

# Mumps in a highly vaccinated Marshallese community in Arkansas, USA: an outbreak report



Virgie S Fields, Haytham Safi, Catherine Waters, Jennifer Dillaha, Lucy Capelle, Sheldon Riklon, J Gary Wheeler, Dirk T Haselow

## Summary

**Background** During 2000–15, Arkansas Department of Health, Little Rock, AR, USA, investigated between one and six cases of mumps each year. From Aug 5, 2016, to Aug 5, 2017, the department received notification of more than 4000 suspected mumps cases in the second largest outbreak in the USA in the past 30 years.

**Methods** Arkansas Department of Health investigated all reported cases of mumps to ascertain exposure, travel, and vaccination histories and identify close contacts. Cases were classified as confirmed if the patient had laboratory confirmation of mumps virus or probable if they had clinical symptoms and either a positive serological test or a known epidemiological link to a confirmed case.

**Findings** 2954 cases of mumps related to the outbreak were identified during the outbreak period: 1665 (56%) were laboratory confirmed, 1676 (57%) were in children aged 5–17 years, and 1692 (57%) were in Marshallese people. Among the 1676 school-aged cases, 1536 (92%) had previously received at least two doses of a vaccine containing the mumps virus. Although 19 cases of orchitis were reported, severe complications were not identified. Unusual occurrences, such as recurrent parotitis and prolonged viral shedding, were observed mostly in Marshallese individuals. Viral samples were characterised as genotype G.

**Interpretation** This large-scale outbreak, primarily affecting a marginalised community with intense household crowding, highlights the need for coordinated, interdisciplinary, and non-traditional outbreak responses. This outbreak raises questions about mumps vaccine effectiveness and potential waning immunity.

**Funding** Council of State and Territorial Epidemiologists and US Centers for Disease Control and Prevention.

**Copyright** © 2019 Elsevier Ltd. All rights reserved.

## Introduction

Mumps is an acute viral infection that is spread by respiratory droplets. Parotitis occurs in 30–40% of infected people.<sup>1–3</sup> Myalgia, malaise, fever, and headache can also occur.<sup>4</sup> Serious complications, such as orchitis, oophoritis, meningitis, encephalitis, and deafness, were common in the pre-vaccine era but are now rare.<sup>5</sup> The incubation period ranges from 12–25 days, but parotitis typically develops 16–18 days after mumps exposure.<sup>4</sup>

In the USA, the incidence of mumps decreased by 99% after the introduction of vaccination in 1967,<sup>5,6</sup> but outbreaks still occasionally occur. In 2006, a resurgence of mumps in the USA was observed primarily among college students (aged 18–22 years) with high coverage of two-dose measles, mumps, and rubella (MMR) vaccination.<sup>7–9</sup> Since then, outbreaks in settings with high vaccination coverage have been reported, primarily among young adults, nationally and globally.<sup>10–14</sup>

Between 1946 and 1958, the USA tested 67 nuclear weapons in the northern Marshall Islands, with a cumulative nuclear yield that was 7200 times more powerful than the atomic weapons used in World War 2.<sup>15</sup> An international agreement with the USA, the Compact of Free Association, was signed in 1986 to settle all claims arising from the nuclear testing. The Compact of Free Association allows Marshallese people

to freely travel to the USA as migrants, requiring a passport but not visas or immigration health screening; however, they are not offered full rights of US citizenship.<sup>15</sup>

Marshallese people have been migrating to the USA since the 1980s in increasing numbers to work (primarily in the poultry industry), educate their children, and seek new opportunities.<sup>16</sup> This increasing migration has been driven by rising tides from climate change, which are predicted to make the Marshall Islands uninhabitable in the next 20–30 years.<sup>17</sup> Springdale, Arkansas, hosts the largest population of Marshallese people in continental USA, likely 8000–14000 inhabitants.<sup>16</sup>

Marshallese culture has been characterised as very close-knit, community-oriented, matriarchal, and matrilineal. Marshallese people traditionally live in densely populated accommodation, often with 12–20 people in a three-bedroom house. They have some of the highest rates of infectious and chronic diseases in the world, including tuberculosis, leprosy, invasive pneumococcal disease, perinatal hepatitis B infection, syphilis, and diabetes.<sup>15,18</sup> Some Marshallese people and medical providers have expressed concern that there might be long-lasting health effects from the nuclear testing. Marshallese adults often maintain a strong belief in traditional healers and distrust in western medicine.

*Lancet Infect Dis* 2019; 19: 185–92

Published Online

January 8, 2019  
[http://dx.doi.org/10.1016/S1473-3099\(18\)30607-8](http://dx.doi.org/10.1016/S1473-3099(18)30607-8)

See [Comment](#) page 119

Arkansas Department of Health, Little Rock, AR, USA (V S Fields MS, H Safi MD, C Waters RN, J Dillaha MD, Prof J G Wheeler MD, D T Haselow MD); Council of State and Territorial Epidemiologists Applied Epidemiology Fellowship, Atlanta, GA, USA (V S Fields); Arkansas Coalition of Marshallese, Springdale, AR, USA (L Capelle); and University of Arkansas for Medical Sciences Northwest Campus, Fayetteville, AR, USA (Prof S Riklon MD)

Correspondence to:

Dr Dirk T Haselow, Arkansas Department of Health, Little Rock, AR 72205, USA  
[dirk.haselow@arkansas.gov](mailto:dirk.haselow@arkansas.gov)

### Research in context

#### Evidence before this study

We initially searched PubMed without language restrictions up to Aug 6, 2018, using the search terms “mumps outbreak” and “Marshallese”, and did not identify any relevant studies. We then repeated the search using the terms “mumps outbreak” and “highly vaccinated” and identified numerous studies describing mumps outbreaks among various highly vaccinated populations, including studies that had also assessed the effectiveness of a third dose of measles–mumps–rubella (MMR) vaccine. Most studies described outbreaks among highly vaccinated college-aged populations. In one study, Nelson and colleagues described a mumps outbreak in a highly vaccinated island population, which had similar characteristics to our outbreak and had also been controlled with a third dose of MMR vaccine. They concluded that high household crowding indices and high student contact rates were the major contributors to the intensity and persistence of the outbreak.

