ELIZABETH R. ZELL, MSTAT ■ TRENA M. EZZATI-RICE, MS
MICHAEL P. BATTAGLIA ■ ROBERT A. WRIGHT

National Immunization Survey: The Methodology of a Vaccination Surveillance System

Ms. Zell, Ms. Ezzati-Rice, and Mr. Wright are with the US Centers for Disease Control and Prevention (CDC). Ms. Zell is a Mathematical Statistician, Division of Bacterial and Mycotic Diseases, CDC, Atlanta, Georgia. Ms. Ezzati-Rice and Mr. Wright are with the National Center for Health Statistics, CDC, Hyattsville, Maryland. Ms. Ezzati-Rice is Chief of the Survey Design Staff, Office of Research and Methodology, and Mr. Wright is Chief of the Utilization and Expenditure Statistics Branch, Division of Health Interview Statistics. Mr. Battaglia is a Vice President of Abt Associates, Inc., Cambridge, Massachusetts.

SYNOPSIS

The National Immunization Survey (NIS) was designed to measure vaccination coverage estimates for the US, the 50 states, and selected urban areas for children ages 19–35 months. The NIS includes a random-digit-dialed telephone survey and a provider record check study. Data are weighted to account for the sample design and to reduce nonresponse and non-coverage biases in order to improve vaccination coverage estimates. Adjustments are made for biases resulting from nonresponse and nontelephone households, and estimation procedures are used to reduce measurement bias.

The NIS coverage estimates represent all US children, not just children living in households with telephones. NIS estimates are highly comparable to vaccination estimates derived from the National Health Interview Survey.

The NIS allows comparisons between states and urban areas over time and is used to evaluate current and new vaccination strategies.

Address correspondence to:
Ms. Zell, NCID, CDC, Mailstop C-09, 1600 Clifton Road NE, Atlanta GA 30333; tel. 404-639-4710; fax 404-639-2780; e-mail <ezr1@cdc.gov>.

Vaccination against childhood disease is an important public health intervention and one of the best ways to prevent unnecessary disease and death. While the US has been quite successful in vaccinating children entering school, many of the youngest children remain susceptible to vaccine-preventable diseases, as was seen during the nationwide measles resurgence in 1989–1991.[1] As recently as 1996, 22% of 2-year-old children remained inadequately protected against diseases that could have been prevented by diphtheria and tetanus toxoids and pertussis (DTP) vaccine, poliovirus vaccine, and measles-mumps-rubella (MMR) vaccine.[2]

In 1993, President Clinton launched the Childhood Immunization Initiative, a national strategy to achieve and maintain high vaccination levels for children during the first two years of life. The Initiative's goals are to improve vaccine delivery, reduce the cost of vaccines, enhance community participation, monitor vaccination levels and disease incidence, and improve vaccines.[3]

Healthy People 2000 calls for at least 90% of 2-year-old children to be fully vaccinated with the recommended schedule of vaccines, that is, by age 2 at least: four doses of DTP vaccine, three doses of polio vaccine, one dose of MMR vaccine, three doses of *Haemophilus influenzae* type b (Hib) vaccine, and three doses of hepatitis B (Hep B) vaccine.[3]

In 1994, the US established a vaccination surveillance system for infants and young children, the National Immunization Survey (NIS). In this article, we describe the sample, the survey design, and the data collection procedures for the NIS, including methods for maximizing survey response, statistical estimation techniques used to ensure the quality of the survey estimates, and the use of the NIS to obtain other important and timely health-related data at the state level.

VACCINATION SURVEILLANCE IN THE US

Monitoring of vaccination programs began in the US as early as 1957, when the Public Health Service contracted with the Bureau of the Census to conduct the National Poliomyelitis Vaccination Survey.[4] This survey continued through 1961 as an annual supplement to the Current Population Survey, and in 1962 became the United States Immunization Survey (USIS) with the inclusion of data on the administration of DTP vaccine to people younger than 15 years of age.[5] As new vaccines were licensed and recommendations for vaccination changed, the USIS became the national vaccination surveillance system. The survey began collecting data on measles vaccine in 1964 and on rubella vaccine in 1970.

