Guidance for Isolation Precautions for Mumps in the United States: A Review of the Scientific Basis for Policy Change

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The 2006 mumps resurgence in the United States raised questions about the appropriate isolation period for people with mumps. To determine the scientific basis for isolation recommendations, we conducted a literature review and considered isolation of virus and virus load in saliva and respiratory secretions as factors that were related to mumps transmission risk. Although mumps virus has been isolated from 7 days before through 8 days after parotitis onset, the highest percentage of positive isolations and the highest virus loads occur closest to parotitis onset and decrease rapidly thereafter. Most transmission likely occurs before and within 5 days of parotitis onset. Transmission can occur during the prodromal phase and with subclinical infections. Updated guidance, released in 2007–2008, changed the mumps isolation period from 9 to 5 days. It is now recommended that mumps patients be isolated and standard and droplet precautions be followed for 5 days after parotitis onset.

Mumps virus (Paramyxoviridae family) causes an acute febrile illness with a nonspecific prodrome followed by painful swelling of the parotid and less commonly, other salivary glands [1, 2]. Infections may manifest clinically as nonspecific respiratory symptoms without parotitis and may be asymptomatic in 20%–40% of cases [3–10]. Mumps virus is transmitted via inhalation of infectious respiratory droplets, direct contact with infected droplets or saliva, and possibly via contaminated fomites [2, 4]. During the 12–25 day incubation period, the virus proliferates in the upper respiratory tract epithelium, followed by viremia and secondary dissemination to glandular and neural tissue [1, 3]. Severe complications include meningoencephalitis, sensorineural deafness, orchitis, oophoritis, and pancreatitis [1]. Although coxsackie, parainfluenza, influenza, and Epstein-Barr viruses can also cause infectious parotitis, mumps virus is the only known cause of epidemic parotitis.

In the United States (US), mumps vaccine was licensed in 1967 and recommended for routine childhood vaccination in 1977 [11, 12]. Following licensure, reported mumps cases decreased from 152,209 cases (87.9 cases per 100,000 persons) in 1968 to 300 cases (0.1 cases per 100,000 persons) during 2001–2005 [12, 13]. In 2006, however, a resurgence of mumps occurred with 6584 cases reported nationwide [14, 15]. Approximately two-thirds of the case patients with known vaccination status had received 2 doses of mumps vaccine or measles, mumps, rubella (MMR) vaccine, and affected colleges reported very high 2-dose MMR vaccine
During the 2006 US resurgence, local differences in interpretation of the national policy guidance for duration of patient isolation precautions (9 days) [7, 18] and other guidance on the infectious period or period of maximum communicability for mumps (3–4 days before to 4–5 days after parotitis onset) [9, 18] resulted in adoption of different recommendations for isolation at the state and local levels (eg, 9 days of isolation following onset of parotitis versus 4 or 5 days). Questions were raised about the strength of the scientific evidence for recommending 9 days, versus a shorter period, for mumps isolation.

In 2007 and 2008, after reviewing data on mumps and its transmission in community, outpatient, and inpatient health care settings, the American Academy of Pediatrics (AAP), the Healthcare Infection Control Practices Advisory Committee (HICPAC), and the Centers for Disease and Prevention (CDC) revised existing guidance from 9 to 5 days for (1) isolation of mumps cases following onset of parotitis in all these settings and (2) use of standard and droplet precautions [19–21]. This review summarizes and discusses the scientific basis for these policy changes.

METHODS

Using MEDLINE, Web of Science, EMBASE, and CINAHL databases, we searched the literature from 1918 through December 2008 with the key word “mumps” in combination with “transmissibility,” “infectiousness,” “nosocomial,” “healthcare-associated,” “virus isolation,” “excretion” or “shedding,” “virus detection,” and “incubation period.” We manually searched for references cited in relevant articles. Information on the presence of infectious virus was derived from studies on mumps virus isolation in cell culture and from studies using molecular detection methods that provided estimates of viral loads (ie, quantity of infectious virus or plaque-forming units), assuming that higher virus titers, genome equivalents, or total viral RNA in secretions correlates with transmission risk. Mumps virus is primarily transmitted by contact with respiratory droplets and saliva; thus, we reviewed studies reporting on isolation of mumps virus or viral load in saliva and respiratory secretions related to parotitis onset and did not consider studies of mumps virus isolation from other clinical specimens. We combined data from identified studies to describe the percentage of specimens with mumps virus isolated relative to parotitis onset.

