

Measles Outbreak in Juneau, Alaska, 1996: Implications for Future Outbreak Control Strategies

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ABSTRACT. *Objective.* To determine the most effective outbreak control strategy for school-based measles outbreaks as the proportion of children with two doses of measles-containing vaccine (MCV) increases.

Setting. A school-based measles outbreak during 1996 involving 63 cases in Juneau, Alaska (population 29 288), where systematic revaccination with MCV was not implemented.

Design. A retrospective evaluation using chain-of-transmission data of three possible outbreak control strategies: no school revaccination, targeted school revaccination (affected schools only), and community-wide school revaccination (all schools). Two-dose MCV coverage among students was estimated from school vaccination records and a survey issued to parents.

Primary Outcome Measures. Potentially preventable cases of measles and doses of MCV administered per case prevented.

Results. Two-dose MCV coverage among Juneau students was estimated to be 44% and 53% immediately before and after the outbreak, respectively. Of all the measles cases, an estimated 24 to 28 and 27 to 31 were potentially preventable by the targeted and community-wide school revaccination strategies, respectively. Either strategy might have optimally decreased the outbreak duration by 1 month, sparing one of seven affected schools and 10 of 12 unvaccinated children who had measles. Approximately 133 to 155 and 139 to 160 doses of MCV per case prevented would have been required for targeted and community-wide school revaccination, respectively.

Conclusions. Either targeted or community-wide school revaccination would have been effective control strategies for this outbreak. Targeted school revaccination is probably the intervention of choice for school-based measles outbreaks in larger communities with higher two-dose MCV coverage. As two-dose MCV coverage continues to increase in the United States, public health control measures to respond to outbreaks need to be reevaluated. *Pediatrics* 1998;102(6). URL: <http://www.pediatrics.org/cgi/content/full/102/6/e71>; *measles, outbreak, vaccination, epidemiology, Alaska*.

ABBREVIATIONS. MCV, measles-containing vaccine; ACIP, Advisory Committee on Immunization Practices; CDC, Centers for Disease Control and Prevention; CI, confidence interval.

Measles outbreaks in the United States are increasingly rare.¹ When they occur, significant medical, public health, and community resources are required.²⁻⁴ As two-dose measles-containing vaccine (MCV) coverage continues to increase nationally, choosing the most effective control strategy during a measles outbreak presents a challenge. In 1989, the Immunization Practices Advisory Committee (now the Advisory Committee on Immunization Practices [ACIP]) of the US Public Health Service began recommending routine revaccination with MCV (ie, administration of a second dose) for all children. In addition, ACIP recommended that during outbreaks, persons ≥ 12 months of age who had received one dose of MCV and were born on or after January 1, 1957, should be revaccinated.⁵ This change to a two-dose policy occurred primarily because 42% of measles cases reported in the United States during 1985-1988 were among persons who had received one dose of MCV,⁵ and numerous outbreaks occurred in schools in which almost all children had received one dose of vaccine.⁶⁻⁸ Although 95% of children vaccinated with one dose of MCV at or after 12 months of age develop detectable measles antibodies,⁵ the remaining 5% (who do not develop antibodies and are presumed to remain susceptible to measles) was sufficient to sustain outbreaks. A second dose of MCV produces antibodies in $>90\%$ of children who failed to respond to the first dose.^{9,10} By 1996, the US Centers for Disease Control and Prevention (CDC) estimated that 50% to 60% of schoolchildren in the United States had received a second dose of MCV (S. C. Redd, personal communication, CDC, 1997).

Three major strategies can be used when a community experiences a school-based measles outbreak. Children who received fewer than two doses of MCV at all schools in the community could be revaccinated, children with fewer than two doses of MCV at affected schools (ie, those with one or more measles cases) could be revaccinated, or no systematic revaccination could be used while ensuring that schoolchildren have received at least one dose of MCV. ACIP recommends either of the first two strategies,⁵ even though both require substantial resources. However, as the proportion of schoolchild-

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dren who have had two doses of MCV continues to increase, outbreak-control strategies need to be evaluated because the impact of systematic revaccination in response to an outbreak will continue to decrease. A measles outbreak during 1996 in Juneau, Alaska, represented an opportunity to evaluate and compare the three possible outbreak control strategies at current and future two-dose MCV coverage levels.

