care–associated out-
breaks can disrupt health care delivery and result in substantial morbidity or mortality among immunocompromised persons [5].

On 20 February 2008, a measles case was reported to the Arizona Department of Health Services (ADHS; Phoenix, AZ) and confirmed by the Arizona State Public Health Laboratory (ASPHL; Phoenix, AZ). Through 21 July, an additional 13 confirmed cases were identified in health care settings and the community. This report describes the epidemiology of the outbreak, examines outbreak-associated costs and risk factors that might have contributed to health care–associated transmission, and provides guidance to prevent outbreaks in health care settings.

METHODS

Case Investigation and Outbreak Response
We used the Council of State and Territorial Epidemiologists measles clinical case definition: (1) fever (temperature, $\geq 101\,^\circ F$ [$\geq 38.3\,^\circ C$]), (2) a generalized maculopapular rash lasting $\geq 3$ days, and (3) presence of cough, coryza, and/or conjunctivitis [8]. Confirmed cases were those that were laboratory confirmed or met the clinical case definition and were epidemiologically linked to another confirmed case. Suspected cases were those in which a generalized rash illness and a fever (temperature, $\geq 38.3\,^\circ C$) were present. Vaccination status was determined by written confirmation of receipt of a measles-containing vaccine. Self-reported receipt of vaccine without written documentation was classified as unknown vaccination status.

After the first measles case report, Pima County Health Department (PCHD; Tucson, AZ) and ADHS enhanced passive surveillance and established active surveillance in health and laboratory facilities at all 7 major community hospitals in Tucson. Activities included daily surveillance of emergency departments (EDs), urgent care, and inpatient and outpatient logs for febrile rash illnesses and measles tests. Commercial laboratories throughout the state were reminded to report positive measles test results. A screening tool was developed to evaluate ED patients who presented with a generalized rash and fever, to guide infection-control measures, and to prompt immediate reporting of suspected measles cases to PCHD.

Patients with suspected measles were interviewed to obtain demographic, clinical, and medical information and a list of potential contacts. Urine, serum, and nasopharyngeal specimens were collected for laboratory testing. Recommendations were made to place any hospitalized or ED patient in whom the diagnosis of measles was suspected or confirmed on airborne precautions during their period of infectiousness.

Household contacts who lacked evidence of measles immunity were offered MMR vaccine or immune globulin (IG) [9]. Community contacts were informed of their potential exposure through telephone calls, letters, television, radio, or print media and instructed to contact their physicians. A hospital contact was defined as any HCP (physicians, nurses, technicians, clerical and support staff, trainees, and volunteers) who had worked in the medical facility on the day of the exposure or as any patient or visitor who had shared the same room at the same time as (or within 4 h after) the patient with confirmed or suspected measles. Inpatient contacts without evidence of immunity were vaccinated or offered IG. Other hospital contacts who lacked evidence of immunity were directed to special immunizations clinics.

Laboratory
Laboratory testing was conducted at ASPHL and confirmed at the Centers for Disease Control and Prevention (CDC; Atlanta, GA). Cases were classified as laboratory confirmed by demonstration of measles IgM antibody in acute-phase serum samples by enzyme immunoassay (Microimmune), isolation of measles virus in cell culture (Vero/hSLAM cells), or detection of measles RNA by reverse-transcription polymerase chain reaction [9]. Nucleic acid from positive viral cultures was extracted, amplified, and sequenced to determine measles virus genotype [10, 11].

Evidence of Immunity for HCPs
We used the 1998 definition of acceptable evidence of measles immunity for HCP during a measles outbreak from the Advisory Committee on Immunization Practices and the Healthcare Infection Control Practice Advisory Committee [9], modified to exclude documentation of physician-diagnosed measles, as follows: (1) serologic evidence of immunity or (2) written confirmation of receipt of measles-containing vaccine according to birth year (defined as at least 1 dose for HCP born before 1957 and 2 doses for HCP born during or after 1957).