#### Added value of this study

We describe the second largest outbreak of mumps in the USA in the past 30 years. The majority of affected individuals were

Marshallese. More cases were identified among school-aged children than among college-aged students. Despite the large number of cases, the proportion of patients who reported complications was low. We also observed unusual outcomes, including recurrent parotitis and prolonged viral shedding, both of which have not been greatly studied. To control the outbreak, we used unique response strategies in terms of communication, partnership, and vaccine clinics, including distributing outbreak doses of MMR vaccine in school settings that met Centers for Disease Control and Prevention criteria for a third-dose clinic.

#### Implications of all the available evidence

Multiple outbreaks with mumps genotype G, including this one, bring into question whether current vaccine effectiveness might be lower for genotype G than for other genotypes or that waning immunity has a part in mumps resurgence. This outbreak highlighted the need for response strategies tailored to the affected populations and consideration of social, cultural, and political factors in controlling transmission.

Illness is often stigmatised and seen as a sign of weakness or divine punishment.<sup>18</sup> Individuals routinely present late in the natural history of disease after traditional healing interventions have failed. In Arkansas, Marshallese people are ineligible for health insurance coverage through Medicaid or Medicare, so care is often sought in an emergency department at high cost and with little emphasis on continuity of primary care.<sup>19</sup> Marshallese adults in Arkansas typically speak Marshallese and interpreter services are extremely limited. Health literacy among Marshallese adults is generally below basic.<sup>20</sup> These issues, in conjunction with a pervasive distrust of the US Government, a lack of familiarity with the US health system, and poverty, lead to a situation wherein the opportunity for, and consequences of, disease spread are high.

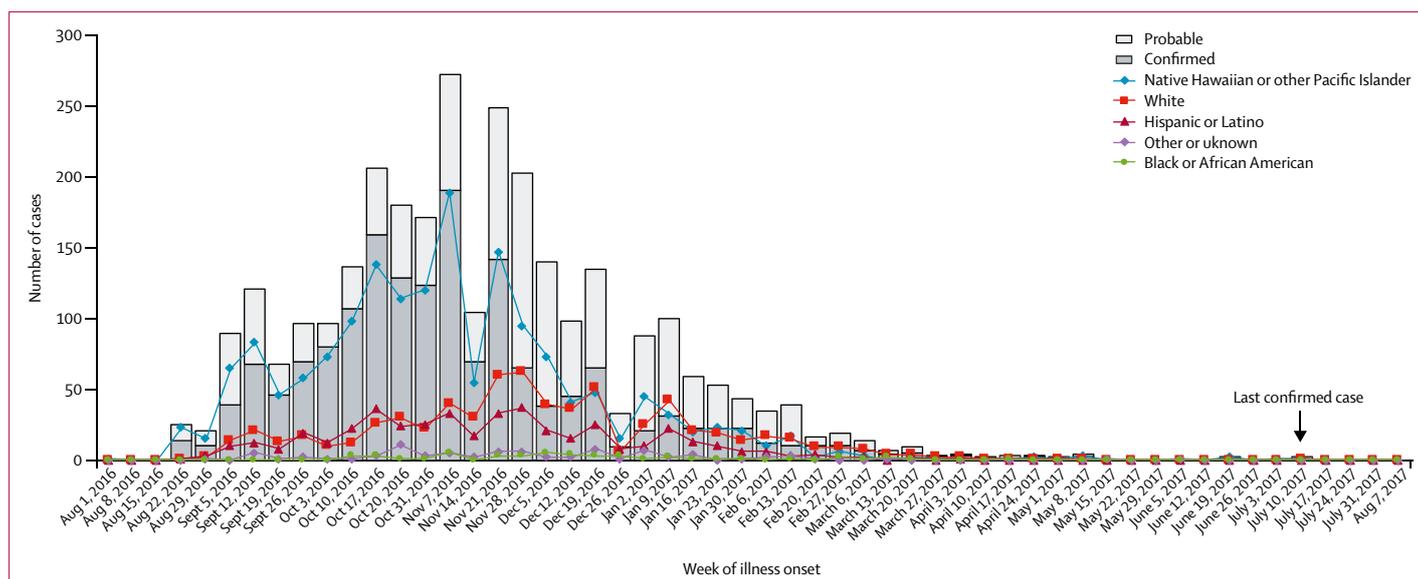
From 2000 to 2015, Arkansas Department of Health, Little Rock, AR, USA, investigated one to six cases of mumps each year; none were in Marshallese people. On Aug 8, 2016, the department received notification that a Marshallese adult residing in Springdale, Arkansas, had developed parotitis 3 days earlier and was confirmed to have mumps. A rapid increase in case counts prompted them to request assistance from the US Centers for Disease Control and Prevention (CDC) on Sept 2, 2016. The outbreak quickly spread in the Springdale community and expanded into the larger northwest Arkansas community, peaking in November, 2016. By August, 2017, incidence rates had decreased to zero. Here, we describe the epidemiology of this outbreak from Aug 5, 2016, to Aug 5, 2017.