The USIS continued through 1985. From 1986 through 1990, no national vaccination surveillance system was in place. Since 1991, the Centers for Disease Control and Prevention (CDC) has relied on the National Health Interview Survey (NHIS) for data on national vaccination coverage levels. A general purpose health survey, the NHIS uses in-person interviews to measure health characteristics of the US civilian, noninstitutionalized population.[6] A supplementary vaccination questionnaire has been part of this survey since 1992.

Like the USIS, the NHIS uses national samples and thus can not provide estimates of vaccination coverage levels for comparisons between states and urban areas or allow local vaccination programs to monitor coverage levels. Before April 1994, when data collection began for the first NIS, state vaccination programs used a variety of approaches to measure coverage levels, including birth certificate followback surveys and retrospective school-entrance surveys. For a couple of years in the early 1990s, all state vaccination programs conducted retrospective school-entrance surveys, but these did not measure "current" vaccination levels. Many states also performed birth certificate followback surveys, but since not all states did so, comparing vaccination levels across the 50 states was impossible.

In the future, computerized registries that include information on all children from birth will provide measures of vaccination levels and will be used to identify and recall those in need of vaccination.[7] In the interim, until registries are available, the NIS provides comparable estimates for states and selected urban areas of vaccination coverage levels.

DEVELOPING THE NIS

In the early 1990s, researchers at CDC's Division of Immunization and National Center for Health Statistics, including present authors ERZ and TME, evaluated various survey methodologies for potential use in monitoring vaccination coverage levels and providing uniform measures of coverage levels for states and urban areas. We established a set of broad criteria; to be considered an acceptable method, the survey methodology needed to:

- be developed and tested quickly and then implemented immediately;
- provide current and continuous estimates of vaccination coverage for children 19–35 months of age (This

target age group was established because by the age of 19 months, children should have received the complete series of vaccinations for DTP, polio, MMR, Hib, and Hep B and because narrowing the age range just to 2-year-olds, that is, children ages 24–35 months, would be extremely costly given very small numbers);
- provide reliable and valid annual estimates of vaccination coverage for 78 separate areas (all 50 states, the District of Columbia, and 27 large urban areas considered to be at high risk for undervaccination), referred to by the CDC's National Immunization Program as Immunization Action Plan (IAP) areas;
- provide timely estimates; and
- produce estimates at a reasonable cost.

Based on these broad specifications, we chose five alternative survey designs for consideration: (*a*) birth certificate followback surveys; (*b*) retrospective school-entrance surveys; (*c*) area probability sample surveys with in-person interviews; (*d*) provider-based surveys; and (*e*) random-digit-dialing (RDD) telephone surveys.

Each option has its own strengths and weaknesses. *Birth certificate followback surveys* have the advantage of using a sample drawn from birth records that includes only children in the target age group. However, this method requires intensive tracking of mothers and can be particularly costly in urban areas or across state boundaries. *Retrospective school-entrance surveys* are relatively inexpensive to conduct, but they cannot provide current vaccination levels. *Area probability sample surveys* with in-person interviews are a well-tested method. Unfortunately, in-person screening to identify households with children ages 19–35 months followed by a household interview would be extremely costly and time-consuming. Although *provider-based surveys* might be cost-effective for children with a regular source of care, such surveys over-represent children with multiple providers and exclude children who do not have a regular source of care.

Finally, *RDD telephone surveys* were examined as a potential option. Their primary advantage is that they can be conducted at lower cost than area probability surveys with in-person interviews, especially in screening for a relatively rare target population group such as households with children ages 19–35 months. In addition, an RDD survey allows for rapid data collection and timely results.

Given the need for a standard methodology that could provide timely vaccination coverage level estimates for 78 individual IAP areas to monitor the success of the Childhood Immunization Initiative, we selected the RDD methodology for the vaccination surveillance system. Of course, a major issue for telephone surveys is potential bias due to the exclusion of children living in households without phones. In addition, because previous studies found poor parental recall of the number of doses received for various vaccines and inaccurate or incomplete parent-held vaccination records,[8–13] the RDD survey would need to address concerns about the quality of the vaccination information reported by household respondents.

