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Pediatricians' Knowledge and Practices Related to Mumps Diagnosis and Prevention

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Abstract

Objectives: To assess pediatricians' mumps knowledge and testing practices, to identify physician and practice characteristics associated with mumps testing practices, and to assess reporting and outbreak response knowledge and practices.

Study Design: From January–April 2020, we surveyed a nationally representative network of pediatricians. Descriptive statistics were generated for all items. Chi-square, t-tests, and Poisson regression were used to compare physician and practice characteristics between respondents who would rarely or never vs. sometimes or often/always test for mumps in a vaccinated 17-year-old with parotitis in a non-outbreak setting.

Results: The response rate was 67% (297/444). For knowledge, over half of pediatricians responded incorrectly or 'Don't know' for six of nine true/false statements about mumps epidemiology, diagnosis, and prevention; and over half reported they would need additional guidance on mumps buccal swab testing. For testing practices, 59% of respondents reported they would sometimes (35%) or often/always (24%) test for mumps in a vaccinated 17-year-old with parotitis in a non-outbreak setting; older physicians, rural physicians, and physicians from the Northeast or Midwest were more likely to test for mumps. Thirty-six percent of pediatricians

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reported they would often/always report a patient with suspected mumps to public health authorities.

Conclusions: Pediatricians report mumps knowledge gaps and practices that do not align with public health recommendations. These gaps may lead to under-diagnosis and under-reporting of mumps cases, delaying public health response measures and contributing to ongoing disease transmission.

Keywords

mumps; vaccination; pediatrics; outbreak response

Routine mumps vaccination was first recommended in the US in 1977.¹ Responding to measles outbreaks among children with one dose of measles-containing vaccine, in 1989, the Advisory Committee on Immunization Practices (ACIP) recommended routine vaccination with two doses of measles, mumps, and rubella (MMR) vaccine at 12–15 months and 4–6 years of age.² In 2019, 91% of US children had received ≥ 1 dose of MMR by 24 months of age and 92% of adolescents aged 13–17 years had received two doses of MMR.^{3, 4}

The incidence of mumps in the US decreased from 88/100,000 persons in 1968 to 0.1/100,000 persons from 1993 to 2005.⁵ However, a resurgence of mumps began in 2006 with an outbreak of over 6,500 cases of mumps involving 45 states with the highest incidence occurring among young adults aged 18–24 years.^{6, 7} Since 2006, the US has seen numerous mumps outbreaks, many involving young adults living in congregate settings including colleges or universities.^{8–14} Children <18 years of age accounted for about one-third of mumps cases reported 2015–2017 including a significant number of non-outbreak associated cases.¹⁵ Contemporary US mumps epidemiology shows a shift of cases from unvaccinated children aged <10 years to adolescents and young adults, a loss of seasonality, and a majority of cases occurring among vaccinated individuals.^{5, 8, 9} Possible causes of mumps resurgence in the US include a median two-dose vaccine effectiveness of 88%, increased susceptibility among vaccinated individuals due to waning immunity and concern for antigenic variation between vaccine and circulating wild-type virus strains.^{16–18}

Because most mumps cases occur among vaccinated individuals, clinicians should consider testing for mumps in vaccinated, un- and under-vaccinated patients. Because mumps is endemic in the US, a mumps diagnosis should be considered during and outside of identified outbreaks. The Centers for Disease Control and Prevention (CDC) recommends obtaining a buccal swab for mumps RT-PCR and, if ≥ 3 days after onset of parotitis, serum for mumps IgM to test for mumps. RT-PCR is more likely to be negative later in disease course and IgM can be negative among vaccinated patients and when tested before appearance of detectable antibodies.¹⁹ Mumps is a nationally notifiable disease, meaning mumps cases should be reported to public health authorities.²⁰

Amidst increasing mumps cases and outbreaks, in 2017, ACIP recommended a third dose of mumps-containing vaccine for individuals who local public health authorities determine to be at increased risk of infection because of a mumps outbreak.²¹ We hypothesized that pediatricians may not be fully aware of current public health mumps guidance. Using a

national survey, our objectives were to assess among pediatricians mumps knowledge, and testing practices, to identify physician and practice characteristics associated with mumps testing practices, and to assess reporting and outbreak response knowledge and practices.

Methods

From January to April 2020, we administered a survey to a national network of pediatricians who spent $\geq 50\%$ of their time practicing primary care. The University of Colorado Denver human subjects review board approved the study as exempt research not requiring written informed consent.

Study Population

This survey was designed and conducted in collaboration with CDC as part of the Vaccine Policy Collaborative Initiative, which designs and executes surveys to assess physician knowledge, attitudes, and practices about vaccination. We surveyed pediatricians from a sentinel network recruited to be representative of the American Academy of Pediatrics' membership.^{22, 23} Census location was determined based on self-reported zip code matched with most recent census urban/rural classification.

Survey Design

The survey (Appendix 1) was developed in collaboration with CDC, pretested by a national advisory panel of pediatricians (n=6), and piloted among a national sample of physicians (n=26). Based on pediatrician feedback, survey questions were revised for clarity and response choices revised to better reflect experiences of practicing physicians. Pediatricians were asked whether they had ever had a patient with confirmed mumps in their practice. Mumps knowledge was evaluated using a series of true/false questions that included a 'don't know' response option. To assess how often physicians would test patients for mumps in a variety of patient scenarios and how frequently they would order different diagnostic tests to determine the cause of parotitis, four-point Likert scales were used ('Never' to 'Often/Always'). Physicians were asked whether they would test a patient in the office or send them elsewhere for a buccal specimen for mumps RT-PCR, whether they would need guidance for several aspects of testing, and how they would interpret different mumps test results. To evaluate how often pediatricians would report a suspected or confirmed case of mumps to public health authorities, four-point Likert scales were used ('Never' to 'Often/Always'). To assess physician response to a mumps outbreak, a four-point Likert scale to ask how likely they would be to give a third dose of MMR to different patients ('Very unlikely' to 'Very likely'). Physician and practice characteristics assessed included physician gender and age; practice location, size, and type; and practice level of decision-making about vaccines.