## Methods

### Case identification and investigation

Mumps is a mandatory reportable disease in Arkansas. Cases were classified, according to definitions of the Council of State and Territorial Epidemiologists (CSTE), as confirmed if mumps genetic material was detected with real-time RT-PCR or the mumps virus was isolated, or probable if the patient had clinical symptoms and either a positive IgM or immunofluorescence test or a known epidemiological link to a confirmed case.<sup>21</sup> Individuals who were not tested or tested negative and did not have an epidemiological link to a confirmed case were classified as non-cases, even if they had parotitis.

Cases that were clinically compatible with mumps were reported by health-care providers and school nurses. Additionally, clinical laboratories reported any positive laboratory results, regardless of clinical symptoms. Providers were instructed to collect and submit buccal swabs from symptomatic individuals to the Arkansas Department of Health Public Health Laboratory for testing. Attempts were made to collect buccal swabs within 5 days of parotitis onset; however, specimen collection occurred later in many cases. Swabs were placed in viral transport media and refrigerated during transport to the laboratory, where testing occurred within 1 working day of receipt. Investigators at the Arkansas Department of Health interviewed each patient or an adult caregiver to gather standardised demographic, clinical, laboratory, vaccination, travel, and contact or exposure information. We encouraged passive reporting of complications to Arkansas Department of Health by both health-care providers and cases.



**Figure 1: Confirmed and probable cases of mumps in Arkansas, USA, by week of illness onset from Aug 1, 2016, to Aug 7, 2017**  
The number of mumps cases according to the week of illness onset are shown for each case classification and each race or ethnicity.

Vaccination histories of patients were verified by Arkansas' immunisation registry or from personal vaccine records. Doses of the MMR vaccine or the measles, mumps, rubella, and varicella vaccine were included if the patient had received the dose 14 days or more before illness onset. People with unverified vaccination status were considered unvaccinated. Individuals were classified as being up to date if they had received the specified number of doses for age, per the CDC's 2016 childhood immunisation schedule and recommendations from the Advisory Committee on Immunization Practices.<sup>22</sup> MMR vaccination is recommended for people aged 12 months and older; the first dose should be administered between ages 12 months and 15 months and the second dose between ages 4 years and 6 years (before school entry). At least one dose is recommended for adults aged 18 years and older. People born before 1957 are not recommended for vaccination as they are presumed to have natural mumps immunity.

#### Laboratory testing

Buccal swab specimens were analysed for the presence of viral RNA (viral shedding) at the Arkansas Department of Health Public Health Laboratory with CDC-approved real-time RT-PCR assays.<sup>23</sup> A subsample of positive specimens was genotyped (*SH* gene sequences were analysed and compared with a library of historical samples) at the US CDC. A few patients underwent serological testing for anti-mumps antibodies at commercial laboratories.

#### Statistical analysis

All confirmed and probable cases were included in the analysis. Odds ratios (ORs) and 95% CIs were calculated for orchitis by vaccination status and for recurrent

disease and prolonged viral shedding by race (Marshallese vs non-Marshallese). All analyses were done with Epi Info (version 7).

#### Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

#### Results

From Aug 5, 2016, to Aug 5, 2017, Arkansas Department of Health identified 2954 outbreak-related cases, of which 1665 (56%) were laboratory confirmed (figure 1). The index patient was a Marshallese woman from Springdale, Arkansas, who regularly attended a large Marshallese church and reported having no history of mumps or MMR vaccination. She developed parotitis on Aug 5, 2016, and was positive for mumps via PCR. 2 weeks later, her spouse, who had previously received one dose of MMR vaccine, developed parotid swelling and was also PCR positive. Neither had travelled outside of Arkansas in the preceding 2 months. Interviews revealed that 2 weeks before symptom onset, the children of the index patient had driven to Arkansas with a relative from Iowa, USA, who had developed parotitis en route. Just 26 days after apparent introduction into the state, more than 50 cases were reported to Arkansas Department of Health, primarily among members of the initially affected church. The peak of the outbreak occurred during week 45 (figure 1). The outbreak remained centred in northwest Arkansas, but at some point affected residents in 37 of the

75 Arkansas counties. Overall, 101 schools in 22 school districts, 16 private schools or daycare centres, 13 colleges or vocational schools, 183 businesses, and 160 churches were affected. The last confirmed case had an onset date of July 17, 2017; 52 days later on Sept 7, 2017, Arkansas Department of Health announced that the outbreak was over.

Patients ranged in age from 3 months to 82 years, with a median age of 15 years (IQR 10–26). The median age of patients increased from the first 300 (13 years [IQR 9–18]) to the last 300 (17 years [11–32]) cases. 1474 (50%) of 2954 patients were male and 1469 (50%) were female (sex was unspecified for 11 [ $<1\%$ ] cases). More than half of patients were Marshallese (table 1). After the introduction of mumps into the state by the index patient, Marshallese children were initially the primary group to be affected, followed by Marshallese adults in religious settings, Hispanic adults in work settings (such as poultry plants), and then non-Hispanic white adults.