BACKGROUND

Juneau, the state capital of Alaska, with a population of 29 228, is reachable only by air or sea. The public school system consisted of five elementary schools, two middle schools (6th to 8th grades), and a high school, which was physically divided into an annex and a main campus. Public school enrollment at the time of the outbreak was 5534 students. Private school enrollment was estimated at 361 students in six schools. During the outbreak period, a youth indoor soccer season was in progress, which involved 110 teams. The middle school and high school wrestling teams traveled to other communities during the outbreak, and a children's gymnastics team traveled to a large international competition in Anchorage.

During 1975–1995, no documented transmission of measles occurred in schools in Alaska. Although a large outbreak occurred in 1990 (80 cases), most case-patients were younger than 5 years old. Vaccination audits at three public schools in Juneau, completed just before the 1996 outbreak, documented that >99% of students had had at least one dose of MCV. At the time of the outbreak, Alaska regulations required one dose of MCV for school enrollment or a medical or religious exemption. A second dose of MCV was recommended, but not required, for school enrollment.

MATERIALS AND METHODS

Outbreak Investigation and Control Measures

On February 17, 1996, a Juneau physician notified the Alaska Division of Public Health of an elementary school student who possibly had measles.¹¹ The diagnosis was confirmed on February 20, 1996, by IgM capture assay. That same week, 4 additional cases were reported among 3 students and a teacher at the same school. The Division of Public Health immediately began active surveillance for measles in Juneau through daily contact with school nurses, primary care practices, and the local hospital emergency department. Weekly outbreak updates were given to health care providers throughout southeastern Alaska. Control measures focused on ensuring that all schoolchildren and contacts of persons suspected of having measles who were born after 1956 had had at least one dose of MCV. In Juneau, 39 unvaccinated schoolchildren (0.7% of students) who had medical or religious exemptions to vaccination were encouraged to stay home but were not excluded from school during the outbreak. For each case or suspected case, data were obtained concerning rash onset, symptoms, vaccination dates, contacts, and the likely chain of transmission. Vaccination dates were verified with health care providers.

A patient with measles lived in southeast Alaska, had onset of illness during the period February to April 1996, was either laboratory-confirmed or met the clinical case definition^a, and was linked epidemiologically to either another patient or probable patient.^b

Between February 17 and April 25, 1996, 63 patients were identified (Fig 1). No cases outside of Juneau were reported. The age of case-patients ranged from 8 months to 45 years, with a median age of 11 years. Three case-patients, including one school

employee, were born before 1957. Forty-one (65%) were schoolchildren representing seven public schools and one private school; 4 (6%) were among public school personnel; and 5 (8%) involved preschool siblings of students. The 1 case-patient who attended a private school was a sibling of a case-patient with an onset of illness 2 weeks earlier who attended public school. The highest attack rates were at the high school annex (5/127; 3.9%), one of the middle schools (15/687; 2.2%), and the elementary school attended by the index case-patient (7/525; 1.3%). Twelve schoolchildren who had measles had religious exemptions and had not been vaccinated with MCV, whereas 29 schoolchildren with measles had had one dose of MCV. The other 13 patients not among public school personnel, schoolchildren, or their siblings involved 7 adults and 6 preschool children. None of the 63 case-patients had received more than one dose of MCV.

Two-dose MCV Coverage

Two-dose MCV coverage among Juneau schoolchildren was estimated from school vaccination records and a survey issued to parents. Children attending a public school were divided into two groups: those attending one of the three schools with the highest attack rates and those attending one of the other schools. Part of the high school student body ($n = 127/1521$) was housed in an annex building, which was viewed as a separate school for purposes of determining attack rates and chains of transmission. All 1339 students from the three high-attack-rate schools were included in the survey, as was a 25% random sample of the 4195 students at the other schools.

