Characteristics of Large Mumps Outbreaks in the United States, July 2010–December 2015

Nakia S. Clemmons,1 Susan B. Redd,1 Paul A. Gastañaduy,1 Mona Marin,1 Manisha Patel,1 and Amy Parker Fiebelkorn2

1Division of Viral Diseases and 2Immunization Services Division, National Center for Immunization and Respiratory Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia

Background. Mumps is an acute viral illness that classically presents with fever and parotitis (inflammation of the salivary glands). However, mumps infection may present only with nonspecific respiratory symptoms or may be a subclinical infection [1]. Mumps complications include orchitis, oophoritis, deafness, aseptic meningitis, and encephalitis [1].

Although the mumps vaccine was licensed in the United States in 1967, it was not until 1977 that the Advisory Committee on Immunization Practices (ACIP) recommended a single dose of mumps-containing vaccine for routine use in children aged ≥12 months, which led to a decrease in reported cases [2]. To improve measles control, a second dose of measles-mumps-rubella (MMR) vaccine was recommended in 1989 for routine use in children 4–6 years of age; this led to further decline in the incidence of mumps [3]. From 1993 to 2005, mumps demonstrated features of elimination in the United States: Vaccination levels (≥90%) were higher than the herd immunity threshold (which has been estimated at 88%–92%), reported incidence was <1 case per million people, there was lack of seasonality, and sustained transmission of mumps seemed to be interrupted, with reported case numbers decreasing annually [4, 5]. However, a resurgence of mumps occurred in subsequent years driven by 2 outbreaks with thousands of cases: One occurred in 2006 throughout several Midwestern jurisdictions, with 6584 reported mumps cases (76% occurring in spring over a 3-month period), primarily associated with 2-dose vaccine failure among college-aged students living in dormitories [6]; the second occurred from June 2009 to June 2010 in the northeastern United States, affecting 3502 individuals, most of whom were members of the Orthodox Jewish community and who had received 2 doses of MMR vaccine [7]. Our objective for this article was to describe the epidemiological characteristics of large mumps outbreaks reported in the United States from July 2010 through December 2015 and factors driving mumps transmission in the United States.

METHODS

Case Definitions and Reporting

We conducted a detailed review of cases sent electronically through the National Notifiable Diseases Surveillance System (NNDSS), and collected supplemental outbreak data through direct communications with jurisdictions on outbreaks and outbreak-associated cases occurring from 1 July 2010 (the month after the large 2009–2010 outbreak in the northeast ended)
through 31 December 2015. For 2 outbreaks that began in 2015 and extended into 2016, we included data only through December 2015. Jurisdictions provided the supplemental outbreak data retrospectively; the request for data was finalized in 2016.

We used the 2012 Council of State and Territorial Epidemiologists case definition for mumps [8]. A confirmed case was defined as a laboratory-confirmed mumps infection (detection of mumps virus via reverse-transcription polymerase chain reaction or culture) and an acute illness characterized by any of the following: acute parotitis or other salivary gland swelling lasting at least 2 days, aseptic meningitis, encephalitis, hearing loss, orchitis, oophoritis, mastitis, or pancreatitis. A probable case was defined as acute parotitis or other salivary gland swelling lasting at least 2 days or orchitis or oophoritis unexplained by another more likely diagnosis, and (1) a positive test for serum anti-mumps immunoglobulin M antibody, or (2) epidemiologic linkage to another probable or confirmed case or linkage to an affected group/community defined by public health during an outbreak of mumps [8]. Cases meeting the criteria for confirmed or probable were included in the analysis. Although mumps outbreaks are defined as ≥3 cases related by time or space, we focused on large mumps outbreaks (defined as ≥20 cases) for this report. The outbreak cutoff of 20 cases was established based on the distribution of reported outbreak cases sent to the Centers for Disease Control and Prevention (CDC) by state and local health departments; most outbreaks reported were either in the single digits or ≥20 cases. We chose to describe outbreaks with ≥20 cases as they occurred relatively frequently during the study period and provided enough cases to understand transmission patterns and the epidemiologic characteristics. Documentation of mumps outbreaks is critical to monitoring the evolution of mumps epidemiology in the United States.