A convenience sample of 14 buccal swabs from early in the outbreak and nine from late in the outbreak was sent to the US CDC for characterisation. *SH* genes were

sequenced; all were genotype G and had identical sequences, except for one that had a single nucleotide difference.

Among the 2917 patients for whom vaccine was indicated by the CDC (including three patients of unknown age), 2014 (69%) had up-to-date immunisations for mumps (table 2). At least 92% of the most affected age group, children aged 5–17 years, were fully up-to-date with mumps immunisation. We did not observe a higher number of cases among people who were vaccinated more than 10 years previously than among those vaccinated in the past 10 years (figure 2).

Of the 2954 patients reported to Arkansas Department of Health, 2846 (96%) had parotitis. In total, 20 complications were passively reported. Table 3 shows the number of complications observed in the outbreak compared with the number that were expected given 3000 cases. Orchitis occurred in 19 (1%) of 1474 male patients; the median age of these patients was 19 years (IQR 14–43). Nine (47%) of these patients had not received MMR vaccination or had received an unknown number of doses. The odds of developing orchitis and being undervaccinated for age were not significant (OR 2.1, 95% CI 0.8–5.1;  $p=0.13$ ). A single case of pancreatitis was reported in a fully vaccinated adult. Six ( $<1\%$ ) of 2954 patients were admitted to hospital, of whom five had received two MMR doses and one had no verified doses. No cases of other mumps complications, such as meningitis, encephalitis, oophoritis, deafness, and death, were reported.

In this outbreak, 33 cases of recurrent disease were observed. Four (12%) patients with recurrent disease developed unilateral parotitis and, more than 2 weeks later, presented with parotitis on the opposite side, whereas the remaining 29 (88%) patients had bilateral or unspecified parotitis laterality. The age of patients with recurrent disease ranged from 5 months to 52 years (median 12 years [IQR 9–26]), with 23 (70%) being in daycare or school. Of the 33 patients, 26 (79%) were Marshallese, five (15%) were white, two (6%) had

	Confirmed	Probable	Total
Native Hawaiian or other Pacific Islander*	1039/1692 (61%)	653/1692 (39%)	1692/2954 (57%)
White	324/689 (47%)	365/689 (53%)	689/2954 (23%)
Hispanic or Latino	235/442 (53%)	207/442 (47%)	442/2954 (15%)
Black or African American	29/48 (60%)	19/48 (40%)	48/2954 (2%)
Other or unknown	38/83 (46%)	45/83 (54%)	83/2954 (3%)
Total	1665/2954 (56%)	1289/2954 (44%)	2954/2954 (100%)

Data are n/N (%). \*Synonymous with Marshallese in this population.

**Table 1: Number of confirmed and probable cases of mumps in Arkansas, USA, by race or ethnicity**

	Number of doses of mumps-containing vaccine				Number of patients with up-to-date vaccination
	None	One	Two or more	Missing*	
<1 year	10/11 (91%)	0	0	1/11 (9%)	NA†
1–4 years	36/100 (36%)	39/100 (39%)	24/100 (24%)	1/100 (1%)	63/100 (63%)
5–17 years	91/1676 (5%)	48/1676 ( $<3\%$ )	1536/1676 (92%)	1 ( $<1\%$ )	1536/1676 (92%)
18–59 years	721/1138 (63%)	134/1138 (12%)	281/1138 (25%)	2/1138 ( $<1\%$ )	415/1138 (36%)
$\geq 60$ years	24/26 (92%)	1/26 (4%)	1/26 (4%)	0	NA†
Missing‡	3/3 (100%)	0	0	0	NA†
Total (1–59 years)	848/2914 (29%)	221/2914 (8%)	1841/2914 (63%)	4/2914 ( $<1\%$ )	2014/2914 (69%)

\*This category included people who said they were up-to-date with vaccination but the information was not in the registry. †Vaccination is not indicated for infants younger than 1 year or adults born before 1957. ‡This category included people for whom age was not available.

**Table 2: Number of mumps cases by age group and vaccination status**

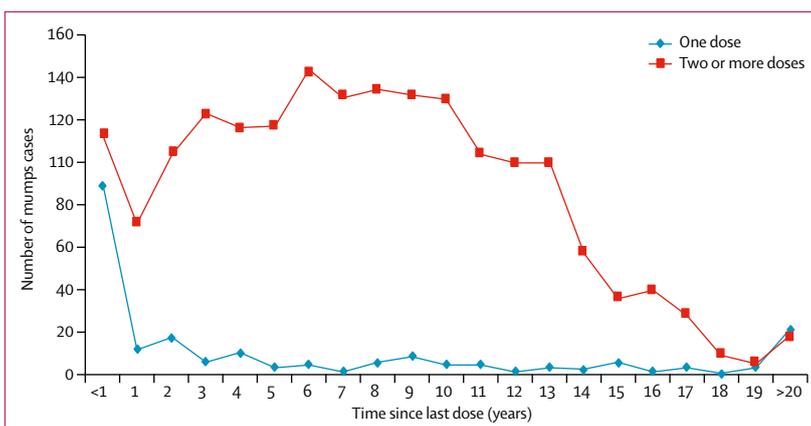
unknown ethnicities, 17 (52%) were female, and 16 (48%) were male. 22 (67%) patients had previously received two doses of a mumps-containing vaccine, five (15%) had received one dose, and six (18%) had not received a mumps-containing vaccine or had received an unknown number of doses. The odds of recurrent parotitis were 2.7 (95% CI 1.2–6.3;  $p=0.0185$ ) times greater for Marshallese patients (26/1645 [2%]) than for non-Marshallese patients (7/1200 [1%]).