School nurses had recorded information from vaccination records about a second MCV dose for 320 children in the survey. Parents of the remaining 2054 students sampled were mailed survey cards and asked to provide the number and dates of MCV doses and the name of the health care provider for their child. Two additional survey mailings were sent to nonrespondents. Sampling weights to account for the differential probabilities of selection among schools were used to estimate two-dose coverage. The percentages of schoolchildren who received a second dose of MCV before the outbreak and during the outbreak were estimated. Ninety-five percent confidence interval (CI) estimates were calculated using the CSample module of Epi Info version 6.0 software.¹²

Surveys were analyzed in three groups: responses that contained complete dates (eg, two doses and two complete dates; $n = 895$), responses with partial dates ($n = 208$), and those with dose information but no date ($n = 251$). For responses containing complete dates in which respondents had listed a Juneau health care provider ($n = 761$), a random sample of 125 was selected for medical record review. For surveys with either partial or no date information in which a Juneau health care provider was listed ($n = 168$ and 132, respectively), a medical record review was attempted. A fourth group, of the 320 students with school two-dose MCV records, was assumed to be comparable with those with complete dates. The percentage of responses validated in each of the four groups was weighted by the size of the group. The estimated minimum two-dose MCV coverage rate was calculated by multiplying two-dose coverage determined from school records and the parental survey by the weighted validation factor.

Cases of Measles by Outbreak Control Strategy

The expected number of measles cases for each of the three possible outbreak control strategies was determined. For the strategy used during this outbreak (no school revaccination), the number of cases was the actual number reported. The number of cases expected using a slight variant of this strategy (no revaccination with school exclusion of unvaccinated students) also was determined.

The next strategy, targeted school revaccination, assumed that students, their siblings, and personnel at the schools affected (those with suspected measles cases) who previously had received one dose of MCV would be revaccinated. This strategy postulated that revaccination would have occurred at the index school 3

^aA probable case met the clinical case definition, had noncontributory or no laboratory testing, and was not epidemiologically linked to any other case.

^bThe clinical case definition was an illness characterized by generalized rash lasting (≥ 3 days; temperature (101°F [38.3°C]); and cough, coryza, or conjunctivitis.

school days after confirmation of the first case and at each subsequent school 2 school days after a suspect case was reported at a school.

The final strategy, community-wide school revaccination, would have required revaccination of students, their siblings, and school personnel at all eight public schools. The strategy assumed that revaccination would have occurred at the index school within 3 school days of confirmation of the first case and that students and staff at the other public schools would have been revaccinated within an additional 5 school days.

For each of the last two strategies (and for the first strategy variant with exclusion), we assumed that unvaccinated students would have been excluded from school from February 23 through May 9, which was 2 weeks after rash onset of the last confirmed case. Five additional assumptions were made for this analysis: 1) unvaccinated schoolchildren would remain unvaccinated for the entire outbreak; 2) for the two revaccination strategies, children who had one dose of MCV before the outbreak would receive a second dose; 3) persons with measles were infectious starting 3 days before rash onset; 4) revaccination would have prevented measles if provided at least 14 days before rash onset; and 5) if a chain of transmission was interrupted by revaccination, transmission would not have occurred by another route, and cases that occurred distal to the point of interruption on the chain would have been prevented.

For each strategy, we determined whether a case was preventable using chain-of-transmission data (Fig 2), rash-onset dates, and dates of the various potential interventions. For example, targeted school revaccination would have been implemented at several points in time. Children (and their siblings and school staff) at school 1 would have been revaccinated on February 23, which was too late to prevent the cases at school 1 with rash onsets on February 28 and February 29. On the other hand, children at school 5 would have been revaccinated on March 5, too late to prevent the four cases at school 5 with rash onsets between March 9 and March 11, but early enough to prevent many cases at that school with later rash onsets.

Doses of MCV for Each Strategy

The number of doses of MCV required for each strategy was calculated. Based on 1990 census data¹³ and Juneau School District data (J. Spiech, personal communication, Juneau School District, 1996), we estimated that the student:sibling ratio was 1:0.8, and that the age distribution of siblings was 6.25% younger than 1 year, 18.75% 1 to 3 years, 12.50% 4 to 5 years, and 62.50% 6 to 18 years of age. Seventy-four percent of siblings 1 to 3 years of age were assumed to have received one dose of MCV before the outbreak, based on 1995 National Immunization Survey results from Alaska among children 19 to 35 months,¹⁴ whereas siblings 4 to 18 years of age were assumed to have the same two-dose MCV coverage as schoolchildren. The two revaccination strategies would have provided a dose of MCV to siblings with only one dose of MCV who had not been revaccinated because of atten-

dance at a school subject to revaccination. The number of school personnel born after 1956 at the public schools was determined from school district data. School personnel born after 1956 were assumed to have had only one dose of MCV and would have received a second dose under either revaccination strategy.