Vaccination Status
Health departments obtained vaccination histories of case-patients from healthcare providers, immunization registries, or personal vaccine cards. Case-patients verified as being unvaccinated and those with unknown vaccination status were classified together as unknown/unvaccinated, as both groups would be considered to lack presumptive immunity, and other evidence to determine presumptive immunity [9] was unavailable for this analysis. A population was considered highly vaccinated if ≥85% of case-patients had received ≥2 doses of MMR vaccine at the appropriate intervals.

Transmission Setting
Transmission settings were characterized into 3 groups: close contact-only, community-only, and close-contact with community involvement. In a close-contact-only setting, there was a common focus of transmission, with opportunity for intimate sharing of air space or saliva (eg, case-patients were on the same sports team, living in the same dormitory). Many close-contact outbreaks occurred in university settings, which could include institutions offering 2- or 4-year postsecondary degrees or technical diplomas. In a community-only setting, there was not a common focus of transmission, but there was opportunity for person-to-person exposure (eg, case-patients were from the same city). In outbreaks of close-contact settings with community involvement, some case-patients were infected in close-contact settings and other case-patients were infected in community settings. The direction of spread (ie, outbreaks that started in a close-contact setting and spread into the community, or alternatively, outbreaks that started in the community and spread into close-contact settings) was not always known.

Outbreak Vaccination Campaigns
Outbreak vaccination campaigns were classified as either catch-up, outbreak dose, or third-dose campaigns. We defined catch-up campaigns as those in which MMR vaccinations were administered to unvaccinated or undervaccinated individuals (ie, individuals with 0 MMR doses were given their first dose and individuals with 1 dose, who were eligible for another dose, were given their second dose); outbreak dose campaigns as those in which vaccination status was not assessed on an individual basis prior to vaccine administration; and third-dose campaigns as those in which vaccination status of each individual was assessed prior to vaccine administration and those with 2 doses of MMR were given a third dose.

Statistical Analyses
We performed descriptive analyses of large mumps outbreaks (≥20 cases), including outbreak size, duration, and setting, as well as demographic characteristics and vaccination status of case-patients.

RESULTS
Outbreak Characteristics
From 1 July 2010 through 31 December 2015, 23 mumps outbreaks with ≥20 cases (median, 39 cases [range, 20–485 cases]) were reported in 18 of 52 US jurisdictions (Tables 1 and 2). The median duration of the 23 outbreaks was 3 months (range, 1.5–8.5 months).

All of the reported outbreaks contained some close-contact involvement and included prisons, jails, universities, a high school, a professional sports league, and a bar. Outbreaks on university campuses were the most common and accounted for 18 of the 23 outbreaks (78%). Eighteen outbreaks (78%) were classified as close-contact-only settings and stayed contained within the affected setting (eg, university, professional sports league) with minimal spread to the outside community. One university outbreak (in Iowa), in which cases were reported in the surrounding community but for which an epidemiological link to the cases in the university could not be ascertained, was
Table 1. Characteristics of Large Close-contact Mumps Outbreaks (≥20 Cases) Reported in the United States, 1 July 2010–31 December 2015