63 patients (4% of 1492 patients who tested positive and had data available on dates of parotitis onset and specimen collection; 3% of all PCR tests done [n=2045]) had mumps confirmed by real-time RT-PCR more than 5 days after onset of parotitis (figure 3). In one patient, shedding was identified 35 days after parotitis onset. Patients with prolonged viral shedding ranged in age from 2 years to 46 years (median 16 years [IQR 11–25]). Of the 63 patients, 43 (68%) were Marshallese, 18 (29%) were white, one (2%) was black, one (2%) had an unknown ethnicity, 31 (49%) were female, and 32 (51%) were male. The risk of prolonged shedding was not significantly different between Marshallese (43/1645 [3%]) and non-Marshallese (20/1200 [2%]) patients (OR 1.6, 95% CI 0.9–2.7;  $p=0.092$ ). Samples taken 6–35 days after parotitis onset from ten randomly identified individuals were sent to the US CDC for viral culture; live virus was cultured (and ultimately characterised as genotype G) from all ten patients.

### Discussion

Despite comprising only 1% of the US population, Arkansas accounted for 2411 (41%) of the 5833 mumps cases reported to the CDC in 2016, which was more than any other state. Several reasons exist for the large size of, and difficulty in controlling, the outbreak in Arkansas.

The mumps component of the MMR vaccine is thought to be about 88% effective (range 66–95%) with two doses.<sup>25</sup> The vaccine was designed with the Jeryl Lynn strain (genotype A), and as evidence of its effectiveness, within 30 years of its introduction in 1967, genotype A was no longer seen worldwide.<sup>25</sup> However, genotype G, which is among the genotypes that are most genetically distinct from genotype A, was the predominant genotype circulating in the USA during the outbreak. Although mumps is considered immunologically monotypic, in that antibodies produced acutely after vaccination prevent infection by all 13 genotypes in a laboratory setting,<sup>25</sup> it is not known how well this in-vitro protection translates into in-vivo protection. Whether the resurgence in mumps caused by genotype G is due to vaccine effectiveness being lower for genotype G than for the other genotypes, waning immunity, or other reasons is unclear. Although the available data and methods used in our study meant that we could not answer this question, most infections were in children, and there was no increase in cases among people vaccinated in the distant



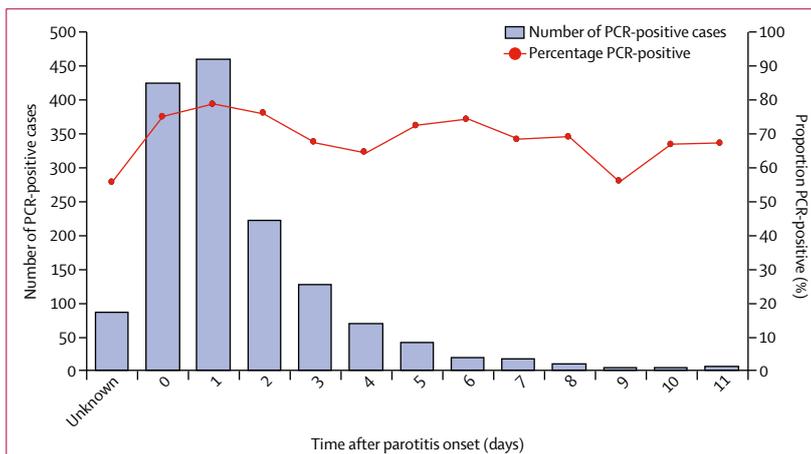
**Figure 2: Years since last vaccination by number of doses received**

Of the 2066 patients with a verified vaccination history, 2062 had accurate dates for when they received vaccination. 23 patients who received their only dose <14 days before illness onset were excluded. For 58 patients who had received two doses but the last dose <14 days before or after illness onset, only the first dose was used in this analysis. Among patients who developed illness within 1 year of being vaccinated, 15 (17%) of the 86 first-dose recipients and 20 (18%) of the 113 second-dose recipients developed mumps within 26 days of vaccination. These illnesses could possibly have been incubating before vaccination or might have been vaccine derived.

	Prevalence in pre-vaccine era (%) <sup>24</sup>	Prevalence in vaccine era (%) <sup>5</sup>	Number expected with 3000 cases*	Observed number
Meningitis	1–10%	<1%	<30	0
Encephalitis	0.5%	<1%	<30	0
Orchitis	12–66%	10%	300	19/2954 (1%)
Oophoritis	5%	<1%	<30	0
Pancreatitis	2–5%	<1%	<30	1/2954 (<1%)
Deafness	0.005%	<0.0001%	Rare	0
Male infertility	4%	Rare	Rare	0
Hospital admission	10%	2%	60	6/2954 (<1%)

\*The approximate number of complications expected to have occurred in an outbreak with 3000 cases was based on estimates from the vaccine era.<sup>5</sup>

**Table 3: Number of expected and observed complications of mumps in Arkansas, USA**



**Figure 3: Number and proportion of PCR positive cases by number of days after parotitis onset**

During the outbreak period, 2045 cases underwent PCR testing at the state public health laboratory. Of the 1665 confirmed cases, parotitis onset date and date of specimen collection were collected for 1492 cases.

past, both of which are inconsistent with waning immunity.