Survey Administration

Based on physician preference, the survey was sent via Internet (Qualtrics^{XM}) or mail. We sent the Internet group an initial email with up to eight e-mail reminders, and sent the mail group an initial mailing with up to three reminders.²³ Non-respondents from the Internet group were also sent up to three mail surveys. The mail protocol was modeled after

Dillman's Tailored design method.²⁴ Participants did not receive incentives or payment for participation. Respondents were able to skip items in mail and Internet surveys.

Statistical Analysis

Internet and mail responses were combined for analyses because prior work has shown physician attitudes are similar when obtained by either method.^{25–27} We compared respondents to non-respondents using t-tests, Wilcoxon tests, and chi-squared tests, as appropriate. To assess knowledge and testing practices, we calculated the proportion of respondents choosing correct responses for true/false items and reporting different testing practices. Chi-squared and t-tests were used to compare physician and practice characteristics between respondents who would rarely or never and who would sometimes or often/always test for mumps in a 17-year-old adolescent with parotitis who is fully vaccinated in a non-outbreak setting, a scenario in which mumps testing should be considered. Because logistic regression yields odds ratios that overestimate the effect when the prevalence of an outcome is large (>10%)²⁸, multivariable Poisson regression with robust error variance was used to generate risk ratios.²⁹ Exposure variables for bivariable and multivariable comparisons included available demographic items and whether a respondent had ever had a patient with confirmed mumps in their practice. To assess reporting and outbreak response knowledge and practices, we calculated the proportion of respondents reporting different responses to items about reporting mumps cases and offering mumps vaccination in outbreak scenarios. Analyses were performed using SAS, version 9.4 (SAS Institute, Cary, North Carolina).

Results

The survey response rate was 67% (297/444). Respondents were more likely than non-respondents to be from the Midwest or Northeast and less likely to be from the South. Additional respondent and non-respondent characteristics are presented in Table 1. Twenty-two percent of physicians reported they had ever had a patient with laboratory-confirmed mumps in their practice.

Mumps knowledge

More than 60% of pediatricians responded correctly to true/false statements about use of a third dose of MMR vaccine for at-risk groups during a mumps outbreak, role of serum IgG in diagnosing mumps, and timing of serum IgM testing to diagnose mumps (Figure 1). Over half of physicians either responded incorrectly or that they didn't know regarding statements that previously vaccinated patients who have acute mumps may not have detectable mumps IgM (true), the majority of people in the US who get mumps have been vaccinated (true), and MMR vaccination is effective post-exposure prophylaxis for mumps (false).

Mumps testing practices

When presented with clinical scenarios, physicians reported they would more frequently test for mumps in unvaccinated patients and in outbreak scenarios (Figure 2 online). Over two-thirds of pediatricians reported they would often/always test for mumps in a patient with parotitis plus a mumps complication (meningitis or orchitis) in a non-outbreak scenario.

Less than one-third of pediatricians reported they would often/always test for mumps in a patient with a complication of mumps without parotitis in a non-outbreak scenario. In a non-outbreak scenario, 53% of respondents would never or rarely test for mumps in a fully-vaccinated 7-year-old with parotitis, and 41% would never or rarely test a fully-vaccinated 17-year-old with parotitis.

To diagnose the cause of parotitis in a patient of any age, 46% of pediatricians would often/always order serum mumps IgM, 32% would often/always order serum mumps IgG, and 24% would often/always order a buccal specimen for mumps RT-PCR (Figure 3 online). Fewer respondents would test for other causes of parotitis (EBV, HIV, influenza, and other respiratory viruses). Only 2% of respondents would often/always send a urine specimen for mumps RT-PCR to diagnose the cause of parotitis.

Of 46% of pediatricians who would test a patient for mumps in their clinic, rather than sending a patient to a lab or specialist, a majority reported they would need additional guidance: 71% would need guidance on specimen collection, 69% where to send the specimen, 61% how to order the test, and 53% whether to contact the local health department.

When presented with four different scenarios for mumps diagnostic test results, more than 20% of physicians reported they did not know how to interpret results for each scenario (Figure 4). Fifty-three percent of pediatricians reported a positive mumps IgG and negative mumps IgM would lead them to rule out mumps, but this combination of results can often be seen in vaccinated patients with mumps infection. Thirty-six percent of pediatricians reported a negative mumps RT-PCR alone would lead them to rule out mumps, though RT-PCR results can be negative with improper specimen collection technique or timing.

Physician and practice characteristics associated with mumps testing practices

Bivariable analysis comparing responses to the question ‘How often would you test for mumps for a 17-year-old adolescent with parotitis who is fully vaccinated in a non-outbreak setting’ by physician and clinic characteristics found mean provider age and region of the country were associated with reported testing practices (Table 2 online). Multivariable analysis found older physicians [RR 1.08 (1.02–1.33) per 5 year increase in age], rural physicians [RR 1.42 (1.12–1.81)], physicians from the Midwest [RR 1.42 (1.07–1.89)] or Northeast [RR 1.50 (1.15–1.96)], and physicians who had ever had a patient with laboratory-confirmed mumps in their practice [RR 1.46 (1.21–1.76)] were more likely to indicate they would sometimes or often/always test for mumps.

Mumps reporting and outbreak response knowledge and practices

Overall, 97% of pediatricians indicated they would often/always report a patient with laboratory-confirmed mumps to public health authorities; however, only 36% indicated they would often/always report a patient with suspected mumps based on history and physical exam.

Pediatrician responses about likelihood of giving a third dose of MMR vaccine in clinical scenarios related to a mumps outbreak at a local university are presented in Figure 5; 97%

of respondents indicated they would very likely give a third dose of MMR to a student who had previously received two doses of MMR and had documentation of being part of a specified group recommended by the health department to get a third dose; this response aligns with public health guidance. Twenty-four percent of physicians reported they would be somewhat/very unlikely to give a third dose of MMR to a student who had previously received two doses of MMR and is part of a specified group recommended by the health department to get a third dose and has positive mumps IgG; forgoing a third MMR dose for patients with positive IgG in this scenario does not match public health guidance. Seventy-one percent of respondents indicated they would be somewhat/very likely to give a third dose of MMR to a student who had previously received two doses of MMR and requests vaccination but is NOT part of the specified groups recommended by the health department to get a third dose.