RESULTS

Two-dose MCV Coverage

The parental survey response rate was 65.9% (1354/2054). Two-dose MCV coverage among students was estimated at 44% (95% CI: 41%–47%), based on parental survey and school record data before the outbreak. The percentage of survey responses that were validated by medical record review differed by the completeness of date information provided by parents: 88.7% (110/124) that had complete dates were validated, 68.3% (112/164) that had partial dates were validated, and 49.6% (56/113) that had only dose information were validated. The weighted percentage of responses validated was 80.3%. Based on validation of medical records, two-dose MCV coverage among students was at least 35% (95% CI: 33%–38%) before the outbreak. The percentage of schoolchildren who received a dose of MCV during the outbreak was estimated to be 10% (95% CI: 8%–11%).

Two-dose MCV coverage among students at the three schools with the highest attack rates was 39% (95% CI: 36%–42%) before the outbreak; an additional 14% (95% CI: 12%–17%) of students were revaccinated during the outbreak. At schools with low attack rates, two-dose MCV coverage among students before the outbreak was estimated to be 46% (95% CI: 42%–50%), and an additional 8% (95% CI: 6%–10%) of children were revaccinated during the outbreak.

Cases of Measles by Outbreak Control Strategy

Using chain of transmission data, rash onset dates, and dates of the various potential interventions, the number of cases of measles preventable by each outbreak control strategy was determined. If unvaccinated children had been excluded from school during the outbreak, 7 to 11 cases of measles would

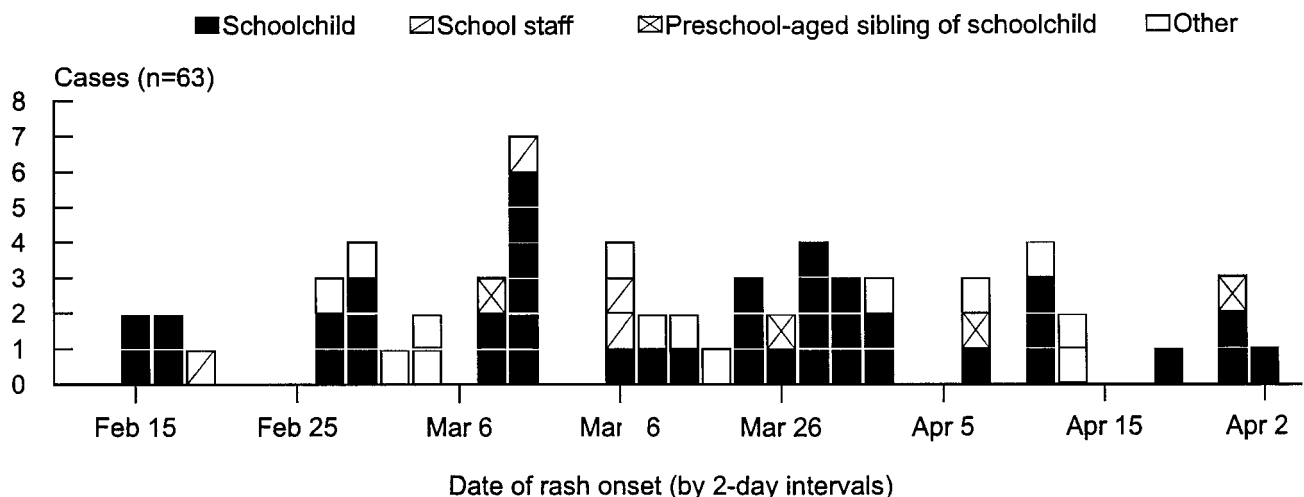


Fig 1. Confirmed cases of measles by date of rash onset, Juneau, Alaska, 1996.