RESULTS

Mumps transmissibility. Mumps is less efficiently transmitted than other infectious diseases, such as measles and varicella, that are typically acquired in childhood [1, 22]. Before use of mumps vaccine, clinical mumps was acquired, on average, 2–6 years later during childhood than varicella and measles and a higher proportion of young adult military recruits in the United States lacked mumps antibodies (24%) than lacked measles antibodies (1%) [2, 10, 23, 24].

Simpson [22] reported a lower clinical secondary attack rate of 31% for mumps, compared with that for measles (76%) and varicella (61%), among children aged <15 years with no disease histories exposed in households. Other household mumps transmission studies have reported secondary attack rate ranging from 33% to 48% among children and adolescents with no history of disease [10, 24]. Mumps secondary infection rates are likely higher [5, 24].

The infectious nature of mumps before parotitis onset has been demonstrated in several settings. Siegel et al [25] described an institutional mumps outbreak that occurred in the first cottage where a newly admitted child spent 24 h before being transferred to another cottage where he developed parotitis 24 h later. In small hospitals studies, Brunell et al [26] and Fischer et al [27] demonstrated mumps virus transmission during the prodromal stage, because transmission of mumps virus occurred despite prompt isolation of the first case after parotitis onset. The findings by Brunell et al [26] are also highly suggestive of mumps virus transmission from subclinical infections.

As expected, secondary transmission rates are much lower among vaccinated than unvaccinated contacts because of the protective effects of vaccine. In 2 roommate contact studies conducted during mumps outbreaks on college campuses in Iowa and Kansas in 2006, secondary attack rates for the development of classical mumps among 2-dose vaccinated contacts exposed mainly to vaccinated cases ranged from 2.2% to 8.1% [16, 17]. No studies have examined the relative contagiousness of vaccinated versus unvaccinated mumps cases.

Duration of virus excretion. We identified 15 studies from the United States, Japan, and Europe that reported cross-sectional or prospectively collected data on mumps virus isolation (relative to parotitis onset) in cell culture from saliva specimens or throat swabs among children and adults with mumps (median number of subjects, 20; range, 1–93). [3, 26, 28–40] (Table 1). Of the 15 studies, 8 (7 conducted in the United States and Japan between 1934 and 1975 before availability of mumps vaccine) included only unvaccinated mumps case patients, 1 included vaccinated and unvaccinated case patients, and for 6 studies vaccination status of case patients was not reported [3, 26, 28–40]. Four of the 15 studies summarized virus isolation from multiple saliva specimens collected prospectively after exposure, before and after onset of disease or infection [3, 26, 31, 38] (Figure 1). The remaining 11 studies, primarily cross-sectional, provided data on mumps virus isolation after onset of clinical illness only.

In these 15 studies, virus was successfully isolated from saliva beginning 7 days [38] before to 8 days [29] after parotitis onset;
however, isolation was more commonly successful around the time of parotitis onset. Ten of these studies [3, 26, 30, 31, 34–39] provided positive and negative results, by day, relative to parotitis onset (Figure 1). Combined data from 8 of these studies that provided information on all case patients showed that the percentage of samples positive for mumps virus increased progressively before parotitis onset and then decreased. On days 4–5, 2–3, and 1 before parotitis onset, 36% (4 of 14 specimens positive), 63% (10 of 16), and 90% (9 of 10) of specimens, respectively, were positive, and on days 1 and 4–5 after onset 78% (32 of 41) and 42% (8 of 19), respectively, were positive [3, 26, 30, 31, 34–36, 38] (Figure 2). From days 6–9 after parotitis onset, 5% (1 of 21) of specimens were positive, and all 10 specimens tested after 9 days were negative.