Although the prevalence of mild parotitis associated with self-limiting mumps among highly vaccinated individuals was higher than expected in this outbreak, severe manifestations, such as orchitis or pancreatitis, were rare, and meningitis, encephalitis, oophoritis, and deafness were not reported. Given that these complications were passively identified, some might have occurred but not been reported, although this is unlikely for several reasons. First, the outbreak centred in a small area of the state, and there was extensive outreach among physicians across the state and in the involved community. Second, most cases were seen in one of two clinics that were in daily communication with Arkansas Department of Health. Third, interest in mumps and its complications among health-care providers and the community was exceptionally high, and the complications were likely to result in prompt care-seeking behaviour. Altogether, only 1–2% of the severe manifestations that were expected in a vaccinated population were identified. This finding supports the assertion that mumps vaccination continues to prevent the majority of severe complications.<sup>26</sup>

Engaging the Marshallese population with public health outreach activities was challenging. Initially, routine mass media-based strategies, such as routine outreach via television, radio, or printed media, to communicate outbreak information were inadequate and felt by Marshallese community leaders to exacerbate the community's perception of stigma. Thus, we used culturally and linguistically targeted communication methods, such as translating educational materials into Marshallese by qualified translators to reduce communication barriers. Social media was useful, but the most effective method was probably having the only Marshallese physician in continental USA champion our efforts over the local Marshallese-language radio station. Furthermore, with instrumental support from the Arkansas Coalition of Marshallese (Springdale, AR, USA), we created a Marshallese Task Force, which was comprised of local leaders, pastors, pastors' wives, and the Marshall Islands' consulate general, to facilitate community engagement and outreach. To ensure effective communications, meetings were held on a weekly basis early in the outbreak, then monthly. During the outbreak, staff from the Marshall Islands' Ministry of Health travelled to Arkansas to help promote control efforts by communicating with the Task Force and Marshallese churches. Arkansas Department of Health also imbedded a medical anthropologist in the Marshallese community for 2 months to better understand cultural and health beliefs to guide the outbreak response.

Involved schools reviewed immunisation records, and students without documented age-appropriate vaccination or serological evidence of immunity were offered an MMR vaccine. Students who could not provide

evidence of up-to-date vaccination were also offered the vaccine. Schools excluded exposed students and unvaccinated staff until 26 days had passed without a new case. During the outbreak, the Arkansas Department of Health ran 71 MMR clinics in a variety of settings and administered 8709 MMR doses: 3675 (42%) in schools, 3083 (35%) in workplaces, 1594 (18%) in local health units, 270 (3%) in churches, and 87 (1%) in the community (eg, residences or grocery stores). At least 10922 doses were also administered by private health-care providers in the two most affected counties. Overall, roughly six times as many MMR doses were administered in those two counties during the outbreak than in the previous year (data not shown).

Most of the vaccination clinics provided a routine second dose of the MMR vaccine, but 27 school-based clinics provided an outbreak dose because they met CDC criteria for a third-dose clinic: high two-dose vaccination coverage, intense exposure setting, and ongoing transmission, with attack rates exceeding five new cases per 1000 population.<sup>27</sup> Although data on the effectiveness of a third dose in controlling outbreaks are scarce,<sup>4</sup> during a meeting in October, 2017, the Advisory Committee on Immunization Practices recommended that a third dose of a mumps virus-containing vaccine be given to people previously vaccinated with two doses who are identified by public health authorities as being part of a group or population at increased risk of acquiring mumps because of an outbreak.<sup>28</sup> A study of the effectiveness of third-dose vaccination, in collaboration with the US CDC, is underway to evaluate these efforts.

Vaccination levels reported in this study were verified by Arkansas' immunisation registry or medical records. However, they likely underestimate true coverage, particularly among adults, because state law before 2013 prohibited the immunisation registry from retaining vaccine records for people older than 22 years at the time of vaccination. True coverage in children might also be underestimated because the registry was replaced in 2014, and some local physicians are still in the process of linking their electronic record systems to the registry. Many Marshallese adults report being vaccinated in the Marshall Islands in the context of a large measles outbreak in 2003,<sup>29</sup> but some reports could not be verified because records were not always maintained electronically within the country.

Historically, it was not unexpected for an individual to develop parotitis on one side and then, within a week, to develop parotitis on the contralateral side, but this recurrent parotitis was rarely seen more than 2 weeks apart.<sup>30</sup> In this outbreak, 33 patients were reported to have parotitis 14 days to 7 months after initially developing parotitis, either on the same or opposite side. The odds of recurrent parotitis were nearly three times higher for Marshallese than for non-Marshallese patients. Potential reasons for this increased risk include intense crowding in Marshallese households, schools, and churches, which increases the risk of exposure, as well as potential genetic

or environmental factors that might contribute to enhanced immunological susceptibility.

As reported by Kutty and colleagues<sup>31</sup> in their review of 15 studies that assessed mumps viral shedding, only one (<1%) of 141 patients with mumps had evidence of viral shedding beyond 5 days after the onset of parotitis. This finding supports the recommendation by the American Academy of Pediatrics Committee on Infectious Diseases of a 5-day period of exclusion from school or other congregate settings after onset of symptoms.<sup>32</sup> In this outbreak, 63 patients had positive PCR tests more than 5 days after parotitis onset, a six-times higher rate of prolonged shedding than observed by Kutty and colleagues,<sup>31</sup> and all ten cultured samples were confirmed to have live virus. This finding brings into question whether a 5-day exclusion period is enough to control transmission of the mumps virus, particularly in close-contact settings.