We reviewed HCP immunization records for evidence of measles immunity in 2 of 7 Tucson community hospitals. HCPs without evidence of measles immunity had blood samples drawn for serological testing and were offered MMR or IG on the same day. A second dose was administered $\geq 28$ days after the first dose to those who were seronegative before the first MMR vaccine dose. All HCP without evidence of immunity were furloughed from work on days 5–21 after last exposure.

Hospital Costs
Costs were assessed in 2 hospitals. Data collected included the number of HCPs furloughed, time spent reviewing employee records for evidence of measles immunity (median, 15 min per record), and time spent conducting serologic tests and administering vaccine doses (median, 10 min per HCP). Furloughed hours were calculated by multiplying the number of HCP furloughed, the number of days in furlough, and a normal work shift (8 h). For the dollar value estimate of personnel time furloughed or spent reviewing employee records, we used the mean hourly earnings for full-time hospital health care practitioner and technical occupations in Arizona ($29.39), as reported by the US Bureau of Labor Statistics. The number of test kits or vaccine doses was assumed to be equal to the number of titers
drawn and HCP vaccinated. The average unitary price for testing kits ($35) was used to calculate the dollar value of the tests performed. No other laboratory costs were included. For the dollar value of vaccine and vaccine administration, we used a $10 vaccine administration cost plus the average cost per dose ($48.31), as listed by the CDC for the private sector.

RESULTS

Descriptive Epidemiology

During the period 13 February through 21 July 2008, there were 363 suspected, 8 probable (discarded after laboratory testing), and 14 confirmed measles cases identified in Arizona (Figures 1 and 2). All patients with confirmed cases were unvaccinated or had unknown vaccination status before exposure, and 2 patients (patients 3 and 8) had received their first dose of MMR vaccine on the same day as exposure. The median age of patients with confirmed cases was 20 years (range, 8 months–50 years), 7 (50%) were male, 4 (29%) were hospitalized for ≥24 h, and 2 (14%) required intensive care. No deaths occurred. Eleven patients (79%) accessed health care while infectious, and of these, 10 (91%) did not receive a prompt measles diagnosis after rash onset; only 1 (9%) was masked and isolated after presenting with rash and fever at a health care facility (Table 1).

Twelve cases were laboratory confirmed, and 5 patients had measles virus sequences identical to each other and to the sequence of the genotype D5 viruses associated with a concurrent outbreak in Switzerland [12].

Exposure and Contact Investigations

Table 2 shows potential places of exposure, clinical and laboratory characteristics, and contact investigations of confirmed measles cases. The index case occurred in an unvaccinated female Swiss traveler aged 37 years. She arrived in Arizona on 2 February, traveled to Mexico on 3 February, developed fever (temperature, 39.6°C) on 8 February, and returned to Arizona on 9 February. She developed respiratory symptoms on 12 February (first ED visit) and rash on 13 February, at which time she was admitted to hospital A with a diagnosis of acute viral illness. She was not isolated until 15 February, when measles was first suspected. The results of initial measles IgM testing from specimens collected on 17 February, 4 days after rash onset, were negative. Because of the high suspicion of measles, additional IgM testing was conducted on...
Positive PCR results

Laboratory result:

- Age, median years: 20
- Age, years:
  - <1: 3 (21)
  - 1–18: 4 (29)
  - 19–50: 7 (50)
- Male sex: 7 (50)
- Complications:
  - Otitis media: 3 (21)
  - Pneumonia: 2 (14)
  - Seizures: 1 (7)
- Hospitalized for ≥24 h: 4 (29)
  - Duration, median days (range):
    - Intensive care: 2 (14)
    - Duration, median days (range): 5 (4–6)
- Laboratory result:
  - IgM positive: 12 (86)
  - Positive PCR results: 7 (50)
  - D5 genotype: 5
  - Not genotyped: 2

**NOTE:** Data are no. (%) of patients, unless otherwise indicated. IgM, anti-measles immunoglobulin M; PCR, polymerase chain reaction.