Discussion

In this nationally representative survey, we examined pediatricians' mumps knowledge and testing practices, identified physician and practice characteristics associated with mumps testing practices, and assessed reporting and outbreak response knowledge and practices. Over half of physicians either responded incorrectly or that they did not know regarding most of the true/false statements used to assess mumps knowledge. Testing practices were influenced by vaccination and outbreak status: in a non-outbreak scenario, 53% of respondents would never or rarely test for mumps in a fully-vaccinated 7-year-old with parotitis, and 41% would never or rarely test a fully-vaccinated 17-year-old with parotitis. Pediatricians' responses about mumps testing, required public health reporting, and outbreak response revealed knowledge gaps and discrepancies between reported and recommended practices, which may lead to under-diagnosis of mumps.

Reported testing practices showed several ways mumps diagnoses may be missed by pediatricians. Although it is understandable physicians may more often suspect mumps among under-vaccinated compared to fully-vaccinated children, current epidemiology of mumps in settings with high mumps vaccination rates shows a majority of cases occur among fully-vaccinated people.^{5, 21, 30} From 2015 to 2017, just over 20% of reported mumps cases in the US were among fully-vaccinated children <18 years old.¹⁵ Pediatricians also reported they would more frequently test for mumps in outbreak compared to non-outbreak scenarios. However, from 2010–2015, 58% of reported mumps cases were not part of large outbreaks (≥ 20 cases).⁸ Mumps is endemic in the US with cases reported in almost every state in recent years, so clinicians should consider mumps even in absence of a known outbreak.³¹ Failure to suspect and test for mumps in a patient with compatible symptoms may contribute to under-diagnosis and delayed identification of new outbreaks if sporadic cases are not identified and reported. Public health communication and educational resources should emphasize this need for increased vigilance for mumps beyond identified outbreaks.

Physicians' reported practices for laboratory test ordering and interpretation also revealed missed opportunities for diagnosing mumps. Mumps is one of many causes of parotitis and although there is no treatment for mumps, diagnosing mumps is crucial for public health

response.^{18, 32} Both buccal swab for RT-PCR, which is more likely to be positive within three days of parotitis onset, and serum IgM, which is more likely to be positive after three days, are recommended tests for diagnosing mumps in patients with parotitis.^{19, 33} Most pediatricians (53%) reported receiving a negative mumps RT-PCR alone would lead them to rule out mumps and 22% reported they didn't know how to interpret the results. Buccal swab for mumps RT-PCR may be negative in patients who are infected due to inadequate specimen collection or if the specimen is obtained later in the disease course, thus a negative buccal swab RT-PCR alone does not rule out mumps in a patient with compatible symptoms.^{9, 33} When clinicians suspect mumps, cases may still go undiagnosed if they do not send appropriate testing or are unsure how to interpret results.³⁴ In addition to providing information about epidemiology, provider support tools should include clear guidance about recommended laboratory testing, specimen collection technique,^{35, 36} and test interpretation.

Early identification and reporting of mumps cases is key to outbreak detection and response and requires partnership between clinicians and public health agencies. While nearly all pediatricians (97%) stated they would often/almost always report a laboratory-confirmed mumps case to public health, only 36% said the same for a suspected mumps case based on history and physical exam. Mumps is a nationally notifiable disease and all suspected and laboratory-confirmed cases should be reported to public health authorities.²⁰ Not reporting suspected mumps cases may lead to underestimation of mumps activity or delayed outbreak identification.^{34, 37} A third dose of MMR is recommended for individuals who have previously received two doses of mumps-containing vaccine and are identified by public health authorities as being part of a population or group at increased risk of acquiring mumps due to an outbreak.²¹ Pediatricians' responses about giving a third dose of MMR in hypothetical patient scenarios highlighted another disconnect between clinical practice and public health recommendations and a need for improved partnership and communication.

When presented with a patient scenario that would warrant consideration of mumps but might require a higher degree of clinician vigilance for the diagnosis (a fully vaccinated 17-year-old with parotitis in a non-outbreak scenario), older physicians, rural physicians, and physicians from the Midwest or Northeast more often reported they would sometimes or often/always test for mumps. Older pediatricians may be more likely to test for mumps because they have more clinical experience before mumps incidence was greatly reduced by two-dose MMR vaccination. The evolution of mumps epidemiology may also have impacted the testing practice of pediatricians. Prior to widespread vaccination with two doses of MMR, mumps was most frequently seen in school-aged children and was clearly endemic with a seasonal pattern of activity.⁵ Frequent mumps outbreaks in more recent years most often involved young adults and were often well-publicized.^{5, 6, 21} These outbreaks may have more strongly impacted practice patterns of younger physicians, leaving them with the impression that mumps is no longer a predominantly pediatric disease and occurs mostly in association with outbreaks. Regional differences in testing practices may reflect the impact of local experiences with large mumps outbreaks, although mumps cases have been reported in almost all states in recent years.^{6-8, 10, 13, 14, 38-40}

This study has several limitations. Respondents may have differed from non-respondents in their mumps knowledge and practices. Respondents may not be fully representative of all pediatricians, although network physicians have been shown to be similar to physicians sampled randomly from the American Medical Association (AMA) Physician Masterfile with regard to practice characteristics, demographics, and attitudes about vaccination.²² Having proportionally fewer respondents from the South limits conclusions about the knowledge and practices of pediatricians in that region and may have biased overall results by having less representation of clinical and epidemiologic conditions in the South. We measured knowledge and practices by self-report, but actual pediatrician behavior was not assessed. External validity of this survey is limited because we did not include other physicians who care for children, adolescents, and young adults with mumps. Family and internal medicine clinicians may be less likely to test for mumps if they view mumps as a childhood disease or more likely to test if they have knowledge or experience related to outbreaks in young adults. Dedicated research to understand mumps knowledge and practices among non-pediatrician clinicians can help inform communication efforts that serve all clinicians caring for children and adolescents.