Three studies compared virus isolation rates from different time periods after parotitis onset [29, 33, 39]. Utz et al [29] isolated virus from 50% (30 of 60) of mouth swab and saliva specimens from 21 patients with clinical mumps with a much higher isolation rate (76% [29 of 38]) for specimens collected within the first 5 days, compared with 5% (1 of 22) collected after 5 days (Table 1). Okafuji et al [33] isolated virus from 33 patients with mumps; 91% (30 of 33) of specimens collected within 2 days were positive, whereas only 36% (9 of 25) of specimens collected 3–7 days after parotitis onset were positive. Chiba et al [39] isolated mumps virus from 61% (17 of 28) of patients with suspected parotitis and performed serial testing on 16. Virus isolation was only successful up to 5 days after onset of parotitis; no virus was isolated from 14 specimens tested after 5 days [39]. We combined all available virus isolation results for testing performed >5 days after parotitis onset in patients with mumps; only 2.4% (2 of 84) specimens were positive for mumps virus [3, 26, 29, 31, 34, 37–39].

One study compared mumps virus isolation rates in 3 groups of patients with clinical mumps classified by history and vaccination status; the virus isolation rate was lowest for patients with a history of previous mumps (presumed reinfections) (5 [17%] of 29), intermediate among vaccinated patients (15 [41%] of 37), and highest in unvaccinated patients (16 [64%] of 25) [28].

Polgreen et al [41] used viral isolation data from mumps cases tested during the 2006 mumps outbreak in Iowa to model the probability of viral shedding relative to symptom (not further defined) onset (169 case patients with a positive viral culture and 697 case patients with a negative culture but positive mumps immunoglobulin (Ig) M immunofluorescence antibody assay result). With use of logistic regression modeling, which provided daily empirical estimates of the probability of viral shedding for 21 days after symptom onset, the probability of viral shedding decreased rapidly from 28.2% on the day of onset of symptoms to 10.7% and 3.7% on days 5 and 10, respectively [41]. Although vaccination status of the patients tested was not stated by Polgreen et al, the vast majority of case patients in 2006 with known vaccination histories were vaccinated; more than one-half had received 2 doses of vaccine [15, 16].

**Virus load.** Methods designed to detect mumps RNA were performed in more recent studies (1996–2007). In general, RNA detection methods are at least as or more sensitive than virus isolation in culture [30, 42, 43]. Attempts are frequently made to correlate the number of detected target sequences (ie, copy number) with the number of infectious units (plaque-forming units) in a given specimen; however, these estimates can vary as much as several orders of magnitude and, thus, are unreliable. Despite that, total RNA levels are a reasonable metric of virus replication, and higher levels are assumed to correlate with higher levels of infectious virus in saliva.

Studies conducted after 2000 examining virus load among patients with mumps described rapid decreases in total mumps viral RNA detected over the first 4–5 days of clinical illness [33, 44]. Okafuji et al [33], using loop-mediated isothermal amplification to measure total mumps RNA levels from the day of clinical mumps onset, found that mumps RNA levels (reported as genome equivalents) were at the highest levels 1–2 days after onset and then decreased from day 3 onwards. Compared with unvaccinated mumps cases, vaccinated cases had significantly lower levels of detectable RNA on day 1. Jin et al [44], in assessing mumps RNA copy numbers as a metric for virus load, found that virus loads 7 days after symptom onset were significantly ($P < .01$) lower, compared with those on day 1.

**Mumps in health care settings.** Although small mumps outbreaks were occasionally described in hospital or institutional settings before mumps vaccine availability, serious consequences of mumps transmission in such settings are rare [45]. Mumps outbreaks have never been reported in high-risk inpatient settings, including intensive care units, transplant centers, burn units, or long-term care facilities [45]. Though there are exceptions, mumps is not typically described as more severe in high-risk groups, including immunocompromised persons, infants, or elderly persons [45–47]. During community mumps outbreaks, some health care workers have acquired mumps but, most commonly, from known or probable exposures in the community [48, 49]. Hospitalizations because of mumps are uncommon [15, 50], and death is rare [8].