Patient 4 was an unvaccinated 11-month-old boy, who had spent 45 min in an ED room across the hall from patient 2 at hospital A on 24 February. Fever (temperature, 38.9°C) developed on 4 March, and a maculopapular rash developed on 10 March. He was also examined at a pediatrician’s office on 3 separate occasions while infectious and was not isolated during his first 2 visits.

Patients 5 and 6 were siblings aged 3 and 5 years, respectively, who had not been vaccinated because of parental opposition to vaccination. Both children were exposed to patient 2 while visiting their mother at hospital A on 24 and 25 February. Their fever onsets occurred on 5 March (temperature, 39.5°C) and 6 March (38.9°C), respectively. Rash developed in both patients on 9 March, and both were examined at a pediatrician’s office on 10 March; the pediatrician referred them to a commercial laboratory for blood sample collection. Neither patient was masked or isolated at the pediatrician’s office or at the commercial laboratory.

Patient 7 was a 47-year-old woman with unknown vaccination status, who was exposed to patient 3 on 7 March in an ED room of hospital A. She developed fever (temperature, 38.9°C) on 19 March and presented to the ED experiencing dehydration and hematuria. She was admitted with a diagnosis of acute heat exhaustion and urinary tract infection and discharged the next day with a regimen of antibiotics. Rash developed on 21 March, and the patient was brought in by ambulance to the ED the next day for fever, cough, chills, and a rash. She was admitted to the intensive care unit for pneumonia and was isolated immediately.

Patient 8 was an unvaccinated 1-year-old girl who was exposed to patient 4 in the pediatrician’s office on 10 March while waiting to receive MMR vaccine. Fever (temperature, 38.5°C) developed on 19 March, a generalized maculopapular rash developed on 20 March, and earache developed on 20 March. Medical care was not sought for her symptoms.

Patient 9 was a 41-year-old man with unknown vaccination status, who was exposed at his home to patient 3. Patients 10–14 were presumably exposed in the community because none had visited health care settings in the 3 weeks before the onset of illness and none had contact with any of the 8 patients with health care–associated infections. Patient 10 was an unvaccinated 2-year-old boy who had not received MMR vaccine, representing a missed opportunity for vaccination; he was admitted to the intensive care unit at hospital B for 6 days for febrile seizures. Patients 11 and 12 self-reported having received 1 dose of MMR vaccine, but no documentation was provided. No viruses were identified or sequenced from these patients. Four of the 5 patients with community-acquired infections had accessed health care while infectious, but they were neither masked nor isolated during their health care visits.

A total of 8231 contact investigations were conducted for all 14 patients; 4793 (58.2%) were hospital or clinic patients, 2868 (34.8%) were HCP, and 550 (7.0%) were other contacts. A total of 6470 investigations (78.6%) were attributable to