Pediatricians report knowledge gaps related to mumps, testing, and prevention, and practices that did not align with CDC recommendations for disease reporting and administration of a third dose of MMR if recommended by public health authorities during mumps outbreaks. These gaps in mumps knowledge and practices may lead to under-diagnosis and under-reporting of mumps cases, which hampers mumps outbreak recognition and control by public health authorities. Resources for pediatricians should emphasize epidemiologic and testing information needed to suspect, test for, and accurately diagnose and report mumps. Successful mumps control efforts also require strengthening communication and cooperation between pediatricians and public health authorities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

ACIP	Advisory Committee on Immunization Practices
CDC	Centers for Disease Control and Prevention

MMR	measles, mumps, and rubella vaccine
RT-PCR	reverse transcription polymerase chain reaction
IgG	immunoglobulin G
IgM	immunoglobulin M

References

- [1]. Centers for Disease Control and Prevention. Recommendation of Public Health Service Advisory Committee on Immunization Practices: Mumps vaccine. *Morbidity and Mortality Weekly Report*. 1977;26:393–4.
- [2]. Centers for Disease Control and Prevention. Measles prevention. *MMWR Supplement*. 1989;38:1–18.
- [3]. Elam-Evans LD, Yankey D, Singleton JA, Sterrett N, Markowitz LE, Williams CL, et al. National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years - United States, 2019. *MMWR Morbidity and Mortality Weekly Report*. 2020;69:1109–16. [PubMed: 32817598]
- [4]. Hill HA, Yankey D, Elam-Evans LD, Singleton JA, Pingali SC, Santibanez TA. Vaccination Coverage by Age 24 Months Among Children Born in 2016 and 2017 - National Immunization Survey-Child, United States, 2017–2019. *MMWR Morbidity and Mortality Weekly Report*. 2020;69:1505–11. [PubMed: 33090985]
- [5]. Barskey AE, Glasser JW, LeBaron CW. Mumps resurgences in the United States: A historical perspective on unexpected elements. *Vaccine*. 2009;27:6186–95. [PubMed: 19815120]
- [6]. Dayan GH, Quinlisk MP, Parker AA, Barskey AE, Harris ML, Schwartz JM, et al. Recent resurgence of mumps in the United States. *New England Journal of Medicine*. 2008;358:1580–9. [PubMed: 18403766]
- [7]. Centers for Disease C, Prevention. Update: multistate outbreak of mumps--United States, January 1–May 2, 2006. *MMWR Morbidity and Mortality Weekly Report*. 2006;55:559–63. [PubMed: 16723967]
- [8]. Clemmons NS, Redd SB, Gastanaduy PA, Marin M, Patel M, Fiebelkorn AP. Characteristics of Large Mumps Outbreaks in the United States, July 2010–December 2015. *Clinical Infectious Diseases*. 2019;68:1684–90. [PubMed: 30204850]
- [9]. Lam E, Rosen JB, Zucker JR. Mumps: an Update on Outbreaks, Vaccine Efficacy, and Genomic Diversity. *Clinical Microbiology Reviews*. 2020;33.
- [10]. Shah M, Quinlisk P, Weigel A, Riley J, James L, Patterson J, et al. Mumps Outbreak in a Highly Vaccinated University-Affiliated Setting Before and After a Measles-Mumps-Rubella Vaccination Campaign-Iowa, July 2015–May 2016. *Clinical Infectious Diseases*. 2018;66:81–8. [PubMed: 29020324]
- [11]. Donahue M, Schneider A, Ukegbu U, Shah M, Riley J, Weigel A, et al. Notes from the Field: Complications of Mumps During a University Outbreak Among Students Who Had Received 2 Doses of Measles-Mumps-Rubella Vaccine - Iowa, July 2015–May 2016. *MMWR Morbidity and Mortality Weekly Report*. 2017;66:390–1. [PubMed: 28406886]
- [12]. Cervantes D, Honza H, Lynch D, Janoski N, Asghar J, Lockwood L, et al. Notes from the Field: Mumps Outbreak Associated with Cheerleading Competitions - North Texas, December 2016–February 2017. *MMWR Morbidity and Mortality Weekly Report*. 2018;67:1019–20. [PubMed: 30212445]
- [13]. Centers for Disease Control and Prevention. Mumps outbreak on a university campus--California, 2011. *MMWR Morbidity and Mortality Weekly Report*. 2012;61:986–9. [PubMed: 23222373]
- [14]. Golwalkar M, Pope B, Stauffer J, Snively A, Clemmons N. Mumps Outbreaks at Four Universities - Indiana, 2016. *MMWR Morbidity and Mortality Weekly Report*. 2018;67:793–7. [PubMed: 30048422]
- [15]. Marlow M, Zhang J, Clemmons NS, Marin M, Patel M, Patel M. 2765. Pediatric Mumps during the 2015–2017 Mumps Resurgence in the United States. *Open Forum Infectious Diseases*. 2019;6:S975–S.