<table>
<thead>
<tr>
<th>Total No. of Cases</th>
<th>Year(s)</th>
<th>Jurisdiction(s)</th>
<th>Outbreak Duration, mo</th>
<th>Setting</th>
<th>Age Group Mainly Affected</th>
<th>Median Age, y</th>
<th>Age Range, y</th>
<th>Documented Vaccination Status, No. (%)</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>235</td>
<td>2015</td>
<td>IA</td>
<td>5</td>
<td>University</td>
<td>Young adults</td>
<td>21</td>
<td>3–69</td>
<td>230 (98) ≥2 doses; 3 (1) = 1 dose; 2 (1) = 0 doses</td>
<td>SOCM; 6 third-dose vaccination clinics: 4700 doses administered</td>
</tr>
<tr>
<td>211</td>
<td>2015</td>
<td>IL 1b</td>
<td>8</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>16–53</td>
<td>188 (89) ≥2 doses; 9 (4) = 1 dose; 14 (7) = 0 doses/unk</td>
<td>SOCM</td>
</tr>
<tr>
<td>80</td>
<td>2013</td>
<td>MD</td>
<td>3</td>
<td>University</td>
<td>Young adults</td>
<td>21</td>
<td>18–54</td>
<td>80 (100) ≥2 doses</td>
<td>SOCM; third-dose vaccine clinics: 185 students vaccinated</td>
</tr>
<tr>
<td>73</td>
<td>2013</td>
<td>VA (72), MA (1)</td>
<td>2.5</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>unk</td>
<td>67 (92) ≥2 doses; 3 (4) = 1 dose; 3 (3) = 0 doses/unk</td>
<td>SOCM; third-dose vaccine clinics: 250 students, 191 faculty/staff vaccinated</td>
</tr>
<tr>
<td>59</td>
<td>2014</td>
<td>NYC (56), PA (2), NYS (1)</td>
<td>3.5</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–37</td>
<td>33 (56) ≥2 doses; 22 (37) = 1 dose; 4 (6) = 0 doses/unk</td>
<td>SOCM</td>
</tr>
<tr>
<td>41</td>
<td>2015</td>
<td>WI</td>
<td>5</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–27</td>
<td>24 (58) ≥2 doses; 2 (5) = 1 dose; 15 (37) = 0 doses/unk</td>
<td>SOCM</td>
</tr>
<tr>
<td>39</td>
<td>2013</td>
<td>MA</td>
<td>2</td>
<td>University</td>
<td>Young adults</td>
<td>19</td>
<td>18–41</td>
<td>39 (100) ≥2 doses</td>
<td>SOCM</td>
</tr>
<tr>
<td>38</td>
<td>2015</td>
<td>IL 3b</td>
<td>4</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–30</td>
<td>35 (92) ≥2 doses; 1 (3) = 1 dose; 2 (5) = 0 doses/unk</td>
<td>SOCM; third-dose recommendation for football team</td>
</tr>
<tr>
<td>36</td>
<td>2014</td>
<td>ID (34), WA (2)</td>
<td>4.5</td>
<td>University</td>
<td>Young adults</td>
<td>22</td>
<td>8–41</td>
<td>9 (25) ≥2 doses; 5 (14) = 1 dose; 22 (61) = 0 doses/unk</td>
<td>SOCM; press releases, physician alerts, Epi-X notifications, provision of sampling kits, in-person visits with providers and school officials</td>
</tr>
<tr>
<td>35</td>
<td>2011</td>
<td>IL</td>
<td>4</td>
<td>University</td>
<td>Young adults</td>
<td>19</td>
<td>17–53</td>
<td>31 (91) ≥2 doses; 0 = 1 dose; 3 = 0 doses/unk</td>
<td>SOCM</td>
</tr>
<tr>
<td>34</td>
<td>2010–2011</td>
<td>TX</td>
<td>3</td>
<td>Jail/prison (2 facilities)</td>
<td>Adults</td>
<td>32</td>
<td>20–57</td>
<td>NA</td>
<td>SOCM; outbreak dose: 1100 doses administered</td>
</tr>
<tr>
<td>34</td>
<td>2014–2015</td>
<td>AZ (1), CA (6), CT (1), MN (7), NJ (3), NYC (3), PA (10), TN (11), VA (2)</td>
<td>3</td>
<td>Professional sports league</td>
<td>Adults</td>
<td>unk</td>
<td>unk</td>
<td>16 (47) = 2 doses; 4 (11) = 1 dose; 14 (41) = 0 doses/unk</td>
<td>SOCM; advisories sent to team physicians, team members stopped visits to hospitals and outreach programs</td>
</tr>
<tr>
<td>30</td>
<td>2010</td>
<td>TX</td>
<td>3.5</td>
<td>Jail/prison (2 facilities)</td>
<td>Adults</td>
<td>30</td>
<td>18–47</td>
<td>NA</td>
<td>SOCM</td>
</tr>
<tr>
<td>29</td>
<td>2011</td>
<td>CA</td>
<td>2.5</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–60</td>
<td>22 (76) = 2 doses; 7 (24) = unk</td>
<td>3600 doses given during 5 clinics</td>
</tr>
<tr>
<td>27</td>
<td>2014</td>
<td>WI</td>
<td>3</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–27</td>
<td>22 (81) ≥2 doses; 0 (0) = 1 dose; 5 (19) = 0 doses</td>
<td>SOCM</td>
</tr>
<tr>
<td>21</td>
<td>2015</td>
<td>VA</td>
<td>&gt;3</td>
<td>University</td>
<td>Young adults</td>
<td>20.5</td>
<td>19–44</td>
<td>21 (100) ≥2 doses</td>
<td>SOCM; memo to local providers</td>
</tr>
<tr>
<td>20</td>
<td>2013</td>
<td>VA</td>
<td>&lt;2</td>
<td>University</td>
<td>Young adults</td>
<td>20.5</td>
<td>19–22</td>
<td>16 (80) = 2 doses; 1- and 0-dose percentages unavailable</td>
<td>SOCM</td>
</tr>
<tr>
<td>20</td>
<td>2014</td>
<td>NJ (15), NYC (5)</td>
<td>1.5</td>
<td>University</td>
<td>Young adults</td>
<td>20</td>
<td>18–23</td>
<td>18 (90) = 2 doses; 1- and 0-dose percentages unavailable</td>
<td>SOCM</td>
</tr>
</tbody>
</table>