<table>
<thead>
<tr>
<th>Age</th>
<th>Vaccination status</th>
<th>Measles exposure</th>
<th>Past medical history</th>
<th>Symptoms</th>
<th>Medical care (date)</th>
<th>Clinical diagnosis/ laboratory testing</th>
<th>Isolated (date)</th>
<th>Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37 years</td>
<td>Unvaccinated</td>
<td>Imported</td>
<td>Thalasemia</td>
<td>Fever, cough, coryza, sore throat, myalgia</td>
<td>ED (12 February)</td>
<td>Acute bronchitis</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ED (13 February), admitted (13–18 February)</td>
<td>Acute viral illness, measles; positive IgM and PCR results; D5 genotype</td>
<td>Yes (15 February)</td>
</tr>
<tr>
<td>2</td>
<td>50 years</td>
<td>Unknown</td>
<td>ED</td>
<td>Chronic obstructive pulmonary disease</td>
<td>Fever, shortness of breath, diarrhea, difficulty breathing</td>
<td>ED (24 February), admitted (24–26 February)</td>
<td>Asthma exacerbation</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ED (28 February), admitted (28 February–3 March)</td>
<td>Allergic drug reaction, pneumonia, measles; positive IgM and PCR results, D5 genotype</td>
<td>Yes (28 February)</td>
</tr>
<tr>
<td>3</td>
<td>41 years&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Unknown</td>
<td>Hospital</td>
<td>Asthma</td>
<td>Fever, cough, coryza, conjunctivitis, shortness of breath</td>
<td>ED (7 March)</td>
<td>Upper respiratory infection</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ED (9 March)</td>
<td>Measles; positive IgM and PCR results, D5 genotype</td>
<td>Yes (9 March)</td>
</tr>
<tr>
<td>4</td>
<td>11 months</td>
<td>Unvaccinated</td>
<td>ED</td>
<td>None</td>
<td>Fever, cough, coryza, diarrhea</td>
<td>Pediatrician (7 March)</td>
<td>Otitis media</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pediatrician (10 March)</td>
<td>Upper respiratory infection</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pediatrician (11 March)</td>
<td>Measles; positive IgM and PCR results, D5 genotype</td>
<td>Yes (11 March)</td>
</tr>
<tr>
<td>5</td>
<td>3 years</td>
<td>Unvaccinated</td>
<td>(PBE)</td>
<td>None</td>
<td>Fever, cough, coryza, rash, koplik spots</td>
<td>Pediatrician (10 March)</td>
<td>Measles; positive IgM result, PCR not performed</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>5 years&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Unvaccinated</td>
<td>(PBE)</td>
<td>None</td>
<td>Fever cough, coryza, rash, koplik spots</td>
<td>Pediatrician (10 March)</td>
<td>Measles; positive IgM result, PCR not performed</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>47 years</td>
<td>Unknown</td>
<td>ED</td>
<td>Hypertension, pyelonephritis, cholecystitis</td>
<td>Fever, cough, coryza, conjunctivitis, dehydration</td>
<td>ED (19 March)</td>
<td>Urinary tract infection</td>
<td>No</td>
</tr>
<tr>
<td>Age</td>
<td>Vaccination status</td>
<td>Past medical history</td>
<td>Symptoms</td>
<td>Medical care (date)</td>
<td>Clinical diagnosis/ laboratory testing</td>
<td>Isolated (date)</td>
<td>Contacts</td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td>1 year&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Unvaccinated</td>
<td>Pediatrician</td>
<td>None</td>
<td>Fever, coryza, rash earache, diarrhea</td>
<td>ED (22 March), ICU (22–25 March)</td>
<td>Pneumonia, measles; positive IgM and PCR results, D5 genotype</td>
<td>Yes (24 March)</td>
</tr>
<tr>
<td>9</td>
<td>41 years&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Unknown</td>
<td>Home</td>
<td>Brain cancer</td>
<td>Rash, fever, cough, coryza, conjunctivitis</td>
<td>No</td>
<td>Positive measles IgM result, PCR not performed</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>2 years</td>
<td>Unvaccinated</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Fever, seizures, rash</td>
<td>ED (3 April), ICU (3–8 April)</td>
<td>Generalized complex seizures, measles; positive IgM and PCR results</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>35 years</td>
<td>Unknown (SR)</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Fever, diarrhea, rash, cough, conjunctivitis</td>
<td>No</td>
<td>Positive measles IgM results, PCR not performed</td>
<td>…</td>
</tr>
<tr>
<td>12</td>
<td>37 years</td>
<td>Unknown (SR)</td>
<td>Unknown</td>
<td>MDS, Down syndrome</td>
<td>Rash, fever, cough, coryza, dehydration conjunctivitis, photophobia, diarrhea, sore throat</td>
<td>Oncology (7, 11, and 15 April)</td>
<td>Measles; negative measles IgM and positive PCR results</td>
<td>…</td>
</tr>
<tr>
<td>13</td>
<td>9 months</td>
<td>Unvaccinated</td>
<td>Unknown</td>
<td>None</td>
<td>Fever, coryza, rash earache</td>
<td>ED (3 May)</td>
<td>Otitis media, measles; positive IgM results, PCR not performed</td>
<td>No</td>
</tr>
<tr>
<td>14</td>
<td>8 months</td>
<td>Unvaccinated</td>
<td>Unknown</td>
<td>None</td>
<td>Fever, cough, coryza, rash</td>
<td>Pediatrician (8 May)</td>
<td>Measles; positive IgM results, PCR not performed</td>
<td>No</td>
</tr>
</tbody>
</table>

**NOTE.** ED, emergency department; HCP, health care personnel; HH, household member; IgM, antimeasles immunoglobulin M; MDS, myelodysplastic syndrome; PBE, personal belief exemption; PCR, polymerase chain reaction; SR, self-reported vaccination.