UNIQUE CHALLENGES

The NIS, an RDD telephone survey with a provider record-check study,[14] began data collection in April 1994. The design of the NIS posed several unique challenges. First, the survey needed to assess vaccination levels for children ages 19–35 months in each of the 78 IAP areas. Second, since only 4% to 5% of households with telephones include a child in this age range,[15] a large number of telephone households would have to be screened to determine whether an age-appropriate child resided in the household. Next, a major concern in RDD surveys is the response rate and, consequently, the potential for bias due to nonresponse.[16,17] Further, to ensure that the estimates would be representative of all children ages 19–35 months, statistical adjustments would be required. And, finally, the research design would have to account for potential reporting errors by household respondents arising from faulty recall or from inaccurate or incomplete written vaccination records.

NIS SAMPLE

The NIS includes ongoing, independent, quarterly surveys in the 78 IAP areas. This design allows any four consecutive quarters to be combined to provide estimates of vaccination levels. A quarterly random sample of telephone numbers is drawn for each IAP area, and trained interviewers administer a screening questionnaire to identify households with one or more children ages 19–35 months. The interviewers then collect vaccination information for all age-eligible children. The NIS is designed to complete telephone interviews each quarter for 110 children ages 19–35 months in each IAP area. Nationally, the target sample size is 8580 interviews per quarter or 34,320 per four-quarter period.

In generating the random sample, the NIS uses list-assisted RDD sampling to increase the proportion of resi-

dential numbers in the sample and thus make screening more efficient.[18] In this technique, telephone numbers grouped into blocks of 100 consecutive numbers are first matched against a proprietary data file of residential directory–listed numbers.[19] Blocks of 100 consecutive numbers that include no residential directory–listed numbers are removed from the sampling frame. A random sample of 10-digit telephone numbers is then drawn from the remaining blocks of numbers. The resulting sample includes both listed and unlisted telephone numbers and has a relatively high percentage of telephone numbers that are residential, rather than business or nonworking.[20,21] All households in the sample that are in the residential directory listing are mailed an advance letter explaining the survey.

The sample numbers that are not listed in residential directories are matched against a proprietary data file of business telephone numbers[19] in an effort to remove a portion of the business numbers before the sample numbers are dialed by interviewers. The sample numbers that are not identified as either residential or business numbers are then sent through an automated dialing procedure that is designed to detect signals from nonworking numbers.

In 1994, these pre-screening steps removed about 39% of the nonworking and business numbers from the initial sample, thereby raising the percentage of working residential numbers from about 46% to 57%.[22] Only about 1.4% of the residential numbers in the sample for the third quarter of 1994 were misidentified as nonworking or business numbers.[22]

In 1996, two million telephone numbers were randomly selected for the NIS. Approximately 19% of these numbers were initially eliminated as business or nonworking. Thus, more than 1.6 million telephone numbers were loaded into the computer-assisted telephone interview (CATI) system for telephone screening by interviewers. CATI provides telephone numbers and questions to the interviewers and allows them to enter respondents' answers directly into the computer. Approximately 36% of the numbers were determined to be business or nonworking numbers. Another 7% could not be classified. Thus 929,066 numbers were determined to be working residential telephone numbers. A household screening interview was successfully completed for 96.8% of these households. The 899,549 screened households yielded 35,021 households (3.9%) with one or more children ages 19–35 months, and an interview was completed for 94% of these eligible households. Because of multiple age-eligible children in some households, the completed household interviews (32,911) generated vaccination information for 33,305 children ages 19–35 months.

Beginning with the 1995 NIS, a provider record-check study was added because of concerns about reporting error by household respondents.

MAXIMIZING PARTICIPATION

Because the NIS is actually 78 separate surveys, the data collection process is automated as much as possible using CATI. The sample of telephone numbers covers six time zones, and the telephone center is in operation from early morning to past midnight seven days a week. Calls to a specific time zone are not conducted beyond 9 p.m. During each data collection quarter, interviewing takes place in the 78 IAP areas simultaneously. The sample for each IAP area is divided into replicates (subsamples) to distribute the sample throughout the quarter in order to obtain the target number of 110 interviews in each IAP area.