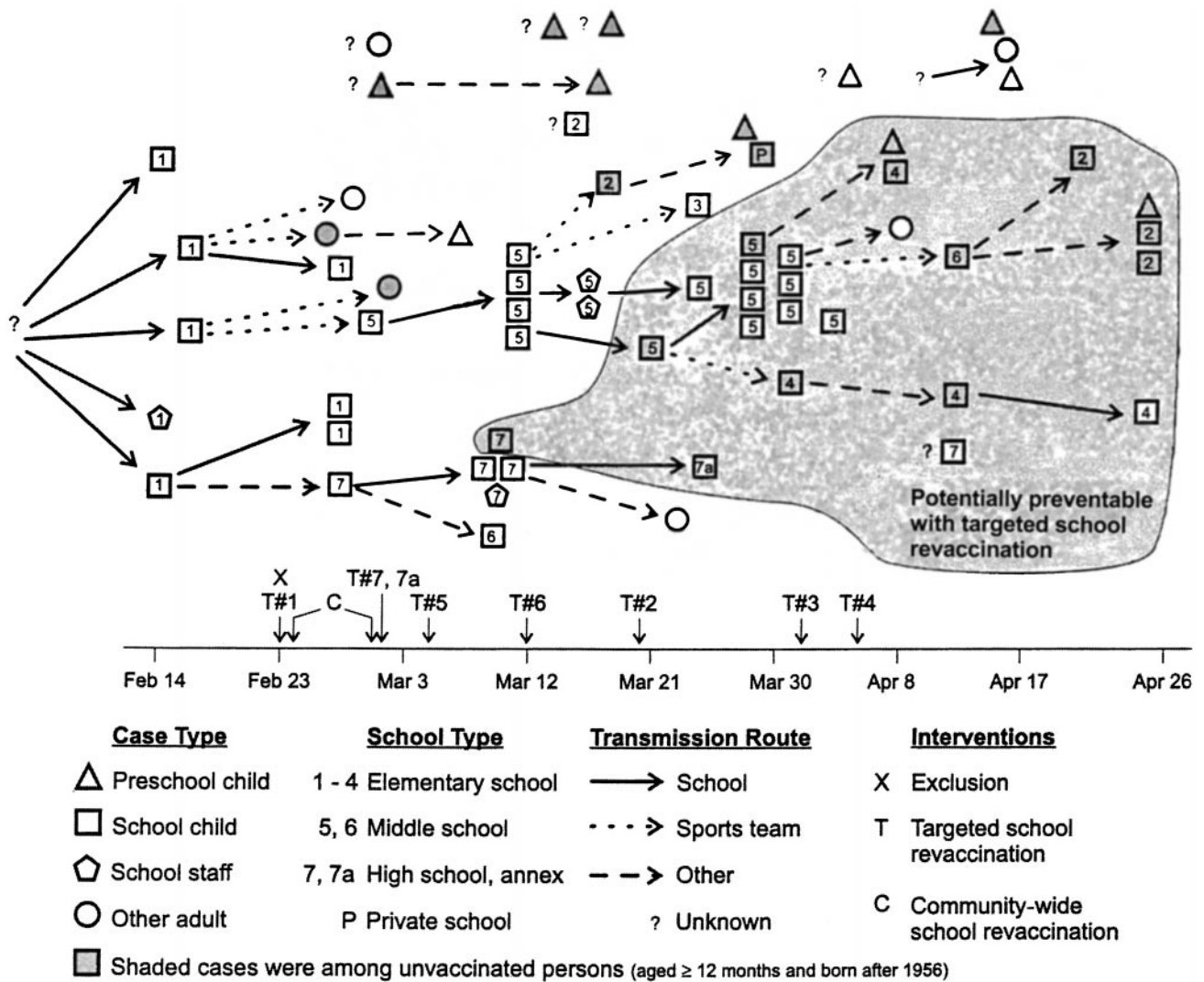


Fig 2. Chains of measles transmission, Juneau, Alaska, February 1996 to April 1996.

likely have been prevented. The minimum estimate, 7 case-patients, included a high school student, 2 middle school students, 3 elementary school students, and a 3-year-old sibling of 2 of the elementary school students. All of these children were unvaccinated. The range resulted from the fact that the chain of transmission was unknown for 4 case-patients who did not attend school and had illness occurring late enough in the outbreak to have been potentially preventable (Fig 2).