- [16]. Bankamp B, Hickman C, Icenogle JP, Rota PA. Successes and challenges for preventing measles, mumps and rubella by vaccination. *Curr Opin Virol.* 2019;34:110–6. [PubMed: 30852425]
- [17]. Plotkin SA. Commentary: Mumps vaccines: do we need a new one? *Pediatr Infect Dis J.* 2013;32:381–2. [PubMed: 23552675]
- [18]. Clemmons N, Hickman C, Lee A, Marin M, Patel M. Mumps. Manual for the surveillance of vaccine-preventable diseases: Centers for Disease Control and Prevention; 2018.
- [19]. Centers for Disease Control and Prevention. Laboratory Testing for Mumps Infection: Questions and Answers about Lab Testing. 2017.
- [20]. Centers for Disease Control and Prevention. National Notifiable Diseases Surveillance System.
- [21]. 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;67:33–8. [PubMed: 29324728]
- [22]. Crane LA, Daley MF, Barrow J, Babbel C, Stokley S, Dickinson LM, et al. Sentinel physician networks as a technique for rapid immunization policy surveys. *Eval Health Prof.* 2008;31:43–64. [PubMed: 18184632]
- [23]. Brtnikova M, Crane LA, Allison MA, Hurley LP, Beaty BL, Kempe A. A method for achieving high response rates in national surveys of U.S. primary care physicians. *PLoS One.* 2018;13:e0202755. [PubMed: 30138406]
- [24]. Dillman DA, Smyth J, Christian LM. Internet, Mail and Mixed-Mode Surveys: The Tailored Design Method, 3rd Edition. New York, NY: John Wiley Co.; 2009.
- [25]. Dillman DA, Smyth JD, Christian LM. Internet, phone, mail, and mixed-mode surveys: the tailored design method: John Wiley & Sons; 2014.
- [26]. Atkeson LR, Adams AN, Bryant LA, Zilberman L, Saunders KL. Considering mixed mode surveys for questions in political behavior: using the Internet and mail to get quality data at reasonable costs. *Political Behavior.* 2011;33:161–78.
- [27]. McMahon SR, Iwamoto M, Massoudi MS, Yusuf HR, Stevenson JM, David F, et al. Comparison of e-mail, fax, and postal surveys of pediatricians. *Pediatrics.* 2003;111:e299–e303. [PubMed: 12671142]
- [28]. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA.* 1998;280:1690–1. [PubMed: 9832001]
- [29]. McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol.* 2003;157:940–3. [PubMed: 12746247]
- [30]. Ramanathan R, Voigt EA, Kennedy RB, Poland GA. Knowledge gaps persist and hinder progress in eliminating mumps. *Vaccine.* 2018;36:3721–6. [PubMed: 29784466]
- [31]. Centers for Disease Control and Prevention. Mumps Cases and Outbreaks. 2020.
- [32]. Maldonado YA, Shetty AK. Mumps Virus. In: Long SS, Fischer M, Prober CG, editors. *Principles and Practice of Pediatric Infectious Diseases.* 5th ed: Elsevier; 2018.
- [33]. Rota JS, Rosen JB, Doll MK, McNall RJ, McGrew M, Williams N, et al. Comparison of the sensitivity of laboratory diagnostic methods from a well-characterized outbreak of mumps in New York city in 2009. *Clin Vaccine Immunol.* 2013;20:391–6. [PubMed: 23324519]
- [34]. Patel LN, Arciuolo RJ, Fu J, Giancotti FR, Zucker JR, Rakeman JL, et al. Mumps Outbreak Among a Highly Vaccinated University Community-New York City, January-April 2014. *Clin Infect Dis.* 2017;64:408–12. [PubMed: 27927872]
- [35]. Centers for Disease Control and Prevention. Mumps Job-Aid Template for Providers. 2019.
- [36]. Centers for Disease Control and Prevention. Collecting a Buccal Swab Clinical Specimen for Mumps Diagnostic Testing. 2017.
- [37]. Doyle JS, Paige EK, Spelman DW. Mumps presenting as epididymo-orchitis among young travellers: under-recognition, missed diagnoses and transmission risks. *Med J Aust.* 2011;194:317–8. [PubMed: 21426289]
- [38]. Albertson JP, Clegg WJ, Reid HD, Arbise BS, Pryde J, Vaid A, et al. Mumps Outbreak at a University and Recommendation for a Third Dose of Measles-Mumps-Rubella Vaccine - Illinois, 2015–2016. *MMWR Morb Mortal Wkly Rep.* 2016;65:731–4. [PubMed: 27467572]

- [39]. Barskey AE, Schulte C, Rosen JB, Handschur EF, Rausch-Phung E, Doll MK, et al. Mumps outbreak in Orthodox Jewish communities in the United States. *N Engl J Med*. 2012;367:1704–13. [PubMed: 23113481]
- [40]. Isaac BM, Zucker JR, MacGregor J, Asfaw M, Rakeman JL, Fu J, et al. Notes from the Field: Use of Social Media as a Communication Tool During a Mumps Outbreak - New York City, 2015. *MMWR Morb Mortal Wkly Rep*. 2017;66:60–1. [PubMed: 28103208]