The NIS incorporates several special procedures designed to maximize the survey response rate. First, an advance letter is mailed to households with directory-listed telephone numbers (about 41% of the households in the 1996 sample). The advance letter explains the purpose of the survey, identifies the CDC as the agency conducting the survey, encourages households to participate, and encourages residents to locate the vaccination records of any young children in the household. Mailings are scheduled so that the advance letter arrives shortly before the first call is made. Camburn et al.[23] report that the advance letter increased the overall survey response rate by about 7 percentage points in the third quarter of 1994.

Second, interviewers follow a specific procedure when they encounter an answering machine (about 20% of the sample telephone numbers in 1996); the primary objective is to differentiate NIS calls from telemarketing calls.[24] After reaching an answering machine for the third time, interviewers leave a brief message describing the NIS and giving a toll-free number for household residents to call to ask questions about the survey and to schedule appointments for interviews. The message delivers the same information as the advance letter.

Third, the NIS uses two approaches to accommodate households in which the primary language spoken is not English. The questionnaire has been translated into Spanish, and Spanish-speaking interviewers and supervisors are always available. The NIS also uses real-time language translation services; the AT&T Language Line pro-

vides the ability to conduct interviews in more than 140 languages, 24 hours a day.[25]

Interviews. The telephone interviewer determines through initial screening questions whether the telephone number reached is a residential number and whether the household includes any children ages 1 to 3 years. The CATI system determines whether any child(ren) is (are) age-eligible for the survey using birth dates provided by the household respondent. The final set of questions in the screening section identifies the respondent most knowledgeable about the vaccination history of the age-eligible child(ren).

The need to collect accurate data requires an instrument that allows, and in some instances encourages, calling respondents back to complete the questionnaire. For example, in some cases the person who is most knowledgeable about the vaccination history of eligible children is not available at the time of the contact, or the time may be inconvenient.

The vaccination questions used in the NIS were adapted from the in-person vaccination questionnaire supplement used in the NHIS. The NIS CATI system first prompts the interviewer to ask the respondent to locate the child's written vaccination record (or arrange to complete the interview at another time when he or she can refer to the written record). When a written record is available, the interviewer asks the respondent to report the number and dates of vaccinations for DTP, polio, MMR, Hib, and Hep B. The respondent is also asked to report any additional vaccinations received by the child but not recorded on the written record. When a written record is not available, the interviewer asks the respondent to recall from memory the number of shots for each vaccine, but not the dates. As in the NHIS, the CATI instrument allows for an unsolicited response of "all" as the number of shots received for a particular vaccine.

Upon completion of the vaccination questions, the interviewer proceeds to obtain information on sociodemographic characteristics (educational level of mother, household income, and respondent-reported racial identification and Hispanic origin of mother and child or children); current residence; residence at time of the child's birth; and the number of telephone lines in the household. (Respondents are given the following racial categories from which to choose: "white," "black," "American Indian," "Asian," other.) Finally, the interviewer asks the respondent to give the names, addresses, and telephone numbers of all health care providers who have administered vaccinations to the sample child(ren). Verbal consent is then obtained from the parent or guardian to contact the named providers.

Provider record check. We mail questionnaires to the named providers with a cover letter from the Director of CDC's National Immunization Program to obtain dates of vaccinations from medical records. Providers have the option of responding by mail or fax. Two weeks after the initial mailing, a postcard is sent to all providers thanking those who have responded and serving as a reminder for those who have not. Five weeks after the original mailing, copies of the materials included in the initial request are mailed to each nonresponding provider. Seven weeks after the initial mailing, all remaining nonrespondents are telephoned. In 1996, calls were made to about 25% of all providers. The purpose of the telephone call is to remind providers to return the questionnaire; however, a small number of providers complete the questionnaire over the phone.

RESPONSE RATES

Household survey. The NIS has unique features that must be considered in calculating the household survey response rate. Specifically, the calculations must deal with (*a*) telephone numbers that have unknown residential status even after several call attempts, and (*b*) numbers known to be residential for which it is never determined whether a 19- to 35-month-old child resides in the household. The NIS's method for determining the response rate is consistent with standard methods.[26–28] It takes into account the proportions of (*a*) identified households with one or more eligible children; (*b*) working telephone numbers; and (*c*) working telephone numbers in which the household status is unknown. Using these standard components, the NIS household response rate was 84.5% in 1996.