Targeted and community-wide school revaccination would have prevented 24 to 28 and 27 to 31 cases of measles, respectively (Fig 2). For example, cases of measles among the 4 children from school 4 were determined to be potentially preventable. The first case-patient from school 4 was exposed to measles during a sports team practice with an unvaccinated child from school 5, who probably would not have contracted measles if he/she had been excluded from school. On the other hand, of the 2 children with measles from school 6, the first case was determined not to be potentially preventable. This child was exposed to a neighborhood friend from school 7 too soon to be affected by revaccination. Either strat-

egy would likely have spared 1 of the 7 affected public schools and 10 of 12 unvaccinated schoolchildren who had measles. The duration of the outbreak may have been reduced by 30 days if targeted school revaccination had been implemented (Fig 2). The three additional cases that were potentially preventable by community-wide school revaccination, when compared with targeted school revaccination, included 2 elementary schoolchildren who had had one dose of MCV and a middle school teacher. The three other cases among school personnel would not have been prevented by either revaccination strategy.

Doses of MCV for Each Strategy

As stated previously, 10% of schoolchildren were estimated to have received a dose of MCV during the outbreak. The number of doses required for the other two strategies are greater (Table 1). Revaccination would not have occurred at two elementary schools if targeted school revaccination had been implemented. No suspected measles cases occurred among children at one of these schools, and all four cases at the second school would likely have been

TABLE 1. Number of Doses of MCV Administered by Strategy

	Population	Targeted School Revaccination	Community-wide School Revaccination
Students	5534	2447	3066
Siblings in school	2767	247	0
Siblings not in school	1660	735	921
School personnel*	335	297	335
Total	10 296	3726	4322
Doses/potentially preventable case		133–155	139–160

* Born after 1956.

prevented by targeted revaccination. An estimated 3726 doses of MCV would have been required for targeted school revaccination, and 4322 doses of MCV would have been required for community-wide school revaccination. Therefore, 133 to 155 doses/case potentially prevented would have been used for targeted school revaccination strategy, whereas 139 to 160 doses/case potentially prevented would have been used for community-wide school revaccination.

DISCUSSION

The choice of which control strategy to use when measles is identified at a school is difficult and will become increasingly so. Before 1989, when ACIP first recommended a routine two-dose MCV schedule, numerous outbreaks were documented at schools where almost all schoolchildren were vaccinated with one dose of MCV.^{6–8} As a result, community-wide school revaccination during an outbreak was recommended until a routine two-dose schedule was fully implemented.¹⁵ During the 1996 outbreak in Juneau, transmission occurred at schools where 99% of children had had at least one dose of MCV and an estimated 44% had had two doses of MCV. Of the 63 measles cases, an estimated 24 to 28 and 27 to 31 were potentially preventable by the targeted and community-wide school revaccination strategies, respectively. The estimated doses of MCV required per case prevented were similar for each strategy.

What are the implications of the Juneau outbreak for future control strategies for school-based measles outbreaks? Either targeted or community-wide school revaccination, if implemented rapidly and comprehensively, would have been effective outbreak control strategies for Juneau. Whereas community-wide school revaccination might have prevented three more cases than targeted school revaccination, children at two schools who probably would not have been revaccinated under the targeted approach would have required vaccination. However, because measles outbreaks are unpredictable, the outbreak could just as easily have spread to other communities, to all eight schools in Juneau, or remained isolated to a single school. The targeted school revaccination strategy provides a more flexible response to these uncertainties. Furthermore, because after this outbreak Alaska mandated routine MCV revaccination for students entering kindergarten and first grade, the number of students susceptible to measles will decrease over time, thus enhancing the relative effectiveness of targeted school revaccination.

