

project, detailed procedures were defined so that the Kessner numbers submitted by the eight States would be comparable. The procedures used before implementation of the new birth certificate in 1988 and 1989 are shown in the box. After implementation of the new birth certificate, clinical estimate of gestation has been used for those births where gestational age could not be calculated based on date of last menstrual period.

Conclusion

In summary, we recommend using the estimates developed by Newacheck (4), added to reported Medicaid births, to derive State-level estimates of the number of women in need of subsidized prenatal care services. These State estimates can be distributed back to counties using the percentage distribution of live births with less than 12 years of education. The number of births with inadequate prenatal care as defined by the Kessner Index can be used as a proxy for unmet need among women in poverty, at both the State and county level.

We have pointed to some of the problems involved in estimating the number of women in need of subsidized maternity services, given the lack of poverty information on birth certificates. While no ideal method can be recommended, we hope that our experience can help others avoid some of the pitfalls that we have discovered and suggest some practical alternatives to pursue. Periodic updates of Newacheck's estimates using the most recent Current Population Survey data would undoubtedly be helpful to the planners in many State maternal health programs.

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New York State's Two-Dose Schedule for Measles Immunization

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Synopsis

In April 1989, New York became the first State in the United States to adopt a two-dose schedule for routine measles immunization. Although a two-dose schedule had been under discussion for the previous 10 years, this policy change was finally prompted in New York State by widespread measles outbreaks in 1989 among college and high school students who had been appropriately vaccinated with a single dose of measles vaccine. These outbreaks affected 21 college and secondary school campuses with 91 cases of measles and led to the

administration of 53,093 doses of vaccine at a cost in excess of \$859,000 for vaccine alone.

In addition, there were major disruptions of intercollegiate athletic and scholastic events and physician and public confusion over the different recommendations for "outbreak" versus "routine" measles immunization. In response, the New York State Department of Health adopted a policy of two doses of measles vaccine required for entrance into kindergarten and college beginning in the fall of 1990. This report describes the data and process that were used in reaching this policy decision.

ALTHOUGH PREVENTABLE, MEASLES remains a disease with the potential to cause serious morbidity and mortality (1). It continues to be a significant public health problem in the United States despite 13 years of efforts to achieve the goal of eliminating indigenous measles (2). In 1989, a total of more than 18,000 cases of measles were reported in the United States, a greater than fivefold increase over the same period in 1988 (3). During 1989, widespread measles outbreaks occurred in New York State (NYS) involving college campuses and secondary schools with spread of the disease into the community. Major efforts were expended in the control of these outbreaks, which were costly both in financing immunizations and in diverting health workers from other important public health priorities.

The evident failure of the one-dose measles immunization schedule to prevent disease outbreaks led the department of health to change to a routine two-dose measles immunization schedule in NYS. New York was the first State to take this step, presaging a change in national policy as stated by the Immunization Practices Advisory Committee (ACIP) and the American Academy of Pediatrics. The purpose of this report is to set forth the basis and rationale of the NYS Department of Health in reaching this decision and to describe the implications of implementing this change.

National Measles Control Policy, 1978-88

In 1978, the ACIP at the Centers for Disease Control (CDC) announced the goal to eliminate indigenous measles from the United States by October 1, 1982 (2). The basis of the national elimination strategy, adopted at the time by NYS, was to achieve and maintain high levels of immu-

nity to measles in the population through the widespread use of a single dose of measles vaccine given at age 15 months. The two other components of the measles elimination strategy were (a) effective surveillance for disease and (b) aggressive control of outbreaks.

The need to eliminate measles was based on the relatively high incidence of adverse consequences of measles infection as well as its apparent preventability. While often still viewed as a normal part of growing up, in the prevaccine era measles accounted for an estimated 500 deaths and 1,000 cases of permanent brain damage due to encephalopathy each year in the United States (1). The case fatality rate was approximately 1 per 10,000 cases (1). Case fatality rates of more than 13 per 10,000 were seen during widespread measles outbreaks during the first half of 1989 (4). Other common complications of measles include pneumonia (1-6 percent), otitis media (7-9 percent), post infectious encephalitis (1 per 1,000 to 1 per 2,000 cases), and subacute sclerosing panencephalitis (1 per 100,000 cases) (1). Measles during pregnancy can lead to miscarriage or premature delivery (5).