Definition of close-contact outbreaks: Cases have a common focus of transmission, with opportunity for intimate sharing of air space or saliva (e.g., case-patients were on the same sports team or living in the same dormitory). Standard outbreak control measures include isolation of ill persons, exclusion of susceptible persons (exclusion practices may have varied by jurisdiction), age- and occupation-appropriate vaccinations, and notification to those possibly exposed and susceptible.

Abbreviations: AZ, Arizona; CA, California; CT, Connecticut; IA, Iowa; IL, 1,2,3; Interleukin-1,2,3; ID, Idaho; IL, Illinois; MA, Massachusetts; MD, Maryland; MN, Minnesota; NA, not available; NJ, New Jersey; NYC, New York City; NYS, New York State; OH, Ohio; PA, Pennsylvania; SOCM, standard outbreak control measures; TN, Tennessee; TX, Texas; unk, unknown; VA, Virginia; WA, Washington; W, Wisconsin.

If an outbreak occurred in >1 state, we noted the number of cases reported by that state in parentheses.

Three separate outbreaks occurred in Illinois during 2015 and are labeled as IL 1, IL 2, and IL 3.

Outbreak continued into 2016; data in this table only include cases reported as of 31 December 2015 due to the time frame used for analysis.

Although there were media reports of cases in Missouri, no cases were ever officially reported to the Centers for Disease Control and Prevention from the state, and therefore none were included in this report.
classified as a close-contact-only outbreak for this report; community cases from this outbreak were not included in this analysis but have been described in a different publication [10]. The remaining 5 outbreaks (22%) were considered to be close-contact with community involvement. These outbreaks had substantial transmission within the surrounding communities due to considerable mixing between individuals within and outside of the close-contact setting. None of the outbreaks had community-only transmission.

The 23 outbreaks included 1791 of the 4289 (42%) total mumps cases that were reported to the CDC via NNDSS during the analysis period (Figure 1). The overall median age of case-patients in these outbreaks was 23 years (range, 11 months–80 years); 16 outbreaks (70%) primarily affected young adults, with these outbreaks having a median age range of 18–24 years. Among the 1791 case-patients, 1225 (68%) were vaccinated, of whom 1113 (91%) had received at least 2 documented doses of MMR vaccine, and 566 (32%) were unvaccinated or had unknown vaccination status.

Fifteen of 18 close-contact-only outbreaks (83%) were among young adults (ie, each outbreak had a median between 18 and 24 years of age), and 9 of 18 (50%) occurred in populations that met criteria for being highly vaccinated. The 5 outbreaks classified as close-contact with community involvement had a slightly wider range of median ages (17–31 years) compared with those which were close-contact-only, and none met the highly vaccinated population criteria. The proportion of case-patients who had received 2 doses of MMR vaccine was also lower in outbreaks with community involvement (42% [range, 28%–74%]) compared with those that were close-contact only (82% [range, 25%–100%]). None of these apparent differences between the 18 close-contact-only outbreaks and the 5 outbreaks that had close-contact with community involvement were statistically significant.