<sup>a</sup> Laboratory testing performed by the Arizona State Public Health Laboratory and/or the Centers for Disease Control and Prevention.

<sup>b</sup> Isolated promptly while infectious with rash and fever.

<sup>c</sup> Same contacts as patient above.

<sup>d</sup> Epidemiologically linked to a confirmed case.
exposures to the index case and 7 patients with confirmed healthcare-associated acquired measles.

HCP Measles Immunization Verification
None of the 7 community hospitals maintained electronic records of the immunity status of their HCP, requiring review of paper records. Of 14,844 HCP employed at the 7 community hospitals, 10,396 (70%) had acceptable evidence of measles immunity. Of 4448 HCP without proof of immunity, 1856 (42%) were born before 1957, and 2592 (58%) were born during or after 1957.

The proportion of HCP with measles immunity documentation at all 7 Tucson hospitals ranged from 58.8% to 85.7%. In hospitals A and B, 5419 (75%) of 7195 screened HCPs had evidence of immunity (Figure 3). Serologic testing was performed for 1583 (89%) of 1776 HCPs without documented immunity; 121 (11%) of 1077 HCPs born during or after 1957, and 18 (4%) of 506 HCPs born before 1957 were seronegative.

Hospital Costs
Approximately 15,120 h were lost in furloughs because of presumptive exposure, disease, or lack of evidence of immunity. Overall estimated economic impact for both hospitals was US$799,136, with HCP furloughs constituting 56% of the cost (Table 3). This represents a mean cost of response and containment of US$105,347 per case at hospital A and US$167,052 for the 1 case at hospital B.

### DISCUSSION
This measles outbreak in Arizona, with 14 confirmed cases, including 7 health care–associated infections, is the largest reported health care–associated measles outbreak in the United States since 1989 [8] and the first to be described in the post-elimination era. All patients were unvaccinated; one-half were infected in health care settings, including 6 in a single hospital. Health care–associated transmission included patient-to-HCP, patient-to-patient, patient-to-visitor, and HCP-to-patient transmission. The outbreak was both costly and disruptive to hospitals and to the state and local health departments. More than one-third of patients were hospitalized, and 2 required intensive care treatment, highlighting the potential severity of measles. Despite thousands of potential exposures, because of the high levels of population immunity (in 2008 in Arizona, coverage with 1 dose MMR vaccine among children aged 19–35

### Table 3. Estimated Costs Associated With Measles Outbreak for Hospitals A and B, Tucson, Arizona, 2008

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of HCP in furloughs for exposure, disease, or lack of measles immunity, h&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14,400</td>
<td>720</td>
<td>15,120</td>
</tr>
<tr>
<td>Time of HCP in records reviews for evidence of immunity, h&lt;sup&gt;b&lt;/sup&gt;</td>
<td>440</td>
<td>1360</td>
<td>1800</td>
</tr>
<tr>
<td>Time of responders in screening HCP, h&lt;sup&gt;c&lt;/sup&gt;</td>
<td>52</td>
<td>212</td>
<td>264</td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titer drawn, no. of kits&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1806</td>
<td>226</td>
<td>2032</td>
</tr>
<tr>
<td>MMR vaccine used, no. of doses</td>
<td>2250</td>
<td>1574</td>
<td>3824</td>
</tr>
<tr>
<td>Estimated costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages and salaries of furloughed HCP, US$&lt;sup&gt;e&lt;/sup&gt;</td>
<td>423,216</td>
<td>21,161</td>
<td>444,377</td>
</tr>
<tr>
<td>Wages and salaries of HCP and responders, US$&lt;sup&gt;f&lt;/sup&gt;</td>
<td>14,460</td>
<td>46,201</td>
<td>60,661</td>
</tr>
<tr>
<td>Cost of measles tests, US$&lt;sup&gt;g&lt;/sup&gt;</td>
<td>63,210</td>
<td>7,910</td>
<td>71,120</td>
</tr>
<tr>
<td>Cost of MMR vaccine doses administered, US$&lt;sup&gt;h&lt;/sup&gt;</td>
<td>131,198</td>
<td>91,780</td>
<td>222,978</td>
</tr>
<tr>
<td>Total costs, US$&lt;sup&gt;i&lt;/sup&gt;</td>
<td>632,084</td>
<td>167,052</td>
<td>799,136</td>
</tr>
</tbody>
</table>