**DISCUSSION**

The 2007 AAP and 2008 HICPAC and CDC changes in US mumps isolation guidance from 9 days to 5 days following parotitis onset were based on scientific evidence of mumps transmission and isolation of mumps virus from saliva and respiratory specimens in conjunction with viral RNA detection methods as metrics of virus load. Virus isolation data and virus
<table>
<thead>
<tr>
<th>Reference</th>
<th>Location</th>
<th>Year</th>
<th>No of patients (Age)</th>
<th>Vaccinated</th>
<th>Clinical presentation</th>
<th>Study methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson and Goodpasture</td>
<td>United States</td>
<td>1933</td>
<td>6 (NR)</td>
<td>No</td>
<td>Parotitis</td>
<td>Cross-sectional; saliva from patients with parotitis inoculated into monkeys</td>
<td>1. Saliva obtained from 4 patients 1 day, 2 days, and “no later than 2 days” after parotitis onset induced parotitis in monkeys 2. Saliva obtained from 2 patients within 3 days and “possibly on the 3rd day” after parotitis onset did not induce parotitis in monkeys</td>
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<tr>
<td>Leymaster and Ward [34]</td>
<td>United States</td>
<td>1948</td>
<td>9 (18 months–45 years)</td>
<td>No</td>
<td>Clinical mumps</td>
<td>Cross-sectional; 1 patient had 2 specimens</td>
<td>1. Virus isolated from samples from 8 of 9 patients 2. Positive results for 8 specimens: 3 on day 1 and 1 each on days 2–6 after the onset of mumps 3. Negative results for 2 specimens: 1 each on days 2 and 5 after onset of mumps; the specimen from day 5 was the 2nd specimen from a case patient with positive isolation results on day 2 4. Amniotic sac inoculation of chick embryo was used for virus isolation</td>
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<tr>
<td>Henle et al [3]</td>
<td>United States</td>
<td>1948</td>
<td>15 (children, NR)</td>
<td>No</td>
<td>Parotitis (4 cases), submaxillary swelling (2 cases), orchitis (1 case), subclinical infection (8 cases)</td>
<td>Longitudinal; experimental inoculation of seronegative children in an institution; 6–9 sequential specimens obtained per case</td>
<td>1. All 15 case patients were confirmed positive for mumps by using serological methods 2. Virus isolated from samples from 13 of 15 children: 4 with parotitis, 2 with submaxillary swelling, 1 with orchitis, and 6 with subclinical infection; earliest positive isolation was 11 days following inoculation A. Parotitis: Virus isolated 11–19 days following inoculation (1–4 days before onset of parotitis) and continued for up to 3 days after onset of parotitis; no virus isolated from 0 of 6 specimens 4–9 days after parotitis onset; overall, 8 of 27 specimens (30%) from 11–24 days after inoculation were positive. B. Submaxillary swelling: Virus isolated from 2–6 days before onset of swelling; overall, 5 of 13 specimens (39%) tested from 11–22 days following exposure were positive and 0 of 3 were positive after onset C. Orchitis: Virus isolation testing began 15 days following inoculation (10 days before onset of orchitis symptoms); virus was isolated on the 9th and 10th day before orchitis onset; no specimens tested after orchitis onset D. Subclinical infections: Virus was isolated in samples from 6 of 8 patients 15–20 days following exposure; overall, 20 of 63 specimens (32%) tested 11–24 days following exposure were positive 3. Inoculation of chick embryos was used for virus isolation</td>
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<tr>
<td>Hook et al [40]</td>
<td>United States</td>
<td>1949</td>
<td>17 (NR)</td>
<td>NR</td>
<td>Parotitis</td>
<td>Cross-sectional; saliva and saline washings obtained 1–7 days after onset of parotitis</td>
<td>1. Virus isolated from samples from 10 of 17 case patients (59%) within 3 days after the onset of parotitis. Virus was not recovered from mouth washings from 3 case patients 7 days after the onset of parotitis 2. Amniotic sac inoculation of embryonated hens’ eggs was used for virus isolation</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Year</td>