The NIS attempts to survey a relatively rare subgroup of the total population of households with telephones; only 4% to 5% of telephone households include a child 19–35 months of age.[15] The NIS uses an alternative to the traditional response rate calculation to estimate nonresponse, taking into account undercoverage of children ages 19–35 months in telephone households (missed children in known telephone households).[29] An approximation to the proportion of missed children is obtained from the percentage of households in the 1994 NHIS without a telephone with an age-eligible child. Applying these additional data to the 1996 NIS, we determined a

more realistic household response rate of 69.5%, compared with a response rate of 84.5% calculated using the traditional approach. The difference between these two response rates can be attributed largely to undercoverage of age-eligible children.[30]

Provider response rate. In 1996, interviews were completed for 33,305 children from 32,911 households (mean of 1.012 children ages 19–35 months per household). Adult respondents named vaccination providers and gave verbal consent for 28,442 (85.3%) of these children. A total of 38,414 providers were identified (mean of 1.35 providers per child). Starting with the third quarter of 1996, the NIS adopted a computer-based tracking mechanism for ongoing monitoring of provider response. For that quarter, 96% of identified providers responded.

Children with both household survey and provider data. Trained data clerks review the provider record-check forms for accuracy and completeness. In 1996, 63.4% of children for whom interview data were collected had provider-reported vaccination information that was of sufficient quality to be used in deriving estimates based on a set of rules used to compare the provider and household vaccination data.

ENSURING THE QUALITY OF NIS ESTIMATES

Telephone surveys have known limitations, namely, the exclusion of households without telephones (noncoverage), the failure of some sample households to participate in the survey (nonresponse), and errors in respondents' reports (response error). NIS data, left unadjusted, do not reflect "true" vaccination levels because of potential bias introduced by these three limitations.

Standard statistical adjustments can be made to account for the first two limitations, resulting in a single weighting factor being assigned to each respondent child in the sample. The sample weights for individual children, when summed, yield estimates that reflect the population of all children ages 19–35 months, not just those in telephone households. The potential bias due to response error associated with vaccinations received is reduced by applying standard procedures for a stratified two-phase sample using the data obtained from the provider record-check study.[31]

Each of the components (household and provider) used to produce vaccination coverage estimates is outlined below.

Weighting the household data. The NIS weighting methodology builds on standard statistical procedures routinely used by NCHS and other statistical agencies to improve the reliability of estimates from household-based sample surveys.[32] Four steps are used for each IAP to arrive at the modified poststratification weight for each respondent child in the sample.

Base sampling weight. Each child in the sample is initially assigned a weight according to the probability of selection of the telephone number within the IAP area. This base weight is adjusted for multiple telephone lines in the household because a household with two or more residential telephone numbers has a proportionally higher probability of being selected.

Standard weighting-class adjustment for nonresponse (nonparticipation). Nonresponse can occur at several points in the NIS interviewing process. Standard weighting-class adjustment accounts for three types of nonresponse: (*a*) The household contains an age-eligible child, but an interview is not completed. (*b*) The sample telephone number is residential, but it cannot be determined whether the household contains any children ages 19–35 months. (*c*) The status of telephone number (residential, business, or not assigned) cannot be determined.

Homogeneous groups of respondent children are formed within each IAP area using sociodemographic characteristics of telephone exchanges such as the percentage of the adult population who are college graduates and the percentage of the population that is nonwhite.[19] An adjustment is made to each responding child's base sampling weight to account for the nonrespondents within the defined groups.

Adjustment to known population totals. National probability sample surveys commonly use an adjustment to known population totals for demographic characteristics, often referred to as a poststratification ratio adjustment,[32] to take undercoverage into account. The NIS makes this adjustment separately for each of the 78 IAP areas, using mother's racial/ethnic identification, mother's educational level, and age of the child to define subdomains of the population. The known population totals for these subdomains within each IAP area are obtained from the NCHS's natality data files, which we adjust for infant mortality, immigration, and migration (using vital statistics infant mortality data, 1990 Census data on country of birth to account for immigration to the US, and 1990 Census data on current residence and residence at birth

to reflect between-area mobility). In the NIS, this adjustment to the known population totals yields a "simple poststratification weight" and does not include an adjustment for households without telephones. The simple poststratification weight assumes that the vaccination level in each subdomain is the same for children in households with or without telephones.