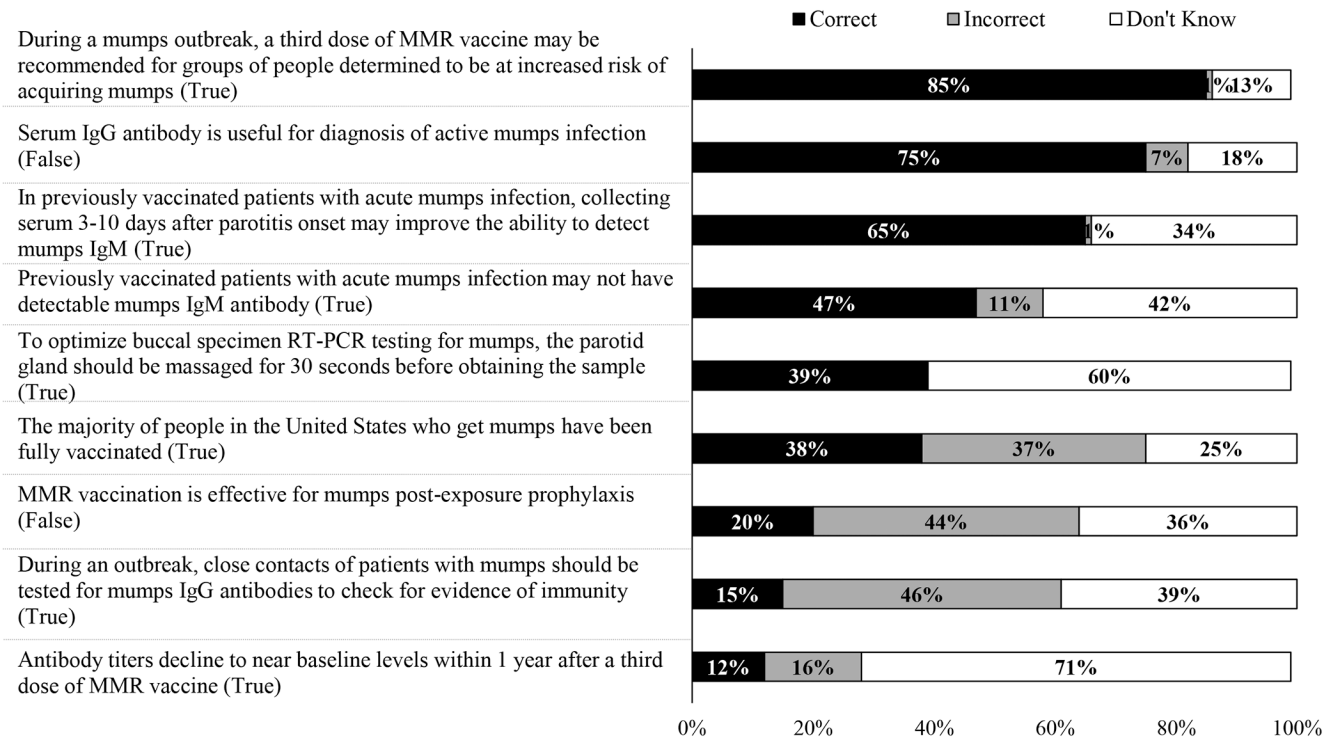
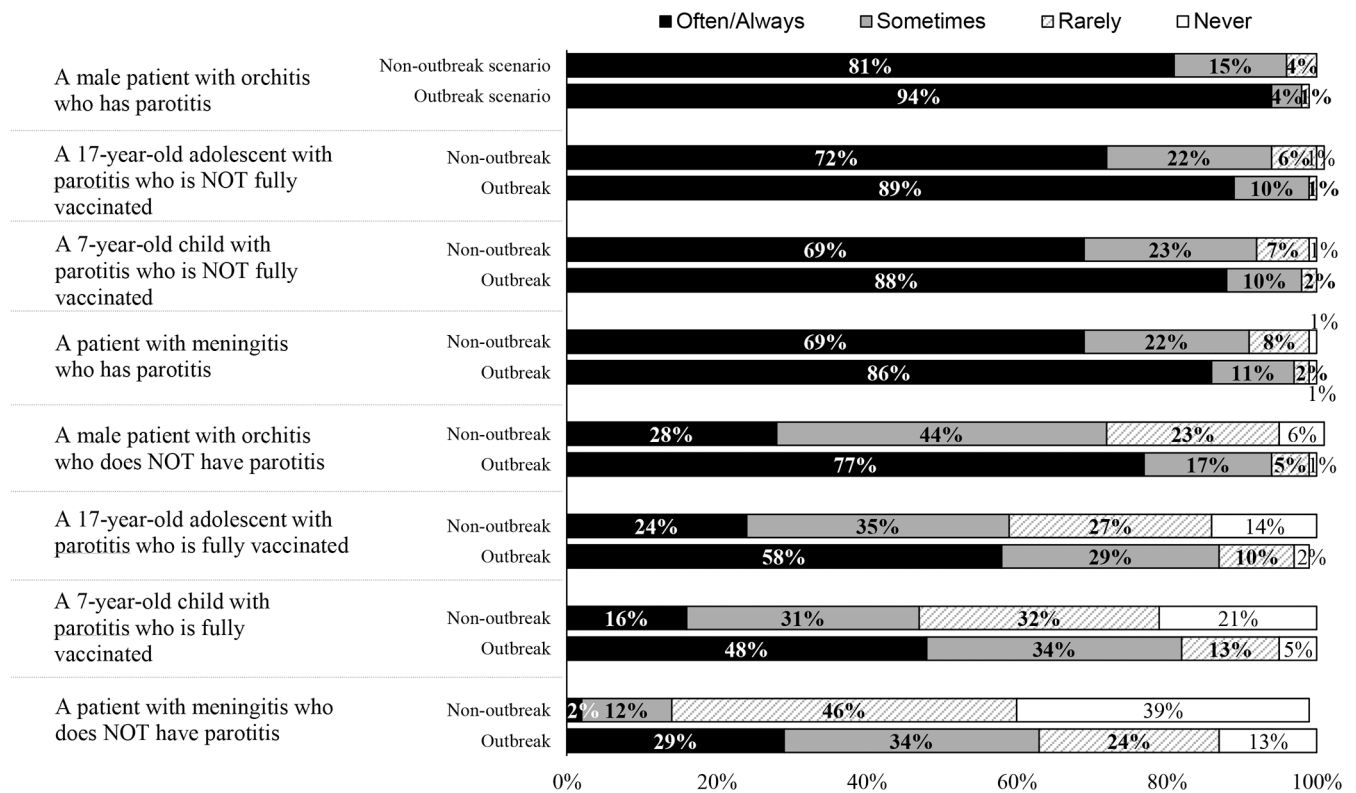


Figure 1:
 Pediatrician knowledge about mumps as measured by responses to true/false statements
 (n=297)
 Percentages may not add up to 100% due to rounding; MMR=measles, mumps, rubella
 vaccine; IgG=immunoglobulin G; IgM=immunoglobulin M; RT-PCR=reverse transcription
 polymerase chain reaction

**Figure 2 online:**

Pediatrician mumps testing practices for different clinical scenarios (n=297)

Percentages may not add up to 100% due to rounding. Parotitis, meningitis, and orchitis are each symptoms of mumps and may be indications for testing for mumps among vaccinated and unvaccinated patients in outbreak and non-outbreak scenarios.