**Outbreak Control Measures**

Standard intervention measures were implemented during the outbreaks in all affected jurisdictions, including isolation of case-patients, exclusion of susceptible individuals who did not have evidence of immunity (exclusion practices may have varied by jurisdiction), age- and occupation-appropriate vaccinations, and notification to those possibly exposed and susceptible. The direction of spread (ie, outbreaks that started in a close-contact setting and spread into the community, or alternatively, outbreaks that started in the community and spread into close-contact settings) was not always known. Standard outbreak control measures include isolation of ill persons, exclusion of susceptible persons (exclusion practices may have varied by jurisdiction), age- and occupation-appropriate vaccinations, and notification to those possibly exposed and susceptible.

**DISCUSSION**

Following historically low mumps incidence in the United States during much of the 1990s and early 2000s, numerous large mumps outbreaks occurred in the United States over the

### Table 2. Characteristics of Large Close-Contact With Community Involvement Mumps Outbreaks (≥20 Cases) Reported in the United States, 1 July 2010–31 December 2015

<table>
<thead>
<tr>
<th>Total No. Cases</th>
<th>Year</th>
<th>Jurisdiction(s)*</th>
<th>Outbreak Duration, mo</th>
<th>Setting</th>
<th>Age Group Mainly Affected</th>
<th>Age, y</th>
<th>Documented Vaccination Status, (%)</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>485</td>
<td>2014</td>
<td>OH</td>
<td>8.5</td>
<td>University/ community</td>
<td>Young adults</td>
<td>23</td>
<td>&lt;1–80</td>
<td>147 (30) ≥2 doses; 54 (11) = 1 dose; 284 (59) = 0 doses/unk</td>
</tr>
<tr>
<td>71</td>
<td>2015</td>
<td>IL</td>
<td>3</td>
<td>Universities, high schools, community</td>
<td>Teens &amp; young adults</td>
<td>17</td>
<td>14–55</td>
<td>53 (78) ≥2 doses; 0 = 1 dose; 18 (25) = 0 doses/unk</td>
</tr>
<tr>
<td>62</td>
<td>2014</td>
<td>IL</td>
<td>&lt;4</td>
<td>University/ community</td>
<td>Adults</td>
<td>28.5</td>
<td>9–59</td>
<td>27 (44) ≥2 doses; 5 (8) = 1 dose; 18 (39) = 0 doses/unk</td>
</tr>
<tr>
<td>57</td>
<td>2013</td>
<td>NJ (53), NYC (2), MA (1)</td>
<td>2 Bar/community</td>
<td>Adults</td>
<td>28</td>
<td>16–57</td>
<td>17 (30) ≥2 doses; 2 (4) = 1 dose; 38 (66) = 0 doses/unk</td>
<td>SOCM; press release, Ep-x notification</td>
</tr>
<tr>
<td>54</td>
<td>2015</td>
<td>NYC (52), NYS (2)</td>
<td>4.5 Neighborhood/ community</td>
<td>Adults</td>
<td>31</td>
<td>4–69</td>
<td>18 (33) ≥2 doses; 1 (2) = 1 dose; 35 (65) = 0 doses/unk</td>
<td>SOCM; letter to providers, target communications via Facebook</td>
</tr>
</tbody>
</table>

*Definition of close-contact with community involvement mumps outbreaks: Some case-patients were infected in close-contact settings and other case-patients were infected in community settings. The direction of spread (ie, outbreaks that started in a close-contact setting and spread into the community, or alternatively, outbreaks that started in the community and spread into close-contact settings) was not always known. Standard outbreak control measures include isolation of ill persons, exclusion of susceptible persons (exclusion practices may have varied by jurisdiction), age- and occupation-appropriate vaccinations, and notification to those possibly exposed and susceptible.

*Abbreviations: IL-1,2,3, Interleukin-1,2,3; IL, Illinois; MA, Massachusetts; NJ, New Jersey; NYC, New York City; NYS, New York State; OH, Ohio; SOCM, standard outbreak control measures; unk, unknown. 

*aIf an outbreak was in >1 state, we noted the number of cases reported by that state.

*bThree separate outbreaks occurred in IL during 2015 and are labeled as IL-1, IL-2, and IL-3.
Mumps Outbreaks in the United States

Last decade. Since 2006, reported outbreaks have generally been confined to settings of intense exposure and have occurred primarily among young adults who have received 2 doses of MMR vaccine. These key features raise important questions about the effectiveness of the mumps component of the MMR vaccine, the duration of mumps vaccine–induced immunity, and transmissibility of mumps in highly vaccinated populations, including the role of infected persons with nonspecific respiratory symptoms or who are asymptomatic.