This mumps outbreak is unique for several reasons. Mumps transmission was intense, far exceeding that expected among a highly vaccinated school-aged population. This population group was younger than the college-aged populations typically involved in recent mumps outbreaks.<sup>9–13,33</sup> Social, cultural, and environmental factors, including the Marshallese's exceptionally dense housing and close-knit community, as well as structural barriers to accessing health services, likely contributed to the size and scale of the outbreak. This outbreak had similar characteristics to the 2009–10 mumps outbreak in Guam, where crowding in the home and high contact rates in schools were major factors in the high rate of transmission.<sup>34</sup> Because the outbreak in Arkansas mainly affected Marshallese people, to be effective, the Arkansas Department of Health had to tailor outbreak response efforts to be culturally informed and sensitive.

The high prevalence of numerous infectious and chronic diseases in Marshallese people might be explained by crowding, obesity, low health literacy, and poor access to health care (Arkansas Department of Health surveillance data, unpublished). Whether Marshallese people have a higher prevalence than non-Marshallese people of an underlying immune-compromising condition, potentially related to lasting effects of nuclear exposure, is worthy of investigation. Regarding health-care access, their overall burden of preventable illness brings into question whether current US national policies that exclude Marshallese people from most federal health benefits are defensible economically, in terms of public health and social justice. To that end, in 2017, the Arkansas State Legislature approved provision of Medicaid coverage to “lawfully residing” Marshallese children younger than 19 years and pregnant women; this rule came in to effect on Jan 1, 2018.<sup>35</sup> However, health-care coverage for Marshallese adults in Arkansas and elsewhere remains problematic.<sup>15</sup>

This mumps outbreak highlighted the need for a rapidly scalable and deployable, highly coordinated,

interdisciplinary, culturally sensitive, outbreak response team to interact effectively with a marginalised community. Language barriers, health literacy, and competing medical priorities complicated the outbreak response, but strong partnerships with stakeholder organisations and community champions overcame these challenges and facilitated successful control.

#### Contributors

VSF, HS, and DTH analysed and interpreted the data. VSF and DTH wrote the manuscript. All authors had a role in outbreak response and control and reviewed the manuscript before submission.

#### Declaration of interests

We declare no competing interests.

#### Acknowledgments

This study was supported in part by an appointment to the Applied Epidemiology Fellowship Program administered by the CSTE and funded by a US CDC Cooperative Agreement (number 1U38OT000143–04) and a non-influenza respiratory outbreak supplement as part of the CDC Epidemiology and Laboratory Capacity Cooperative Agreement (number CK000366–03–03). We thank the Marshallese community in Arkansas for engaging with us to help keep their community safe. We acknowledge the hard work of Arkansas Department of Health staff in local public health units, the central office, and the public health laboratory in investigating cases, coordinating vaccine clinics, and performing diagnostic testing. We also acknowledge numerous valuable partners at the University of Arkansas for Medical Sciences, the Arkansas Coalition of Marshallese, the Marshallese Ministry of Health, the Marshallese Consulate, and the CDC for their support and collaboration. The content of this publication reflects the views of the authors and does not necessarily reflect the views or policies of the CDC, the CSTE, or the institutions affiliated with the authors.

#### References

- Conly JM, Johnston BL. Is mumps making a comeback? *Can J Infect Dis Med Microbiol* 2007; **18**: 7–9.
- Falk W, Buchan K, Dow M, et al. The epidemiology of mumps in Southern Alberta, 1980–82. *Am J Epidemiol* 1989; **130**: 736–49.
- Cooney MK, Fox JP, Hall CE. The Seattle Virus Watch. VI. Observations of infections with and illness due to parainfluenza, mumps and respiratory syncytial viruses and *Mycoplasma pneumoniae*. *Am J Epidemiol* 1975; **101**: 532–51.
- CDC. Manual for the surveillance of vaccine-preventable diseases. Atlanta, GA: Centers for Disease Control and Prevention, 2012.
- McLean HQ, Fiebelkorn AP, Temte JL, Wallace GS. Prevention of measles, rubella, congenital rubella syndrome, and mumps, 2013: summary recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep* 2013; **62**: 1–34.
- Barskey AE, Glasser JW, LeBaron CW. Mumps resurgences in the United States: a historical perspective on unexpected elements. *Vaccine* 2009; **27**: 6186–95.
- Kancherla VS, Hanson IC. Mumps resurgence in the United States. *J Allergy Clin Immunol* 2006; **118**: 938–41.
- Centers for Disease Control and Prevention. Update: multistate outbreak of mumps—United States, January 1–May 2, 2006. *MMWR Morb Mortal Wkly Rep* 2006; **55**: 559–63.
- Huang AS, Cortese MM, Curns AT, et al. Risk factors for mumps at a university with a large mumps outbreak. *Public Health Rep* 2009; **124**: 419–26.
- Centers for Disease Control and Prevention. Update: mumps outbreak—New York and New Jersey, June 2009–January 2010. *MMWR Morb Mortal Wkly Rep* 2010; **59**: 125–29.
- Centers for Disease Control and Prevention. Mumps outbreak on a university campus—California, 2011. *MMWR Morb Mortal Wkly Rep* 2012; **61**: 986–89.
- Albertson JP, Clegg WJ, Reid HD, et al. Mumps outbreak at a university and recommendation for a third dose of measles–mumps–rubella vaccine—Illinois, 2015–16. *MMWR Morb Mortal Wkly Rep* 2016; **65**: 731–34.