Failure of Single-Dose Vaccination

Since its introduction in 1963, the single-dose schedule for measles vaccination has decreased the number of measles cases reported in NYS and the United States by 99 percent. However, the 1982 goal to eliminate measles has not been met. Between 1981 and 1989, a minimum of 1,497 (1983) to a maximum of 18,193 (1989) cases have been reported annually in the United States (3,6,7).

Nationally, the highest levels of measles morbidity and mortality in the last decade occurred in 1989. That year was the worst year for measles

Table 1. History of measles immunization among New York State college and secondary school students with measles ¹

Category	None		Age of measles immunization							
			< 12 months		12-15 months		> 15 months			
	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent		
Colleges...	9	12	3	4	23	31	39	53		
Schools...	0	0	0	0	8	47	9	53		
Total	9	10	3	3	31	34	48	53		

¹ Data collected during the 1989 spring semester.

morbidity (202 cases) in NYS (excluding New York City) since 1981.

The failure to eliminate measles in the United States has been primarily due to two factors, the failure to vaccinate preschool children on time and the failure of measles vaccine to induce immunity in appropriately vaccinated children (4). Measles outbreaks have continued to occur in populations appropriately immunized with one dose of measles vaccine. Nationwide, 40 percent of measles cases in outbreaks during 1985 and 1986 occurred among previously vaccinated persons (8). Of those occurring predominantly in one setting, 58 percent occurred in primary and secondary schools and 12 percent in colleges and universities.

In major measles outbreaks in 1985-86 among school-aged children, between 41 percent and 90 percent of children ages 5-19 years with measles had been appropriately vaccinated after 12 months of age (personal communication from W. A. Orenstein, MD, Director, Division of Immunization, CDC, January 1990). The majority of cases in several other reported outbreaks (9-13) and in outbreaks at schools and colleges in NYS in 1989 (table 1) were among persons appropriately vaccinated with one dose of measles vaccine.

Reasons for Single-Dose Vaccination Failure

The two major categories of measles vaccine failure are (a) failure of the initial immunization to induce an immune response (primary vaccine failure) and (b) declining levels of measles antibodies after successful immunization with return to measles susceptibility (secondary vaccine failure). Primary vaccine failure is thought to account for the majority of recent measles cases in vaccinated populations (8).

A significant proportion of measles cases occurring among singly vaccinated high school and college students may be due to primary vaccine failure following vaccination between the ages of

12 and 15 months. Vaccination at this age has been shown to be a risk factor for primary vaccine failure in several outbreaks (14-16) because persisting maternal antibodies may neutralize the vaccine in some persons. Vaccination at 12 months of age was the recommended schedule until 1976 and continues to be acceptable for school entry in many States. Additional factors leading to primary vaccine failure in older children and young adults include the use of a possibly less efficacious vaccine before 1979 when a new stabilizer was added to the vaccine (6), vaccine mishandling leading to loss of potency, or errors in recording the date or age when the measles vaccination took place (8). The cause or causes of most cases of primary vaccine failure are not known (6).

There is some evidence that waning immunity (secondary vaccine failure) after measles vaccination plays a role in measles outbreaks in school-age children. In a 16-year longitudinal study of 70 school children vaccinated successfully with measles vaccine, all had detectable measles antibody titers 14 years after vaccination or had a rapid secondary immune response to revaccination suggesting that protection from natural measles disease would still be conferred (17). In a second large cross-sectional study, up to 98.8 percent of vaccinated high school students had measurable measles antibodies 14-16 years after vaccination (18). Although some outbreak investigations have shown a slightly increased risk of disease with increasing time since vaccination, these results were not statistically significant (8). Two recent studies have suggested that secondary vaccine failure may play a limited role in measles outbreaks. In the first study, a 5 percent secondary vaccine failure rate was found in a vaccine trial cohort during a large measles outbreak in British Columbia (19). In the second study, 16 percent of the instances of vaccine failure in an outbreak in Wisconsin were attributed to secondary vaccine failure (20). Edmonson and coworkers concluded that secondary vaccine failure did "not appear to be a major impediment to measles control" (20). In general, therefore, waning immunity has not yet been shown to be a major factor contributing to continued measles outbreaks (21).