The Jeryl Lynn mumps component of the MMR vaccine is less effective than the measles and rubella components, with a 1- and 2-dose effectiveness against mumps of approximately 78% (range, 49%–91%) and 88% (range, 31%–95%), respectively [9, 13]. This implies that despite high national MMR vaccination coverage (92% 1-dose coverage among children aged 19–35 months and 91% 2-dose coverage among adolescents) [14, 15], the vaccine may not be effective enough to maintain herd immunity in densely populated settings, allowing for transmission of mumps and propagation of outbreaks. Nonetheless, high MMR vaccination coverage has been decidedly effective against mumps in the general population and has been the primary catalyst for disease reduction in the United States since introduction of the vaccination program [5]. Additionally, the current US mumps outbreaks are orders of magnitude smaller than outbreaks that occur in countries without or with lower 2-dose coverage [16]. However, like the United States, countries with high 2-dose coverage have reported mumps outbreaks with similar characteristics—cases primarily among fully vaccinated young adults in close-contact settings—suggesting common risk factors as in the United States [17]. Direct comparison of rates of disease between countries is limited by differences in case definition, vaccination policies, and surveillance systems and techniques [18].

The epidemiology of mumps in the United States has shifted from a childhood disease in the prevaccine era to one that predominantly affects 2-dose vaccinated young adults [19–21], suggesting that waning immunity to the mumps component of the MMR vaccine may be a contributing factor to current outbreaks. Lack of natural mumps boosting in a setting with low background incidence of mumps may intensify waning immunity in the population. A few studies have shown an association between both vaccine failure [12, 16, 19, 22–25] and decreased levels of antibodies against mumps with increasing time since MMR vaccination [26–28]. However, the threshold of antibodies needed to confer protection is unknown, as a correlate of mumps immunity has not been established [29]. Furthermore, genotype G has been the primary cause of outbreaks in the United States since establishment of molecular surveillance in 2006. Although studies have demonstrated that sera from persons vaccinated with the Jeryl Lynn strain, which is genotype A, fully neutralize genotype G strain 6 weeks and 10 years after vaccination with 2 doses of MMR, it is possible that differential immune responses between vaccine and nonvaccine strains may become more clinically significant with time since vaccination [30].

Waning of immunity may not fully explain the recent surge in mumps incidence. It is important to note that recent outbreaks have occurred and flourished in close-contact or crowded settings, without substantial transmission into the broader community, indicating that force of infection in these settings may
overcome protection offered by the vaccine. This phenomenon is supported by increased outbreaks in crowded settings despite high vaccination coverage (due to ecologic factors, such as sharing of air space and behaviors fostering sharing of oral secretions), compared with community-involved outbreaks in which these factors may not be as intense and thus transmission may largely be driven by lack of vaccination. Understanding mumps transmission is further complicated by the fact that transmission from persons with asymptomatic infection may occur (based on isolation of mumps virus from saliva of persons with asymptomatic infections) [31–34]. These factors warrant the need for enhanced mumps surveillance and continued assessment of risk factors for mumps transmission and disease in outbreak settings.

Offering an outbreak dose of MMR vaccine has been part of the containment strategy during several outbreaks, but limited data are available regarding the effectiveness of a third dose in mitigating the size and duration of outbreaks when given as an outbreak control measure to persons previously vaccinated with 2 doses. Although vaccine effectiveness was not evaluated in the 2 outbreaks in 2013 (Maryland and Virginia) when a third-dose campaign was implemented, vaccine effectiveness of a third MMR dose was studied in the 2015 Iowa outbreak and in 2 outbreaks in 2009–2010. In Iowa, students who had received a third dose of MMR had a 78% lower risk of mumps than those who had previously received 2 doses [12]. Similarly, in 2010, a lower attack rate among 3-dose vaccine recipients than among 2-dose recipients and a reduction in the incidence of mumps following intervention was observed in 2 outbreaks [35, 36]. However, the decline in cases could not be directly attributed to the third-dose vaccination: in one study the findings were not statistically significant, and in both studies, the intervention was implemented late in the course of the outbreak when incidence may have already been on the decline [35, 36].