<td>Age</td>
<td>Clinical Status</td>
<td>Study Design</td>
<td>Samples</td>
<td>Virus Isolation Details</td>
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<tr>
<td>Utz et al [29]</td>
<td>United States</td>
<td>1957</td>
<td>21 (NR)</td>
<td>No</td>
<td>Clinical mumps</td>
<td>Cross sectional; &gt;1 specimen/patient (mouth washings, 31; saliva, 29)</td>
<td>1. Virus isolated from 13 of 31 of mouth washing (42%) and 17 of 29 saliva specimens (59%) on days 2–8 of clinical mumps 2. 29 of 38 specimens (76%) were positive &lt;5 days of mumps onset 3. 1 of 22 specimens (5%) were positive &gt;5 days of mumps onset 4. Monkey-kidney-cell and HeLa-cell tubes were used for virus isolation</td>
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<tr>
<td>Ennis and Jackson [38]</td>
<td>United States</td>
<td>1967</td>
<td>1 (3 years)</td>
<td>No</td>
<td>Clinical mumps</td>
<td>Longitudinal; saliva specimens obtained on alternate days, starting 1 day after exposure to sibling with mumps</td>
<td>1. Virus isolated 7 days before to 3 days after the onset of parotid swelling 2. Virus not isolated from specimens obtained 9–17 days before or 5–11 days after onset of parotid swelling 3. Primary thymus kidney cell cultures were used for virus isolation</td>
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<tr>
<td>Brunell et al [26]</td>
<td>United States</td>
<td>1967</td>
<td>16 (16 months–12 years)</td>
<td>No</td>
<td>Clinical mumps; subclinical infection</td>
<td>Longitudinal; saliva specimens obtained almost daily in children hospitalized for TB, starting 15 days after exposure</td>
<td>1. 15 children were exposed to another TB patient with mumps; study group comprised 12 of the exposed children who were negative for neutralizing antibodies 7 days after exposure; 8 developed parotitis and 4 had subclinical infections confirmed by increase in IgG neutralizing antibodies 2. Mumps virus specimens obtained from 7 parotitis case patients and 2 case patients with subclinical infection 3. Primary thymus kidney cell cultures were used for virus isolation</td>
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<tr>
<td>Shope et al [31]</td>
<td>United States</td>
<td>1969</td>
<td>3 (children, NR)</td>
<td>NR</td>
<td>Clinical mumps</td>
<td>Longitudinal; saliva specimens obtained daily for 14 days in an institution</td>
<td>1. Child with mumps was not isolated and exposed 25 other children, of whom 3 developed clinical mumps 2. Virus isolated at least 4 days prior and as long as 5 days after onset of parotitis 3. Primary thymus monkey cell cultures were used for virus isolation</td>
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<tr>
<td>Chiba et al [39]</td>
<td>Japan</td>
<td>1973</td>
<td>28 (NR)</td>
<td>No</td>
<td>Clinical mumps</td>
<td>Cross sectional, with serial collection on subset of 16 of 18 virus-positive patients (1–5 viral specimens/patient)</td>
<td>1. Virus isolated from 17 of 28 (61%) specimens from patients; serial specimen data provided for 16 patients. An additional patient had virus confirmed by direct immunofluorescence testing 2. 24 of 41 samples (59%) obtained from 0–23 days, 24 of 27 (89%) obtained 0–5 days, and 0 of 14 obtained &gt;5 days after onset were positive 3. Vero cell cultures were used for virus isolation</td>
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<tr>
<td>Isomura et al [37]</td>
<td>Japan</td>
<td>1975</td>
<td>57 (children, NR)</td>
<td>NR</td>
<td>Clinical mumps; subclinical infection</td>
<td>Longitudinal; pharyngeal swab samples collected as many times as possible after exposure</td>
