An Outbreak of Measles among Unvaccinated Young Adults and Measles Seroprevalence Study: Implications for Measles Outbreak Control in Adult Populations

Kristen R. Ehresmann,1,a Norman Crouch,2 Paula M. Henry,1 John M. Hunt,2,a Tonia L. Habedank,2,a Robert Bowman,4 and Kristine A. Moore 1,a

1Acute Disease Epidemiology Section, Division of Disease Prevention and Control, and 2Public Health Laboratory Division, Minnesota Department of Health, Minneapolis, and 3St. Paul–Ramsey County Department of Public Health and 4Medical School, University of Minnesota, Minneapolis

Measles incidence has declined significantly in the United States since the 1989–1991 resurgence. Several conditions, including pockets of underimmunization, international importation, and the inability to rapidly detect and contain cases, represent potential threats to this success. During the 1995–1996 winter holiday season, the Minnesota Department of Health investigated an outbreak of measles among unvaccinated young adults affiliated with a religious community. A total of 26 outbreak-associated cases of measles were identified; most case patients (65%) were 20–29 years of age (range, 18 months to 35 years). Although case patients had multiple opportunities to expose the general public, no subsequent transmission was identified despite extensive surveillance efforts. A measles seroprevalence survey of 508 Minnesota blood donors aged 20–39 years was conducted; 91% had serological evidence of immunity to measles. Our findings illustrate that high levels of population immunity can prevent transmission of measles, despite multiple opportunities for exposure.

The incidence of measles in the United States in the year 2000 has reached a record low since the 1989–1991 measles resurgence, with <1 case per million population reported [1]. Additionally, the epidemiology of reported measles cases has changed, with implications for public health and outbreak control. These changes include a shift in incidence from preschool-aged children to older age groups, an increasing proportion of international importations, and a disease focus among groups whose members do not routinely accept vaccination, such as those opposed to vaccination for religious or philosophical reasons [2]. Surveillance for measles in the United States represents a critical component of the measles outbreak control strategy; however, surveillance systems are, by definition, imperfect [3]. The current limitations of the US surveillance system, coupled with the risk of pockets of unvaccinated persons and international importation, suggest that measles could be continuously reestablished in the United States [3]. A recent study of population immunity for measles in the United States that made use of the National Health and Nutrition Examination Survey data found that 93% of the population was immune to measles [4]. Thus, the level of population immunity is so high, it is likely that personal and herd immunity will prevent the reestablishment of measles in the United States despite international importations and the surveillance system’s limited ability to rapidly detect and contain cases. We report a 1996 outbreak of measles in Minnesota that provides a striking local illustration of this. Measles was extensively introduced into the Minneapolis–St. Paul metropolitan area by members of
an unvaccinated religious community; cases went undetected and unreported until the third generation. Despite this, no spread within the general population occurred because of high levels of population immunity.

**METHODS**

**Outbreak investigation.** On 6 January 1996, the Minnesota Department of Health was notified by a local emergency room of 2 young adult males presenting with a history of upper respiratory tract symptoms, fever >39.4°C, and fine rash; measles was suspected. Both patients were treated for dehydration; 1 was hospitalized. Both case patients had positive results of serological testing for measles IgM antibody using the Centers for Disease Control and Prevention (CDC)'s IgM capture assay. Although neither case patient had a clear exposure history for measles, several friends had had similar symptoms, and a cousin of one of the case patients was hospitalized concurrently in Wisconsin with a similar clinical presentation.

Both patients were affiliated with the same religious group in St. Paul. At its inception in 1972, the community was opposed to immunization; vaccination rates in this religious group remained low. The ~450 members of this religious community share economic, social, and religious activities. Members live in community-owned housing, including triplexes, apartments, and dormitories. There is a kindergarten–grade 12 school for children in this community, with extensive extracurricular activities; the school is well known for its outstanding basketball teams. Young adults who no longer live in community housing maintain social contacts with the group, particularly during the holiday season.

A clinical case of measles was defined by the following criteria: history of cough, coryza, or conjunctivitis; temperature of ≥38.3°C; and a characteristic generalized rash lasting for ≥3 days. Cases were confirmed on the basis of isolation of the virus from a clinical specimen, a 4-fold rise in titer of IgG antibody to measles virus, or a positive result of serological testing for measles IgM antibody [5]. Case patients with measleslike symptoms who could be linked epidemiologically to a laboratory-confirmed case also were considered confirmed. Virus specimens collected from several of the case patients were sent to the CDC for molecular genotyping.