Adjustment for households without telephones. This final adjustment for households without telephones leads to the modified poststratification weight. Direct information on the variable of interest (vaccination coverage level) for children in telephone and nontelephone households is available from another population-based survey, the NHIS. The NHIS collects information from both nontelephone and telephone households. An analysis of 1994 NHIS data suggests that, even when one takes into account the available demographic and socioeconomic factors, the percentage of children 19–35 months of age who are up-to-date with ≥4 DTP, ≥3 polio, and ≥1 MMR (4:3:1 series) is generally lower for children in households without telephones than for children in households with telephones.[33] The 4:3:1 series was chosen because Hib vaccine was not recommended for universal childhood vaccination until the early 1990s, and thus 4:3:1 coverage would be more stable than the 4:3:1:3 series (≥4 DTP, ≥3 polio, ≥1 MMR, and ≥3 Hib); during the early years of the NIS, 4:3:1:3 coverage estimates would have been more likely to reflect the implementation of this new recommendation.

To obtain the modified poststratification adjustment, each NIS subdomain is divided into two subgroups: children whose vaccinations are up-to-date and children whose vaccinations are not up-to-date.[34] Then the ratio of the 4:3:1 series vaccination level of children in nontelephone to telephone households, obtained from the NHIS, is used to adjust the simple poststratification weight to account for the exclusion of nontelephone households.

Adjustment for interruption in telephone service. The presence of a telephone may change over time for a substantial portion of households due to varying economic circumstances.[35] Starting with the second quarter of 1998, questions have been added to determine if the household experienced an interruption in telephone service in the previous 12 months. This information will be used to increase the weights for children who live in households with an interruption in telephone service to represent all children living in households without telephones. This approach offers the potential for a direct nontelephone adjustment for each IAP area.

Estimating vaccination coverage levels using both household survey and provider record data. In the NIS, provider reports are regarded as the "gold standard." While provider reports are usually more accurate and complete than survey respondent reports of vaccination levels,[36] provider reports still tend toward a slight underreporting of "true" vaccination coverage levels.[12] NIS provider data yield a set of ratio-adjustment factors that are applied to vaccination level estimates derived from the household interviews.

The procedure for combining household data and provider data to produce "provider-adjusted" estimates of vaccination levels involves three steps. First, children are assigned to categories of household responses that reflect the availability of a written record in the home (yes, no) and the response received concerning their 4:3:1:3 series status (up-to-date, not up-to-date, don't know). In each category, children are linked to their provider data, where available, using assigned identification numbers. Next, an adjustment factor is calculated for each vaccination or combination of vaccinations for each household response category. The adjustment factor is the weighted proportion of children in the category with provider data who, according to their providers' records, are up-to-date for the vaccine or combination of vaccines. The final step in producing provider-adjusted estimates is accomplished in each category by multiplying the category adjustment factor by the weighted total number of children in that category to provide an estimate of the total number of children up-to-date for a specified vaccine or combination of vaccines in that IAP area. This estimate is divided by the weighted total number of NIS children in the IAP area to yield an overall estimate of the proportion of children who are up-to-date in the area.

The procedure for deriving provider-adjusted estimates is illustrated in Table 1 using data on polio vaccine coverage levels from one IAP area. The five household response categories are shown, as defined above. For each category, the table shows the number of children with adequate provider data, the total of their modified-poststratification weights, the corresponding total weight for children who are up-to-date on polio vaccination according to their providers, the resulting weighted proportion up-to-date on polio vaccinations, the total number of respondent children, their total modified-poststratification weight, and the corresponding estimated total weight for children who are up-to-date on polio vaccina-

Table 1. Steps in developing provider-adjusted estimate of polio vaccination coverage level for children 19–35 months of age in one IAP area, National Immunization Survey, 1996