Levels of Immunity Needed for Eradication

A single dose of measles vaccine produces antibodies in at least 95 percent of those vaccinated (6). In the past, theoretical considerations of herd immunity suggested that outbreaks could be prevented when measles was introduced into a popula-

tion if the vaccine efficacy was 95–97 percent, and the vaccine coverage was 94–97 percent (22,23). However, the data presented earlier suggest that even this low rate of primary vaccine failure can result in sufficient numbers of susceptible persons in a population to allow sustained measles outbreaks to occur. The earlier models may have underestimated the number of susceptible persons exposed by a person with measles (8), especially in school and college settings where large numbers of persons may be in close contact. Higher vaccine efficacy and coverage may be necessary to prevent outbreaks from occurring in those settings.

Revised One-Dose Immunization Policy, 1989

In January 1989, in response to continued measles outbreaks, the ACIP modified the measles prevention strategy to lower the age of measles vaccination to 12 months in counties where measles transmission recurred. The committee also recommended that persons in outbreak settings be revaccinated if they had received their most recent measles vaccination before 1980 (6). The year 1980 was chosen to protect persons vaccinated between 12 and 15 months of age (as was recommended until 1976), to make immunization records easier to review, and to address the possibly increased risk of primary vaccine failure with vaccines used before 1980.

NYS College Outbreaks, 1989

During 1989, two large, explosive outbreaks of measles attributed to importation of index cases from outside the United States occurred in NYS among college students. These two outbreaks were followed by outbreaks in 19 other college and secondary school campuses throughout the State; five outbreaks were directly linked to 1 college (table 2). These outbreaks occurred in well-vaccinated populations (table 1). While a number of persons who developed measles had been vaccinated between 12 and 15 months of age, the majority of vaccinated persons with measles in these outbreaks had been immunized after 15 months of age.

The department of health adopted the January 1989 ACIP revised single-dose vaccination recommendations, including the 1980 cutoff for revaccination in outbreaks. This action resulted in giving a second dose of measles vaccine to most students on affected campuses. More than 53,000 doses of measles vaccine were administered at 21 colleges

Table 2. Measles outbreaks in New York State during the 1989 spring semester

Category	Cases	Source	Date of first onset	Administered MMR ¹ doses
Subtotal ...	74	Puerto Rico	Jan. 23	43,346
College A.....	31	Rico	Jan. 23	3,200
College B.....	21	Montreal	Jan. 25	4,599
College C.....	5	College A	Feb. 21	900
College D.....	2	...	Mar. 3	4,999
College E.....	1	...	Mar. 13	563
College F.....	1	Florida	Apr. 5	6,878
College G.....	2	Florida	Apr. 8	10,100
College H.....	1	Florida	Apr. 10	2,321
College I.....	5	...	Apr. 22	4,770
College J.....	1	...	Apr. 28	1,189
College K.....	1	College G	May 2	3,777
College L.....	3	...	May 12	50
Subtotal ...	17	9,747
High school A....	7	College A	Mar. 3	1,095
High school B....	1	College A	Mar. 5	1,350
High school C ...	1	...	Mar. 5	2,068
High school D ...	1	...	Mar. 6	570
High school E....	1	...	Apr. 10	695
High school F....	2	Europe	Apr. 29	850
High school G ...	2	Florida	May 1	1,239
Middle school A..	1	College A	Feb. 21	880
Middle school B..	1	College A	Feb. 23	1,000
Total	91	53,093

¹MMR = combined measles, mumps, and rubella vaccine.

and secondary schools during the 1989 spring semester at a cost of \$859,000 for vaccine alone. Nonvaccine related costs were also significant in college and school revaccination campaigns, exceeding a quarter of a million dollars as a result of one college outbreak and three related secondary outbreaks (table 3). Although it was difficult to quantify many of the indirect costs, overall outbreak control efforts in 1989 probably approached \$3 million in NYS.