<td>1. 33 children had clinical infection and 24 had subclinical infection 2. Information presented on isolation of virus relative to parotitis onset in 8 case patients: virus isolated in 25 of 39 (64%) specimens from day 0 (day of onset) to day 5. No virus isolated after day 5 3. Virus isolation was attempted from 7 of the 24 (29%) children with subclinical infection and was successful in 2 during 12–21 days after exposure 4. Primary green monkey kidney cells were used for virus isolation</td>
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<tr>
<td>Knowles and Cohen [35]</td>
<td>United Kingdom</td>
<td>2001</td>
<td>20 (9 months–39 years)</td>
<td>NR</td>
<td>Parotitis</td>
<td>Cross-sectional; conducted during mumps outbreak 1998–1999; compared virus isolation with RT-PCR</td>
<td>1. Mumps virus isolated from 8 of 20 (40%) throat swab specimens with RT-PCR–positive test results 2. When virus was isolated using 2 different cell cultures, 8 of 11 specimens (73%) obtained within 2 days of parotitis onset yielded infectious virus, and 0 of 12 obtained 3–14 days after parotitis onset were positive for virus 3. Secondary thymus monkey kidney cells and EBV-transformed marrow lymphoblastoid cell line B95a were used for virus isolation</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Year</td>
<td>Sample Size</td>
<td>V. Localization</td>
<td>Study Design</td>
<td>Methodology</td>
<td>Outcomes</td>
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<td>Reina et al [32]</td>
<td>Spain</td>
<td>2001</td>
<td>41 (NR)</td>
<td>NR</td>
<td>Parotitis</td>
<td>Cross-sectional; conducted during mumps outbreak; specimens obtained within the first 48 h of illness</td>
<td>1. Mumps virus isolated from 35 of 41 saliva specimens (85%) 2. Vero (green monkey kidney cell), LLC-MK2, MDCK cells, MRC-5 (human lung embryonated), and Hep-2 (Vircell) cell lines were used for virus isolation</td>
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<tr>
<td>Okafuji et al [33]</td>
<td>Japan</td>
<td>2005</td>
<td>75 (NR)</td>
<td>No</td>
<td>Clinical mumps</td>
<td>Cross-sectional; virus isolation, RT-PCR, and LAMP; sequential sampling 34 cases</td>
<td>1. From 75 case patients specimens obtained without onset; 18 of 75 (24%) had negative serology results; of the remaining 57 case patients, results were positive for 30 (53%) by virus isolation, 48 (84%) by LAMP, and 47 (83%) by RT-PCR 2. 34 case patients with mumps: virus was isolated from 30 of 33 specimens (91%) obtained 0–2 days and from 9 of 25 specimens (36%) obtained from 3–7 days after onset 3. Vero cell cultures were used for virus isolation</td>
</tr>
<tr>
<td>Uchida et al [30]</td>
<td>Japan</td>
<td>2005</td>
<td>46 (NR)</td>
<td>NR</td>
<td>Parotitis</td>
<td>Cross-sectional; 46 throat swab samples obtained 0–5 days after onset; virus isolation, Real-time PCR and RT-n-PCR</td>
<td>1. Virus was isolated from 24 of 46 samples (52%) 2. RT-n-PCR results were positive for 33 of 46 samples (72%) 3. Vero cell and BS-C-1 cultures were used for virus isolation</td>
</tr>
<tr>
<td>Yoshida et al [28]</td>
<td>Japan</td>
<td>2008</td>
<td>93 (NR)</td>
<td>No and yes, with some reinfections</td>
<td>Clinical mumps</td>
<td>Cross-sectional; salivary swab samples obtained within 2 days of onset; virus isolation and RT-LAMP</td>
<td>1. Of the 93 cases, A. 25 were primary cases among unvaccinated persons; virus isolated from 64% of samples, and RT-LAMP results positive for 72%, B. 26 were reinfections among unvaccinated persons; virus isolated from 17% of samples, and RT-LAMP results positive for 41%, C. 37 were among vaccinated persons; virus isolated from 41% of samples, and RT-LAMP results positive for 68%, and D. 2 were cases among persons with history of vaccination and mumps infection; virus isolated from 50% of samples, and RT-LAMP results positive for 100% 2. Vero cell cultures were used for virus isolation</td>
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</table>