	Children with adequate provider data				All children		
Variable	Number	Weighted total number	Weighted number verified up-to-date on polio	Proportion verified up-to-date on polio	Number	Weighted total number	Population total up-to-date on polio[a]
Response categories							
Written record: up-to-date on 4:3:1:3	146	18,044	17,143	0.96	193	23,520	22,491
Written record: not up-to-date on 4:3:1:3	55	7580	5910	0.78	82	11473	8945
No written record: up-to-date on 4:3:1:3	30	3540	3322	0.94	60	7172	6730
No written record: not up-to-date on 4:3:1:3	21	2757	2324	0.84	44	5936	5005
Don't know 4:3:1:3 status	34	4749	3100	0.65	49	6560	4282
Total	286	36,670	31,799	—	428	54,661	47,453
Provider-adjusted estimate	—	—	—	—	—	—	86.8%

[a]Adjusted based on proportion verified up-to-date from provider records

4:3:1:3 series = ≥4 diphtheria and tetanus toxoids and pertussis vaccine, ≥3 poliovirus vaccine, ≥1 measles-mumps-rubella vaccine, and ≥3 *Haemophilus influenzae* type b vaccine

tions. In this example, the provider-adjusted estimate of polio vaccine coverage is 86.8% ([47,453/54,661] x 100%).

For each category except the first, the adjustment factor for an IAP area is calculated only from data for that IAP area. In the first category, "written record: up-to-date on 4:3:1:3," the adjustment factor is calculated from the combined data for all IAP areas (see Table 1). The national proportion is used for the first category because the proportion of these children reported as up-to-date by their providers is expected to be close to 1 and to vary little among IAP areas. Using the national proportion in this category reduces the impact of variation associated with the small sample size in each IAP area.

The variance of NIS provider-adjusted estimates is calculated according to standard procedures for stratified two-phase samples.[31] The variance accounts for the complex survey design and the two-phase estimation procedure.

EVALUATING THE QUALITY OF NIS ESTIMATES

In the previous section, we described the special procedures that the NIS uses to ensure the quality of vaccination coverage estimates. We now highlight specific improvements that have resulted from the various post-survey adjustment procedures. The direct adjustment to reduce potential bias associated with the exclusion of households without telephones is unique. To illustrate the effect of this adjustment, Table 2 shows for each IAP area in 1996 simple poststratification-weighted (without nontelephone adjustment) and modified poststratification-weighted (with nontelephone adjustment) 4:3:1:3 series estimates and the difference between the two estimates. The median difference in vaccination estimates associated with modified poststratification adjustments was -1.0 percentage point, with a range from -0.2 to -4.3 percentage points. Lower estimates are not surprising given that we know from the 1994 NHIS that children in nontelephone households tend to have lower vaccination levels.

The IAP areas with the largest differences included Arizona-Rest of State, Arkansas, Kentucky, Oklahoma, Tennessee-Rest of State, and West Virginia. Here "Rest of State" refers to all areas in the state excluding the urban IAP area(s). In each of these IAP areas, a substantial percentage of the households that contained a 2-year-old child did not have a telephone. According to the 1990 Census, the percentages of households with a 2-year-old child and no telephone range from 18.4% in Oklahoma to 25.4% in Arizona-Rest of State.[15]

The post-survey adjustments to reduce response error use both the modified poststratification estimates (with a

Table 2. Effect of nontelephone adjustment on estimates of percentage of children ages 19–35 months up-to-date for 4:3:1:3 series, National Immunization Survey, 1996