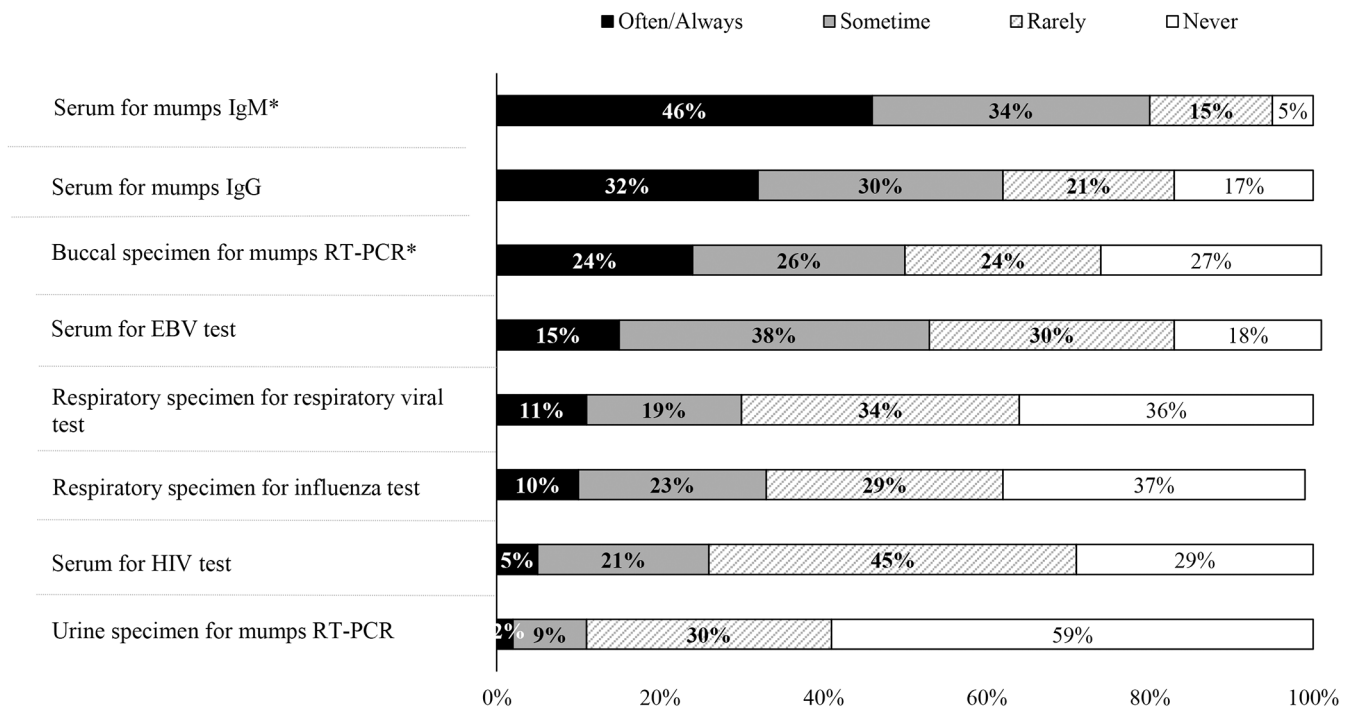


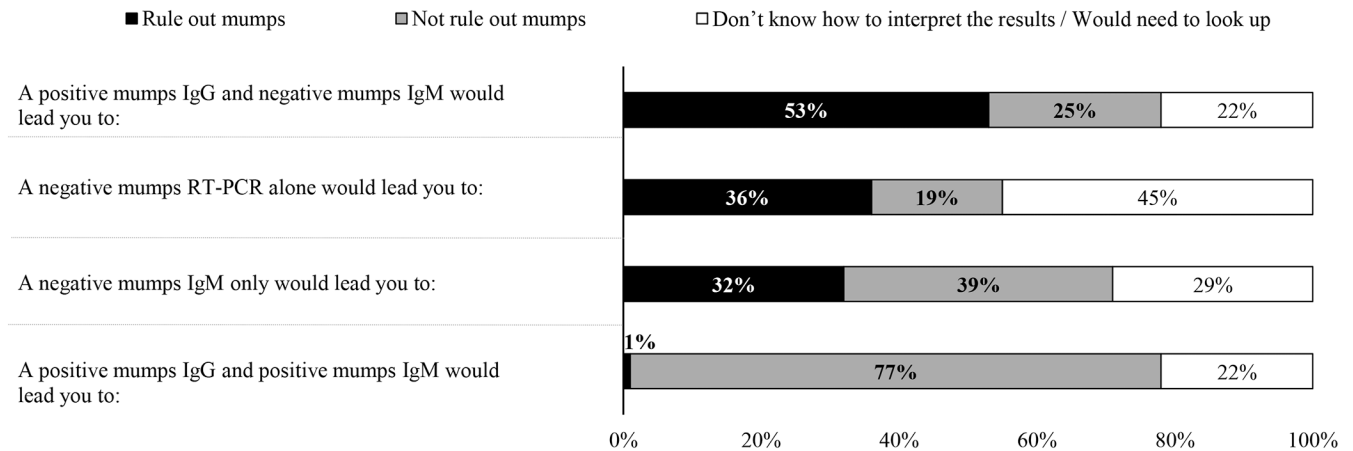
Figure 3 online:

Pediatricians' testing practices to diagnose the cause of parotitis (n=297)

Percentages may not add up to 100% due to rounding; IgM=immunoglobulin

M, IgG=immunoglobulin G, EBV=Epstein-Barr Virus, RT-PCR=reverse transcription

polymerase chain reaction. *The Centers for Disease Control and Prevention recommend sending both serum for mumps IgM and a buccal specimen for RT-PCR to test for mumps in patients with compatible clinical features.

**Figure 4:**

Interpretation of laboratory test results to diagnose mumps in a patient with parotitis (n=297)

Percentages may not add up to 100% due to rounding; RT-PCR=reverse transcription

polymerase chain reaction, IgM=immunoglobulin M, IgG=immunoglobulin G. None of the laboratory test results presented are sufficient to rule out mumps in a patient with parotitis.