Surveillance to identify cases within the religious group began immediately. To identify measles cases outside the religious group, the following steps were taken: A press release was issued, notifying the public of the measles cases and encouraging persons with compatible symptoms to seek medical attention; a telephone number was established for persons to call with immunization questions and reports of rash illness; the public health and medical communities received regular updates; and enhanced surveillance for rash illness in the general population was established.

Outbreak control activities included canceling extracurricular activities at the religious group’s school until 2 weeks after rash onset for the last identified case; providing measles, mumps, and rubella (MMR) vaccine for members of the religious group; and providing immune globulin to nonimmune pregnant women and infants <6 months of age in the religious group. No recommendations were made to provide second doses of measles-containing vaccine to the general public.

**Serosurvey.** Retained serum samples (n = 508) from the Red Cross Regional Blood Services, representing routine blood donations between 7 and 17 October 1996, were tested for measles antibody. Donors were selected on the basis of age (20–29 or 30–39 years of age) and residence (the Minneapolis–St. Paul metropolitan area). Immunity to measles was evaluated by use of a rubeola IgG ELISA (product no. RBE 100; Gull Laboratories) according to the manufacturer’s instructions. Compared with that of a commercially available immunofluorescent antibody test, the sensitivity of this assay was 96.4% and the specificity was 100% [6]. Equivocal specimens were not included in the statistical analyses. Approval for human subject research was received from the Committee for the Protection of Human Subjects, American Red Cross Biomedical Services.

**Statistical analysis.** Odds ratios and 95% confidence intervals were determined by standard univariate analyses. Differences in proportions were tested with χ² or Fisher’s exact test [7].

**RESULTS**

**Outbreak.** Twenty-six cases were associated with the outbreak, including 2 Wisconsin residents. Rash onsets occurred between 29 November 1995 and 30 January 1996 (figure 1). Thirteen cases were laboratory-confirmed with a positive result of serological testing for measles IgM antibody by the CDC IgM capture assay; the remaining 13 cases were linked epidemiologically to a laboratory-confirmed case. Twenty-five case patients had had some social contact with members of the religious group. The remaining case patient was a 35-year-old...
medical receptionist who worked at a clinic where several of the case patients were evaluated.

The case patients ranged in age from 18 months to 35 years. The majority (16 [62%]) were young adults aged 20–29 years, 3 were >30 years of age, 6 were 10–19 years of age, and 1 was 18 months old. At the time of the outbreak, only 34% of the age-eligible community members had received 1 dose of MMR. Of those members ≥18 years of age, only 16% had documentation of having received 1 dose of MMR. Of the 26 patients with outbreak-associated cases, only 1 (the 18-month-old child) had a documented measles vaccination history. After on-site immunization clinics were held, the immunization rate for age-eligible persons within the religious community increased to 91%; the rate for receipt of 2 doses of MMR vaccine increased from 7% to 60%.

All 24 Minnesota case patients were associated with the religious group (e.g., members of the religious community or their adult children). However, only 12 case patients lived in religious community housing at the time of the outbreak; the remaining 12 lived in the community at large. Despite the communal nature of the religious community, case patients had multiple opportunities for exposure within the community at large. At least 18 medical visits to 7 different clinics and 3 hospital emergency rooms were documented; 1 case patient was hospitalized. Fifteen of these visits were made by case patients with history of prodrome and rash illness before health care providers alerted public health officials. Case patients were employed in a variety of settings, including retail establishments, a building supply company, a carpet cleaning service, a snow removal service, restaurants, and a physician’s office. One case patient was a student at a St. Paul high school. Case patients reported multiple visits to malls, bars, and restaurants throughout the Minneapolis–St. Paul area during their infectious period.

The Minnesota Department of Health laboratory isolated measles virus from urine and throat specimens of 2 case patients who had positive results of serological testing for measles IgM. Molecular genotyping of these isolates identified a strain similar to a strain associated with a measles outbreak in San Antonio, Texas, in October 1995. The source of that outbreak is unknown; however, the strain is genetically related to a strain that caused measles in the Netherlands in 1991 [8].

**Serosurvey.** Sera from 245 persons 20–29 years of age and 263 persons 30–39 years of age were tested. Four hundred sixty-three blood donors (91% [95% confidence interval, 88%–94%]) had serological evidence of immunity to measles, 45 (9%) did not have detectable antibody, and 2 (<1%) had equivocal results.

When immune status was compared by age group, donors in the 20- to 29-year age group were slightly less likely to be immune to measles than were donors 30–39 years of age. Twenty-nine (12%) of those 20–29 years old were not immune, compared with 16 (6%) of those 30–39 years old (odds ratio, 2.09; 95% confidence interval, 1.06–4.15; P = .03).