To determine the most effective outbreak control strategy in other settings, the size of the community, the two-dose MCV coverage among students, and the feasibility of implementing control measures should be considered. National two-dose MCV coverage among schoolchildren was 50% to 60% during 1996 (S. C. Redd, personal communication, CDC, 1997), and this percentage should increase steadily as a result of mandatory revaccination requirements adopted by most states. ACIP has set a goal for full coverage with two doses of MCV for all schoolchildren by the year 2001.¹¹ For communities smaller than Juneau with similar or lower two-dose MCV coverage, either the targeted or the community-wide revaccination strategy should be efficient. For a community of any size with higher two-dose coverage than Juneau, the targeted school revaccination strategy would likely be more efficient because the proportion of students susceptible to measles would be reduced and the risk of transmission to other schools likely would be less. For large communities with many schools, the percentage of schools affected in an outbreak is likely to be lower than that for a smaller community, thus making targeted revaccination even more efficient. Even for a large community with lower two-dose MCV coverage, targeted revaccination would likely be more efficient, because most schools probably would be unaffected during an outbreak.

Is there a two-dose MCV coverage level among students at or above which a community should not implement mandatory revaccination during a school-based outbreak? For example, before the outbreak, Juneau's 5534 schoolchildren had an estimated two-dose MCV coverage of 44%. Assuming a 1% vaccine failure among students with two doses, a 5% vaccine failure for those with one dose, and 0.7% unvaccinated students suggest the outbreak occurred primarily among a population of 224 susceptible students. Exclusion of unvaccinated students from school would decrease the number of susceptible students in school to 186. Similar calculations using preoutbreak coverage levels of 75%, 90%, and 99% yield estimates of 109, 76, and 56 susceptible students, respectively. Because some students still would be susceptible as two-dose coverage increases and the resources required to revaccinate students would decrease as two-dose coverage increases, targeted school revaccination still might be more efficient than no school revaccination at relatively high two-dose coverage.

There were several limitations to the study. Be-

cause the revaccination strategies were hypothetical, they required numerous assumptions regarding implementation. When revaccination interrupted a chain of transmission, susceptible persons on the same chain distal to the interruption were assumed to be spared from measles, although theoretically transmission could have reached them through an alternate route. Unvaccinated students, who were assumed to have remained at home for 2½ months during the outbreak, may have received MCV, and the legality of such a lengthy exclusion could be tested. The feasibility of obtaining written parental permission and revaccinating students within the described timeframe would be difficult. Only public school students were included in this study, but had the community-wide revaccination strategy included private schools where there was no evidence of measles transmission, the relative efficiency of the targeted strategy probably would have been enhanced. The MCV coverage estimates, which were critical to interpreting the findings, were based primarily on a parental survey with a 66% response rate. By not adjusting for nonresponse, we may have overestimated two-dose coverage rates. And the cost of each strategy was represented by the number of doses of vaccine required, not by a comprehensive cost-benefit analysis.

On the other hand, the epidemiologic data on which the evaluation of strategies was dependent was strong. A likely chain of transmission was determined for most cases. The small size of the community and the excellent cooperation of health care providers provided good case determination. Validation of many of the parental responses by medical record review increased the level of certainty for the two-dose MCV coverage estimate.

Both targeted and community-wide school revaccination would have been effective outbreak control strategies during this outbreak. However, when compared with community-wide school revaccination, the targeted strategy becomes more efficient as the two-dose MCV coverage level increases and the number of susceptible students decreases. Only communities smaller than Juneau with a lower two-dose coverage would possibly benefit from community-wide school revaccination over targeted school revaccination. Although the strategy of no school revaccination saved doses of vaccine and resources, the substantial difference in number of cases makes this strategy less acceptable.

Even when two-dose MCV coverage becomes relatively high nationally, targeted mandatory school revaccination should remain the desired strategy for

school-based measles outbreak control, although eventually systematic school revaccination will not be required. Although routine MCV revaccination will continue to play the major role in reducing measles transmission in the United States,¹¹ targeted mandatory school revaccination during an outbreak should be used until nearly all schoolchildren have received two doses of MCV. School-based measles outbreak control recommendations should be revisited as two-dose MCV coverage continues to increase in the United States. State and local health departments may need to revise regulations and policies to enable implementation of evolving measles outbreak control strategies.

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