**NOTE.** EBV, Epstein-Barr virus; LAMP, loop-mediated isothermal amplification; MDCK, Madin-Darby canine kidney; MRC-5, Medical Research Council 5; NR, not reported; PCR, polymerase chain reaction; RT, reverse transcription; RT-n-PCR, reverse transcription nested PCR; TB, tuberculosis.
load served as correlates, albeit imperfect, for the risk of mumps virus transmission. Other scientific evidence considered included mumps severity and the consequences of mumps transmission in high-risk populations and health care settings.

Data on mumps virus isolation and virus load relative to onset of parotitis suggest that the risk of transmission is likely to be highest immediately preceding parotitis onset and then decreases rapidly over the next 5 days. A study from Iowa in 2006 that modeled virus isolation data to estimate the probability of viral shedding by days since disease onset is consistent with these findings, though this study estimated that up to 10% of patients with mumps may be shedding virus 5 days after parotitis onset [41]. Other studies reporting on direct viral isolation showed that by 6–9 days after parotitis onset, mumps virus may rarely be isolated from saliva or respiratory specimens, because by this time, infectious virus has decreased to very low levels. Thus, the risk of mumps transmission after 5 days is considered to be extremely low; most transmission likely occurs before parotitis onset and within the subsequent 5 days. Transmission may occur from patients with mumps before parotitis onset and from persons with subclinical infections who are not isolated. Thus, a 9- versus 5-day isolation after parotitis onset is unlikely to significantly decrease mumps transmission, and the longer isolation is likely to result in higher costs to the individual, the healthcare and public health systems, and the community, as well as reduced compliance [51].

Subclinical mumps infections and milder vaccine-modified clinical illness may play a significant role in mumps transmission. Henle et al [3], in their experimental study of 14 children exposed to a patient with mumps, described similar mumps virus isolation rates over similar time periods from exposure among children with subclinical mumps infections (20 [32%] of 63 specimens), parotitis (8 [30%] of 27), and submaxillary swelling (5 [39%] of 13). Brunell et al [26], in a hospital study of children exposed to mumps virus, documented significant shedding of mumps virus in 2 children with asymptomatic infections. Over 8 days, virus was isolated 4 times in each child. And in mumps outbreaks among highly vaccinated students on college campuses, only 15% of case patients could identify an exposure with clinical mumps. This implies either a low awareness of clinical mumps exposures, transmission from subclinical infections, from atypical modified mumps clinical presentations, or both [15–17].

Termination of mumps virus excretion is likely related to the

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Patients</th>
<th>Virus isolated</th>
<th>Days before onset of parotitis</th>
<th>Days after onset of parotitis</th>
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<tbody>
<tr>
<td>Johnson et al [36]</td>
<td>1954</td>
<td>N=6, S=5</td>
<td>+ + -</td>
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<tr>
<td>Leymaster et al [34]</td>
<td>1947</td>
<td>N=9, S=10</td>
<td>+ + + + +</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Henle et al [3]</td>
<td>1946</td>
<td>N=15, S=33</td>
<td>- - - - + + + +</td>
<td>-</td>
<td></td>
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<tr>
<td>Ennis et al [38]</td>
<td>1965</td>
<td>N=1, S=16</td>
<td>- - - + + + + + + + +</td>
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<tr>
<td>Brunell et al [26]</td>
<td>1969</td>
<td>N=4, S=44</td>
<td>- - - - + + + + + + +</td>
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<tr>
<td>Shope et al [31]</td>
<td>1969</td>
<td>N=3, S=42</td>
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<td>Chiba et al [39]</td>
<td>1973</td>
<td>N=17, S=39</td>
<td>+ + + + + + + + + + +</td>
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<tr>
<td>Isomura et al [37]</td>
<td>1975</td>
<td>N=6, S=56</td>
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<td>Knowles et al [35]</td>
<td>2001</td>
<td>N=20, S=20</td>
<td>+ + + + + + + + + + +</td>
<td>-</td>
<td></td>
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<tr>
<td>Uchida et al [30]</td>
<td>2005</td>
<td>N=46, S=46</td>
<td>+ + + + + + + + + + +</td>
<td>-</td>
<td></td>
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+ Virus isolated  - Virus not isolated