NYS Reconsiders Its Control Strategy

The expense and disruption of efforts to control outbreaks in NYS in 1989 led to a reconsideration of the revised single-dose measles vaccination policy. It was apparent, first, that the widespread coverage with a single dose of measles vaccine had not achieved the goal of measles elimination and had not prevented outbreaks from occurring in well-vaccinated populations. Second, the new ACIP recommendations for revaccination in outbreaks using the 1980 cutoff date meant that a majority of most college and secondary school students would have to be revaccinated in measles outbreaks for at least the next 10 years, an expensive and disruptive proposition.

Table 3. Estimated costs associated with the measles outbreak at college A and three related outbreaks,¹ January-February 1989

Category	Costs
<i>Department of health</i>	
Personnel:	
435 hours of professional staff time	\$ 10,715
551 hours of clerical support staff time	5,710
Laboratory personnel	2,776
Supplies:	
5,980 doses of MMR ² vaccine at \$16.18 per dose	96,756
Testing supplies	8,712
Travel:	
1,500 miles at 23 cents per mile	345
Subtotal, department of health expenses	\$125,014
<i>Local agencies</i>	
Personnel:	
County health departments-nursing services ...	\$ 14,011
College-school districts	10,442
Hospitals	520
Other	400
Supplies and travel:	
County health departments-nursing services ...	\$ 1,606
Cancellation of events (lost revenues):	
County health departments-nursing services ...	\$ 1,800
College-school districts	131,100
Hospital infirmary charges for inpatient stay (approximate)	9,600
Hospital inpatient stay (approximate)	3,268
Subtotal, other expenses	\$172,747
Grand total	\$297,761

¹ College C and middle schools A and B.

² MMR = combined measles, mumps, and rubella vaccine.

Another consideration was that the revaccination policy was not consistent with usual public health strategies; it was reactive rather than preventive. In addition, the revised single dose recommendations for outbreak control now differed from routine vaccination policy, a difficult concept to communicate to physicians, school personnel, and the public. Finally, it became evident that the 1980 revaccination date adopted by the ACIP was not based on clear epidemiologic evidence showing an increased risk of disease for those vaccinated before 1980, but rather represented a compromise to provide vaccine to those most in need: young adults in outbreak settings where almost all would have been vaccinated before 1980 (personal communication from W. A. Orenstein, MD, Director, Division of Immunization, CDC, January 1990).

Routine Two-Dose Measles Vaccination

Four arguments supported the conclusion that two doses of measles vaccine would result in

significantly better measles immunity than one dose. First, revaccination with measles vaccine of persons who failed to seroconvert after the first dose was thought to induce immunity at the same rate as in first-time vaccinees, although most of the data supporting this belief came from studies of children initially vaccinated before their first birthday (1). No genetic factors for primary vaccine failure had been identified (24), and initial vaccine nonresponders develop antibodies readily on revaccination (1,25).

Second, in several outbreak investigations, researchers had found that persons who had received two doses of measles vaccine had one-half to one-third the rate of illness compared to single dose recipients (12-14). The rate of disease in doubly immunized persons in one NYS college measles outbreak in 1989 was one-half that of single-dose recipients (NYS Department of Health, unpublished data).

Third, models of measles outbreaks had indicated that a two-dose schedule would be sufficient to produce the high levels of immunity necessary for significant herd immunity to be achieved (23). Continued reliance on one dose of measles vaccine in one modeling study resulted in a greater proportion of susceptible persons in the population by the year 2050 than were present in the prevaccine era when virtually everyone older than 5 years was immune to measles due to natural disease (26). With a two-dose vaccination schedule this would not occur.

A final consideration was that at least 10 European countries have had markedly reduced measles cases following implementation of a two-dose vaccination policy (1,27,28). In the United States, after years of continuous measles outbreaks, the military has immunized all new recruits with measles vaccine. This policy had effectively resulted in a second vaccine dose for most recruits and nearly eliminated measles cases and outbreaks (29,30).