**NOTE.** HCP, health care personnel; MMR, measles, mumps, and rubella vaccine.

<sup>a</sup> Furloughed hours were calculated by multiplying the number HCP furloughed (n = 20 at hospital A; n = 6 at hospital B) by the number of days in furlough (3 × 5/7, to exclude weekends), and a normal work shift (8 h).

<sup>b</sup> Time spent reviewing records was calculated by multiplying a median of 15 minutes per record reviewed (0.25 h) by the number of HCP records reviewed (n = 1757 at hospital A; n = 5438 at hospital B).

<sup>c</sup> Time spent screening HCP was calculated by multiplying a median of 10 minutes (0.167 h) per HCP by the number of screened HCP (n = 313 at hospital A; n = 1270 at hospital B).

<sup>d</sup> Number of test kits or vaccine doses was assumed to be equal to the number of titer drawn and HCP vaccinated, respectively.

<sup>e</sup> Estimated costs of salaries was calculated by multiplying the mean hourly earnings for full-time hospital health care practitioner and technical occupations in Arizona ($29.39) by the number of HCP hours.

<sup>f</sup> Estimated cost of measles tests was calculated by multiplying the average unitary price for a test kit ($35) by the number of test kits used.

<sup>g</sup> Estimated cost of vaccine doses administered was calculated by multiplying the average cost per dose ($48.31) plus a $10 vaccine administration cost by the number of vaccine doses used.

<sup>h</sup> All costs are in 2008 US dollars.
months was 92%, and reported coverage with 2 doses among children entering kindergarten was 96% in public schools and 91% in private schools.) and the highly efficacious MMR vaccine, no cases occurred among vaccinated persons.

This outbreak extends previous work documenting the high cost that hospitals can incur responding to measles in their facilities in the postelimination era [13]. During this outbreak, 2 hospitals spent almost US$800,000 responding to 7 patients with measles. Lack of readily available electronic HCP immunity status led to unnecessary serologic testing and vaccination of HCP who were immune to measles, which was funded largely by the health care facilities. Despite advances in measles control worldwide, in 2007, an estimated 20 million cases of measles occurred globally [4], and measles importations into the United States will continue. Optimal preparedness for measles exposures includes ensuring that all HCP have documented and easily retrievable measles immunity records to guide case management and outbreak response. Failure to implement these recommendations resulted in the continued exposure of non-immune HCP to measles in the hospital, putting them and patients at further risk. A hospital patient infected by an unvaccinated HCP patient required intensive-care management for 4 days. This confirms previous findings that patients exposed in hospital settings might be at increased risk for severe outcomes of measles, given their relatively high prevalence of underlying medical conditions [6]. A measles-related death after health care–associated transmission in a hospital ED was reported elsewhere [14].