- 13 Greenland K, Whelan J, Fanoy E, et al. Mumps outbreak among vaccinated university students associated with a large party, the Netherlands, 2010. *Vaccine* 2012; **30**: 4676–80.
- 14 Cordeiro E, Ferreira M, Rodrigues F, Palminha P, Vinagre E, Pimentel JP. Mumps outbreak among highly vaccinated teenagers and children in the central region of Portugal, 2012–13. *Acta Med Port* 2015; **28**: 435–41.
- 15 McElfish PA, Purvis RS, Maskarinec GG, et al. Interpretive policy analysis: Marshallese COFA migrants and the Affordable Care Act. *Int J Equity Health* 2016; **15**: 91.
- 16 Marshallese Educational Initiative. Marshallese in Arkansas. 2017 <https://www.mei.ngo/marshallese-in-arkansas> (accessed Aug 6, 2018).
- 17 Davenport C. The Marshall Islands are disappearing. *The New York Times* (New York, NY), Dec 2, 2015. <https://www.nytimes.com/interactive/2015/12/02/world/The-Marshall-Islands-Are-Disappearing.html> (accessed Aug 6, 2018).
- 18 Hallgren EA, McElfish PA, Rubon-Chutarro J. Barriers and opportunities: a community-based participatory research study of health beliefs related to diabetes in a US Marshallese community. *Diabetes Educ* 2015; **41**: 86–94.
- 19 Duke MR. Neocolonialism and health care access among Marshall Islanders in the United States. *Med Anthropol Q* 2017; **31**: 422–39.
- 20 Tan C, Haumea S, Juarez DT, Grimm C. A descriptive study of Marshallese and Chuukese patients with diabetes in Hawaii. *Hawaii J Med Public Health* 2014; **73**: 168–71.
- 21 Council of State and Territorial Epidemiologists. CSTE position statement 09-ID-50. June 10, 2010. <https://c.ymcdn.com/sites/www.cste.org/resource/resmgr/PS/09-ID-50.pdf> (accessed Aug 6, 2018).
- 22 Centers for Disease Control and Prevention. Immunization schedules. Resource library. <https://www.cdc.gov/vaccines/schedules/resource-library/index.html#ui-id-5> (accessed Dec 20, 2018).
- 23 Boddicker JD, Rota PA, Kreman T, et al. Real-time reverse transcription-PCR assay for detection of mumps virus RNA in clinical specimens. *J Clin Microbiol* 2007; **45**: 2902–08.
- 24 Litman N, Baum SG. Mumps virus. In: Mandell, Douglas, and Bennett's principles and practice of infectious diseases. 7th edn. Philadelphia, PA: Churchill Livingstone Elsevier, 2010: 2201–06.
- 25 Rubin SA, Link MA, Sauder CJ, et al. Recent mumps outbreaks in vaccinated populations: no evidence of immune escape. *J Virol* 2012; **86**: 615–20.
- 26 Gouma S, Hahne SJ, Gijsselaar DB, Koopmans MP, van Binnendijk RS. Severity of mumps disease is related to MMR vaccination status and viral shedding. *Vaccine* 2016; **34**: 1868–73.
- 27 Centers for Disease Control and Prevention. Mumps vaccination. Feb 2, 2018. <https://www.cdc.gov/mumps/vaccination.html> (accessed Aug 6, 2018).
- 28 Marin M, Marlow M, Moore KL, Patel M. Recommendation of the Advisory Committee on Immunization Practices for use of a third dose of mumps virus-containing vaccine in persons at increased risk for mumps during an outbreak. *MMWR Morb Mortal Wkly Rep* 2018; **67**: 33–38.
- 29 Hyde TB, Dayan GH, Langidrik JR, et al. Measles outbreak in the Republic of the Marshall Islands, 2003. *Int J Epidemiol* 2006; **35**: 299–306.
- 30 Cherry JD, Quinn KK. Mumps virus. In: Cherry JD, Harrison GJ, Kaplan SL, et al, eds. Feigin & Cherry's textbook of pediatric infectious diseases. 7th edn. Philadelphia, PA: Saunders Elsevier, 2014: 2395–407.
- 31 Kutty P, Kyaw M, Dayan G, et al. Guidance for isolation precautions for mumps in the United States: a review of the scientific basis for policy change. *Clin Infect Dis* 2010; **50**: 1619–28.
- 32 American Academy of Pediatrics. Mumps. In: Kimberlin DW, Brady MT, Jackson MA, Long SS, eds. Red book: 2018–21 report of the Committee on Infectious Diseases. 31st edn. Itasca, IL: American Academy of Pediatrics, 2018: 567–73.
- 33 Centers for Disease Control and Prevention. Mumps cases and outbreaks. <https://www.cdc.gov/mumps/outbreaks.html> (accessed Dec 21, 2018).
- 34 Nelson GE, Aquon A, Valencia E, et al. Epidemiology of a mumps outbreak in a highly vaccinated island population and use of a third dose of measles–mumps–rubella vaccine for outbreak control—Guam 2009 to 2010. *Pediatr Infect Dis J* 2013; **32**: 374–80.
- 35 Arkansas Department of Human Services. Arkansas register. <http://170.94.37.152/REGS/016.06.17-020F-17629.pdf> (accessed Dec 20, 2018).