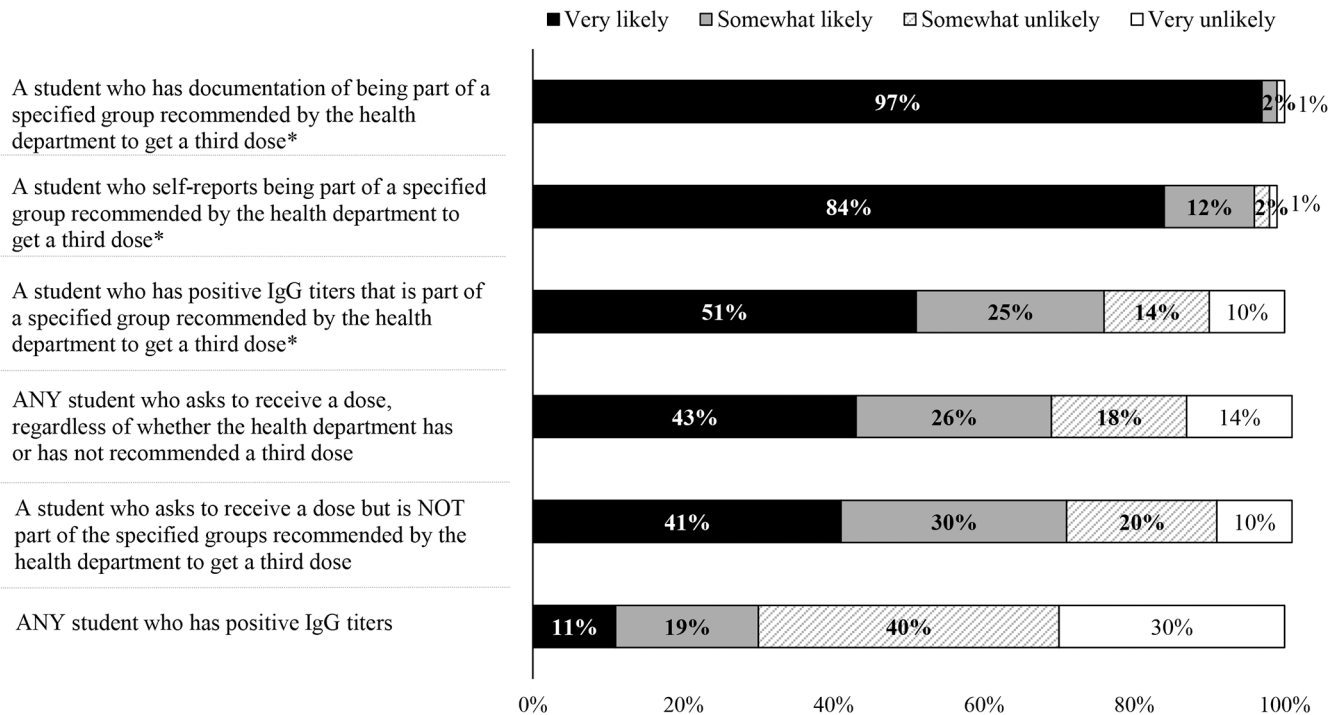
Positive mumps IgG with negative IgM can occur in previously vaccinated patients infected with mumps.

Negative mumps RT-PCR in an infected individual can occur if specimen collection technique or timing is not optimal.

Negative mumps IgM can be seen in an infected individual if specimen collected before the appearance of detectable antibodies.

Positive mumps IgG with positive IgM suggest recent mumps infection.

Positive mumps IgG with positive IgM suggest recent mumps infection.

**Figure 5:**

Likelihood that physicians would give a third dose of MMR vaccine to a previously vaccinated student in different mumps outbreak scenarios (n=297)

Percentages may not add up to 100% due to rounding; IgG=immunoglobulin G. *The Centers for Disease Control and Prevention recommends a third dose of MMR vaccine be given to persons previously vaccinated with two doses who are identified by public health authorities as being part of a group at increased risk for acquiring mumps because of an outbreak regardless of mumps IgG.

Table 1:

Pediatrician and clinic characteristics of survey respondents and non-respondents (n=444)

Characteristic	Category	Non-respondents (N=147)	Respondents (N=297)	P-value (chi-square test)
Provider gender	Female	69% (101)	63% (188)	0.26
Practice setting	Hospital or Clinic	18% (27)	16% (47)	0.77
	HMO	4% (6)	4% (11)	
	Private practice	78% (114)	80% (239)	
Census Location	Rural	1% (1)	1% (3)	0.82 *
	Urban-Non-Inner city	44% (64)	46% (138)	
	Urban-Inner city	56% (82)	53% (156)	
Region of Country	Midwest	18% (27)	23% (69)	0.02
	Northeast	14% (21)	24% (70)	
	South	46% (68)	33% (99)	
	West	21% (31)	20% (59)	
Decision-making about vaccines	Independent	68% (99)	71% (204)	0.58
	Larger System Level	32% (46)	29% (84)	
Age of provider in years [mean (SD)]		52.3 (10.6)	54.1 (10.5)	0.08
Number of providers in practice [median (IQR)]		5.0 (4.0–10.0)	6.0 (3.0–9.0)	0.64 ^

* Fischer's exact test,

^ Wilcoxon test

Table 2 online:

Pediatrician and clinic characteristics associated with testing for mumps in a vaccinated adolescent with parotitis in a non-outbreak setting

		How often would you test for mumps for a 17-year-old with parotitis who is fully vaccinated in a non-outbreak setting?				
Variable	Category	Rarely / Never (N=116)	Sometimes / Often / Always (N=168)	Bivariable P-value	Multivariable RR (95% CI)	Multivariable P-value
Practice setting	Univ/Hosp/ Public/Other	14% (16)	17% (29)	0.71	1.27 (0.97–1.67)	0.27
	HMO	4% (5)	4% (6)		1.01 (0.58–1.76)	
	Private practice	82% (95)	79% (133)		Ref.	
Self-Reported Location	Rural	7% (8)	13% (21)	0.27	1.42 (1.12–1.81)	0.047
	Urban-Non- Inner	80% (93)	73% (123)		Ref.	
	Urban-Inner	13% (15)	14% (24)		0.99 (0.73–1.35)	
Region of Country	Midwest	20% (23)	26% (43)	0.02	1.42 (1.07–1.89)	0.02
	Northeast	17% (20)	29% (48)		1.50 (1.15–1.96)	
	South	42% (49)	26% (44)		Ref.	
	West	21% (24)	20% (33)		1.27 (0.92–1.75)	
Decision-making	Independent	72% (82)	70% (114)	0.78	Ref.	0.86
	Larger System Level	28% (32)	30% (48)		0.98 (0.78–1.23)	
Proportion of patents insured by Medicaid or your state's CHIP	0–49%	72% (78)	69% (114)	0.61	Ref.	0.62
	>=50%	28% (31)	31% (52)		0.95 (0.76–1.18)	
Have you ever had a patient with laboratory-confirmed mumps in your practice?	Yes	9% (10)	32% (54)	<0.001	1.46 (1.21–1.76)	0.0003
	No	91% (105)	68% (113)		Ref.	
Mean (sd) age of provider in years		51.7 (10.5)	56.0 (10.2)	<0.001	1.08 (1.02–1.13) per 5 year increase in age	0.004