N represents the number of patients; S represents the number of specimens
*Longitudinal studies

Figure 1. Isolation of mumps virus from saliva specimens before and after the onset of parotitis.
development of neutralizing antibodies to mumps virus. Chiba et al [39] studied the relationship between mumps virus excretion and antibodies development and demonstrated that the neutralizing ability of salivary IgA antibody was greater than that of serum IgG or IgM. Salivary antibody was first detected on the 4th day after parotitis onset, coincidental with the termination of virus excretion by the 5th day.

Data are limited concerning the degree to which vaccination affects the duration of viral shedding in patients with mumps, and no studies have examined the effect of vaccination on the contagiousness of patients with mumps. However, the theory of reduced contagiousness in vaccinated case patients is supported by (1) the lower virus isolation rate in vaccinated, compared with unvaccinated, case patients described [28]; (2) shorter duration and the lower rate of viral detection (22%) described in recent studies in vaccinated (or presumed vaccinated) case patients [52], compared with past studies of mumps in unvaccinated persons; and (3) the lower viral load in vaccinated, compared with unvaccinated, case patients [26, 28, 30, 33, 52, 53]. If vaccination reduces the infectious period, this may provide an even larger margin of error for shortening the mumps isolation period from 9 to 5 days in vaccinated populations.

The following limitations should be considered in interpreting the data from our review. First, the few published studies on mumps transmission and mumps virus isolation are limited by study methods and small sample sizes. Second, non-standardized methods for collection of specimens, virus isolation, and detection of viral RNA may have influenced the variation in the study results presented. Third, the following factors may have contributed to overestimation of virus isolation rates: (1) studies may have reported data from case patients with positive virus isolation only, and (2) our method for calculating percentages of specimens positive for mumps virus by day overestimated the likelihood of mumps virus isolation for days 3–14 following parotitis onset. For the study by Knowles et al [35], we did not include negative virus isolation results that were provided for multiple rather than single days (ie, 3–7 and 8–14) (Figure 2).

The most effective strategy for preventing mumps in community and health care settings is promoting high levels of vaccination. Since initiation of the US mumps vaccine program,
the prevalence of mumps has decreased to extremely low levels; even with the 2006 mumps resurgence, the post-vaccine era has seen an overall decrease of 96% in reported mumps cases [54]. One dose of Jeryl-Lynn mumps vaccine is ∼80% (range, 62%–91%) effective in preventing clinical mumps, and 2 doses are ∼90% (range, 79%–95%) effective [1, 15–17, 54–58]. In the United States, 2 doses of MMR vaccine are currently recommended for all children, with the first MMR vaccine dose administered at 12–15 months and the second at 4–6 years. Unless they have other evidence of immunity (documentation of physician-diagnosed mumps, serologic evidence of immunity [i.e., positive mumps IgG results], or birth before 1957), all students in post–high school institutions, including college students, international travelers, and health care personnel, should also receive 2 doses of vaccine [59]. Other adults should receive at least 1 dose.

Health care and public health providers in the United States should be aware that US guidance now recommends isolation of patients with mumps for 5 days in community and hospital settings and exclusion of health care personnel from work for 5 days after parotitis onset. In health care settings, both standard and droplet precautions with respiratory etiquette apply during the 5 day isolation.

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