There were many challenges in responding to mumps outbreaks. Laboratory diagnostics are known to be difficult in vaccinated populations and may result in false-positive or false-negative results [37]. In outbreaks in close-contact settings, most students lived in dormitories and frequently mixed in numerous other settings such as common dining halls, classrooms, and social events. Physical layouts of college campuses and behavioral patterns of students often made implementation and maintenance of isolation and quarantine measures difficult in university settings. Frequently, no foci of transmission were identified, which made targeted interventions impossible. With tens of thousands of students attending some of the affected universities, campus-wide vaccination campaigns were resource-intensive to perform. In community-involved outbreaks, when vaccine catch-up campaigns were implemented but vaccination status was not documented, it was not feasible to determine impact. With no foci of transmission and the wide age distribution of case-patients, targeted interventions could not be implemented. Additionally, as cases in some of the community-involved outbreaks became more sporadic and widely distributed in time and place, determining the end of the outbreak became a challenge. It was difficult to determine whether new cases were outbreak-related or if they were sporadic cases that were only identified as a result of heightened awareness.

Our manuscript addresses a knowledge gap regarding the epidemiology of mumps in the United States by highlighting that multiple outbreaks of ≥20 cases were occurring frequently during 2010–2015, the common characteristics of these outbreaks, and that the number of outbreaks gradually increased annually. Prior to this article, a literature search would have suggested that only very infrequent (n = 5), very large outbreaks with hundreds of cases occurred during this time.

Limitations must be considered when describing mumps outbreaks from a national perspective. Although individual cases of mumps are nationally notifiable through NNDSS [8], it is often not possible to determine which cases are part of a specific outbreak within this surveillance system. Furthermore, some outbreaks may not have been recognized and, therefore, not reported to state/local health departments. Detailed data on mumps case-patients and outbreaks with which those cases may have been associated may not always be routinely collected, leaving potential gaps in our understanding of the epidemiology of the outbreak(s). Because only aggregate outbreak data were reported to the CDC, we could not assess the age at vaccination in our study; nonetheless, previous college outbreak investigations found that the majority of students received their second MMR dose during childhood [12, 38, 39].

In October 2017, after reviewing the available evidence on burden of disease, effectiveness, and safety of a third dose of MMR, ACIP recommended a third dose of a mumps virus–containing vaccine (ie, MMR or measles-mumps-rubella-varicella vaccine, an option for children aged ≤12 years) for persons previously vaccinated with 2 doses who are identified by public health authorities as being part of a group or population at increased risk for acquiring mumps because of an outbreak [13]. The purpose of the recommendation is to improve protection of persons against mumps and its complications during an ongoing outbreak. Further studies are needed to better characterize the impact of a third dose on reducing the size or duration of an outbreak.

Our review of recent mumps outbreaks in the United States emphasizes the importance of national, high 2-dose MMR vaccine coverage throughout the population; recent outbreaks generally had limited spread, unless factors such as prolonged close-contact among a large group of people continually occurred. Young adults previously vaccinated with MMR vaccine during childhood are at highest risk, suggesting that waning immunity plays a role. Evaluation of risk factors for mumps outbreaks and policy options to control them are warranted. A third dose of MMR vaccine is now available to improve protection of individuals at high risk for mumps in outbreak settings.
Notes

Acknowledgments. The authors thank Paul Rota, Carole Hickman, Don Latner, and Rebecca McNall from the Centers for Disease Control and Prevention (CDC). Mumps Laboratory Team for their guidance and help, and CDC editor Mary Ann Hall. They also thank the individuals at state health departments who collected and compiled the data used for this article: Jennifer Zipprich, California Department of Public Health; Kris Carter, Idaho Department of Health and Welfare; Heather Reid, Illinois Department of Public Health; Jake Riley and Patricia Quinlisk, Johnson County and Iowa Departments of Public Health; Kurt Seetoo, Maryland Department of Health and Mental Hygiene; Stephen Fleming, Massachusetts Department of Public Health; Rachel Wiseman, Texas Department of State Health Services; Elizabeth Zaremski, New Jersey Department of Health; Jennifer Rosen, New York City Department of Health and Mental Hygiene; Jeremy Budd, Ohio Department of Health; Sandra Sommer, Virginia Department of Health; and Stephanie Schauer, Wisconsin Department of Health and Family Services.

Disclaimer. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC.

Potential conflicts of interest. All authors: No reported conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

References