This outbreak posed considerable logistical challenges for hospital and health department staff. The outbreak response required rapid review of measles documentation of 14,844 HCP at 7 hospitals and emergency vaccination of ~4500 HCP who lacked documentation of measles immunity. The number of seronegative HCPs identified (n = 138) at 2 hospitals would have been sufficient to sustain a sizeable health care–associated outbreak. Although under routine circumstances, birth before 1957 is considered acceptable presumptive evidence of measles immunity, during a measles outbreak, HCP born before 1957 should receive 2 doses of MMR vaccine or be excluded from work, unless they can demonstrate other evidence of immunity [9]. Because performing rapid serology testing during an outbreak is costly and disruptive, health care facilities should have serologic evidence of immunity available for all HCP to facilitate rapid vaccination response during a measles outbreak.

Health care–associated measles outbreaks after measles importations have been reported from other countries that have interrupted endemic measles transmission. Common risk factors identified include unvaccinated contacts and HCP [15], delayed measles diagnosis, and delayed implementation of infection-control procedures [16, 17]. During this outbreak, the following factors likely contributed to health care–associated transmission. First, none of the 14 patients with confirmed measles had been vaccinated before exposure. Besides 1 infant infected early in the outbreak and a 12-month-old child infected in the pediatrician’s office the day that she received her routine MMR vaccine, 11 US cases were potentially preventable through adherence to US vaccine policy recommendations. Second, patients often accessed health care early during their illness before rash onset, resulting in substantial numbers of exposures to other patients and HCP. Strict adherence to infection-control guidance for persons in health care settings experiencing respiratory symptoms is the only available method to decrease risk for transmission at this stage of the illness [18]. Third, infection-control recommendations were only implemented for 1 of 11 patients who presented after rash onset. To prevent measles transmission in health care including ambulatory settings, all persons with an illness clinically compatible with measles should be immediately isolated in an examination room with a closed door or in a negative–air pressure room if available; and they should wear a size-appropriate mask, if feasible and tolerated, to prevent transmission while in common waiting areas [19]. Fourth, delays occurred in diagnosis and laboratory confirmation of measles. In the post-elimination era, when physicians are less familiar with diagnosing measles, a high index of suspicion is needed especially in persons with history of travel overseas or contact with someone with measles. Health care providers who suspect measles should obtain appropriate specimens for laboratory testing including specimens for viral isolation. Genotype data from this outbreak demonstrate the role of molecular epidemiologic surveillance in linking domestic measles outbreaks with imported measles cases. Health care providers are also reminded that the CDC recommends that negative measles IgM results for serum samples collected within the first 72 hours after rash onset should be confirmed with a second serum obtained 72 hours or longer after rash onset [20]. Laboratory testing results for the index case in this outbreak (IgM negative 4 days after rash onset) highlight that when there is a strong suspicion for measles, repeated testing is prudent even >72 h after rash onset.

The following limitations apply to our findings. Because some measles cases appeared to be community acquired with no demonstrable epidemiological links, it is likely that cases were missed in the community and that the outbreak was larger. HCP measles serologic data analysis was based on information collected at 2 hospitals, corresponding to 48% of all HCPs employed in Tucson during the outbreak, and therefore might not be representative. Birth year was not available for all HCPs, limiting our ability to determine the proportion of all HCPs born before 1957 who were measles seronegative. Our estimated outbreak costs likely underestimated the true cost for hospitals A and B. Data limitations prevented estimation of costs related to IG use, in-house or contracted laboratory work, overtime payments, HCP volunteers furloughed, and other administration or liability costs incurred by the hospitals. Our cost analysis...
was performed from a hospital perspective and did not include costs incurred by the state and local health departments, private and public insurance, and indirect costs borne by the patients and families. Better strategies are needed to ensure compliance with current guidelines to prevent measles transmission in medical settings [3, 5]. Hospitals that are not in compliance risk incurring substantial costs when faced with a measles exposure. Standard guidance for preventing measles transmission in health care settings include (1) increasing measles awareness among providers, especially among persons presenting with fever, rash, and travel history; (2) ensuring all HCP have evidence of measles immunity at the time of employment and have such data electronically available at the work site; (3) allowing only HCP with evidence of measles immunity to provide care to patients with measles [18]; and (4) instituting a screening plan to identify suspected measles cases for immediate isolation during a measles outbreak.

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References