**DISCUSSION**

Even with high overall immunization levels in given communities, outbreaks can occur among pockets of susceptible persons (e.g., those belonging to unvaccinated religious groups). This outbreak of measles occurred in young adults who were susceptible because their religious group had opposed immunization 25 years earlier. Although the religious group subsequently adopted a more neutral position on routine childhood immunizations, no systematic effort was made subsequently to offer catch-up vaccinations for those who had not been vaccinated. At the time of the outbreak, <35% of the religious group members had received 1 dose of MMR vaccine. Because the community operated a school, state-mandated annual reports of their students’ immunization status could have been used as a way to identify this at-risk community. Such reports should be reviewed annually by the health department to identify undervaccinated populations [9].

Ongoing education is needed to prompt health care providers to have a high index of suspicion for measles in young adults presenting with rash illness and upper respiratory tract symptoms [3]. Fifteen medical visits were made by case patients with classic measles symptoms, including rash, before health care providers suspected measles and alerted public health officials. Sixteen of the case patients had rash onset in the month before the first case was brought to the attention of public health officials. This represents at least 2 generations of measles transmission that were undetected by the medical community and contributed to the large number of cases ultimately associated with the outbreak.

Most (91%) blood donors 20–39 years of age had serological evidence of immunity to measles. Adults 20–29 years of age were slightly less likely to be immune to measles than were 30- through 39-year-olds. The older age group may have had a higher level of detected antibody because of a greater likelihood of having had natural disease. Although this seroprevalence study was conducted ~10 months after the outbreak, the detected antibody level likely was representative of the level at the time of the outbreak. Fewer than 400 persons received vaccine as a result of the outbreak, and only 3 cases of measles occurred in Minnesota during the intervening time period.

In this study, measles antibody was measured by ELISA. Several investigators have reported that the plaque reduction neutralization assay is more accurate than ELISA in determining levels of protective antibody [10]. One comparative study demonstrated that the positive predictive value of measles antibody detected by ELISA is high (98.7%) and the negative predictive value is somewhat lower (58.3%) than the positive
and negative predictive values of the plaque reduction neutralization assay [11]. Even among persons with no detectable measles antibody by plaque reduction neutralization assays, some are protected [12]. It is likely that the level of seroprevalence for measles antibody reported in our study represents the minimum prevalence of measles antibody in the population.

This serosurvey measured levels of measles immunity in persons 20–39 years of age. Persons aged 40 years at the time of the outbreak were born before 1957 and likely had had natural disease. Since 1967, documentation of vaccination against measles has been required for school entrance in Minnesota. The measles coverage level among students during the 1995–1996 school year was 98.2% (Minnesota Department of Health, unpublished data). Since the 1989–1991 resurgence of measles, hospitals and clinics have placed an increased emphasis on ensuring that health care workers have evidence of 2 doses of measles vaccination. This likely contributed to the single case of measles identified among health care workers despite multiple exposures. In this outbreak, the 91% immunity documented by serology among young adults combined with immunity in the preschool- and school-age population, persons born before 1957, and health care workers, was sufficient to prevent spread of measles. A recent study of population immunity in the United States found that 93% of the population had evidence of immunity to measles (S. Hutchins, unpublished data).

The likelihood of a measles outbreak occurring in a given population following introduction of the virus is based on susceptibility of the population and number of exposures to an infectious measles case among susceptible persons. In relatively closed populations such as schools, measles can be transmitted and an outbreak sustained through several generations, despite high levels of immunity, because of repeated exposures [13–15]. When contact rates are high, the likelihood of spread of virus is elevated, even in the presence of high population immunity. However, when immunity is relatively high and contact rates are low, spread of virus is less likely. The absence of spread of measles into the general population despite multiple opportunities for exposure coupled with the seroprevalence data indicate that population immunity is sufficient in the Minneapolis–St. Paul metropolitan area to prevent easy establishment of measles. Most reported measles in adults is associated with transmission in college and university settings, where the frequency of exposure is high [16].

Results of this outbreak investigation are reassuring. Spread of measles to the general population did not occur, despite multiple community exposures, suggesting that the level of demonstrated immunity (91%) was sufficient to protect the population, given the relatively low frequency of exposure for any 1 person. This investigation provides data to support the current CDC recommendation that mass revaccination of entire communities is generally not necessary for control of measles outbreaks, particularly for outbreaks involving predominantly adults [17].

Acknowledgments

We thank Vera Stahl (Red Cross Regional Blood Services) for assistance in obtaining serum samples, Mary Beth Grimm (St. Paul–Ramsey County Department of Public Health) for assistance with the outbreak investigation, and Rafael Harpez and Wendy Mills for manuscript review.

References