NYS's Revised Two-Dose Policy

In April 1989, in consultation with an expert panel convened by the NYS commissioner of health, the department of health adopted a routine measles two-dose immunization policy. The panel recommended that the second measles dose be administered between 4 and 6 years of age, by the time of entry into kindergarten, a time chosen to coincide with the diphtheria-tetanus-pertussis (DTP) and oral polio vaccine (OPV) immunizations currently given at this age. A second measles

vaccine dose was added to school entrance requirements for kindergarten students in the fall of 1990. In subsequent years, the requirement will apply to school enterers born after 1984 to maintain complete two-dose coverage of the kindergarten class of 1990 and subsequent cohorts. Complete two-dose coverage of all school children in NYS will occur after 13 years. In the interim, a second dose of measles vaccine would be required of children in schools with measles outbreaks. A second measles vaccine dose was also required for college students beginning in the fall of 1990. This requirement would apply to all students born since 1956. Both the college and kindergarten entrance requirements have been incorporated into State regulations.

Persons born before 1957 are likely to be immune to measles due to naturally occurring disease. Persons of college age or older born before this time, who do not attend college, have been generally at lower risk for measles and have not needed to receive a second immunization unless they enter a high-risk setting (employment in a medical field or travel to a measles affected area). In concert with the ACIP, the panel recommended that all vaccine doses be given as combined measles, mumps, and rubella (MMR) vaccine (31).

Implications of the Two-Dose Policy

The routine two-dose schedule is expected to result in a reduction in the incidence of measles and in progress toward the prevention of this serious disease. Complete elimination of measles will not occur due to the constant threat of imported cases and to the continued presence in the population of persons who are not vaccinated. These include persons with religious and medical exemptions, children younger than the recommended age for measles immunization, and preschool children who have not been immunized at the appropriate age. The public health community's response when measles cases do occur in doubly vaccinated populations in the future will be less disruptive than the current strategies of outbreak control. It will involve only exclusion from school of known susceptible children and revaccination of the few not in compliance with requirements. Cancellation of activities and limited quarantine will no longer need to be considered in outbreak control. The new two-dose vaccination policy should alleviate confusion in the public and in the medical community since outbreak and routine vaccination recommendations will be similar. This

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change should improve public confidence in public health immunization efforts.

There are costs associated with both the revised one-dose and routine two-dose policies. The costs of the one- and two-dose policies are approximately equivalent, assuming that measles cases and outbreaks will continue to occur at 1989 rates with the need to revaccinate large numbers of persons on an emergency basis. For example, the cost of vaccine to provide a second dose to entering college freshmen in NYS is \$3 million to \$4 million, the same order of magnitude as measurable costs of outbreak control in NYS in 1989. The disruption of outbreak control efforts in the future, a factor that cannot be assigned an exact cost, will be avoided, and fiscal policies can be developed on an ongoing, routine basis rather than on an episodic, crisis basis.

The ACIP and the American Academy of Pediatrics have recently recommended two-dose measles vaccination schedules after a number of years of discussion and debate related to the indications for and the costs of such a policy (31,32). Both recommendations are similar to the New York requirement except that the American Academy of Pediatrics recommends that the second dose be scheduled at sixth grade to achieve two-dose vaccine protection more quickly in the secondary school group, to increase the importance of a preteenage visit to the physician, and to ensure that children will have higher levels of antibody protection into adulthood if waning immunity is found to be a more important issue. NYS chose not to adopt this schedule as a requirement for school entry for four reasons: (a) public clinics in NYS, which provide vaccination to about a third of preschool children (NYS Department of Health, unpublished data), do not routinely provide clinic services to older children; (b) the college-age group, which has had the highest risk of measles in recent years, will be covered immediately by a separate college en-

trance requirement; (c) the requirement for the second dose at a younger age will eventually provide two-dose protection to the entire population of school children, not just those in sixth grade or above; and (d) waning immunity was not considered to be a major concern.

Conclusion

The revised two-dose measles immunization policy can be expected to reduce the number of measles cases that occur among primary and secondary school and college-age persons. These proposed guidelines will reduce confusion among the public and uncertainty among pediatric practitioners and the general community about the measles control strategy. The two-dose strategy of measles prevention should eliminate the need to engage in epidemic control or "firefighting." Increased costs of routine vaccine administration will be more than offset by the potential reductions in the amount of vaccine and number of medical personnel needed during epidemics, as well as disruption of school events and activities that often have occurred in the past.

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