IAP area	Simple weight[a]	Modified weight[b]	Difference
Alabama			
Rest of state	50.4	47.8	-2.6
Jefferson County	46.1	45.2	-0.9
Alaska	50.6	48.7	-1.9
Arizona			
Rest of state	58.3	54.0	-4.3
Maricopa County	51.1	49.7	-1.4
Arkansas	55.0	51.2	-3.8
California			
Rest of state	57.2	56.6	-0.6
Los Angeles	53.4	53.2	-0.2
Santa Clara	50.8	50.5	-0.3
San Diego County	67.2	66.7	-0.5
Colorado	54.7	53.7	-1.0
Connecticut	47.6	47.2	-0.4
Delaware	53.4	52.5	-0.9
District of Columbia	46.0	45.1	-0.9
Florida			
Rest of state	50.8	49.4	-1.4
Duval County	50.7	49.2	-1.5
Dade County	59.8	59.1	-0.7
Georgia			
Rest of state	50.0	47.9	-2.1
Fulton/DeKalb	42.6	42.1	-0.5
Hawaii	52.0	51.4	-0.6
Idaho	54.6	52.7	-1.9
Illinois			
Rest of state	53.0	51.9	-1.1
City of Chicago	46.8	45.8	-1.0
Indiana			
Rest of state	59.2	56.5	-2.7
Marion County	52.7	51.4	-1.3
Iowa	58.1	57.1	-1.0
Kansas	61.8	60.1	-1.7
Kentucky	54.0	50.1	-3.9
Louisiana			
Rest of state	62.7	60.5	-2.2
Orleans Parish	55.7	54.5	-1.2
Maine	55.6	54.6	-1.0
Maryland			
Rest of state	54.8	54.3	-0.5
Baltimore City	54.0	52.7	-1.3
Massachusetts			
Rest of state	56.7	56.2	-0.5
City of Boston	50.2	49.7	-0.5
Michigan			
Rest of state	61.0	59.6	-1.4
Detroit	51.5	50.8	-0.7
Minnesota	55.3	54.6	-0.7
Mississippi	57.6	54.7	-2.9
Missouri	63.5	61.4	-2.1
Montana	55.4	53.7	-1.7
Nebraska	60.0	58.5	-1.5
Nevada	53.4	52.5	-0.9
New Hampshire	52.2	51.4	-0.8
New Jersey			
Rest of state	52.1	51.6	-0.5
City of Newark	51.3	50.3	-1.0
New Mexico	52.6	49.8	-2.8
New York			
Rest of state	40.7	40.0	-0.7
Metro New York City (5 counties)	48.1	47.4	-0.7
North Carolina	57.2	55.1	-2.1
North Dakota	54.5	53.7	-0.8
Ohio			
Rest of state	52.5	50.7	-1.8
Cuyahoga County	57.4	56.6	-0.8
Franklin County	52.5	51.6	-0.9
Oklahoma	52.5	49.2	-3.3
Oregon	47.8	46.3	-1.5
Pennsylvania			
Rest of state	43.3	42.6	-0.7
Philadelphia	41.6	41.0	-0.6
Rhode Island	50.4	49.4	-1.0
South Carolina	61.9	59.6	-2.3
South Dakota	64.6	62.3	-2.3
Tennessee			
Rest of state	62.4	58.7	-3.7
Shelby County	50.3	49.4	-0.9
Davidson County	55.8	54.2	-1.6
Texas			
Rest of state	45.4	44.2	-1.2
Dallas County	41.9	41.1	-0.8
El Paso County	46.4	45.3	-1.1
City of Houston	42.7	42.1	-0.6
Bexar County	49.1	48.7	-0.4
Utah	57.8	56.8	-1.0
Vermont	59.4	58.2	-1.2
Virginia	46.8	45.7	-1.1
Washington			
Rest of state	54.4	53.1	-1.3
King County	58.6	58.2	-0.4
West Virginia	57.2	53.5	-3.7
Wisconsin			
Rest of state	57.1	56.4	-0.7
Milwaukee County	50.2	49.2	-1.0
Wyoming	60.7	58.5	-2.2
United States	52.9	51.6	-1.3

[a]Simple-poststratification weight (without a direct nontelephone adjustment)

[b]Modified-poststratification weight (with a direct nontelephone adjustment)

4:3:1:3 series = ≥4 diphtheria and tetanus toxoids and pertussis vaccine, ≥3 poliovirus vaccine, ≥1 measles-mumps-rubella vaccine, and ≥3 *Haemophilus influenzae* type b vaccine

direct nontelephone adjustment) and information from providers. To illustrate the effect of this adjustment on vaccination estimates, Table 3 shows for each IAP area in 1996 the modified poststratification-weighted and provider-adjusted estimates for the 4:3:1:3 series and the differences between the two estimates. The provider adjustment produced a median increase in estimated vaccination levels of 23.85 percentage points, with a range of 6.4 to 41.5 percentage points. In every IAP area, the provider adjustment had a much greater effect than the modified poststratification-weighted adjustment (the nontelephone adjustment). As Table 1 illustrates, this important improvement in the accuracy and reliability of survey estimates came from establishing through the provider reports that many children who were not up-to-date by household report were actually current with their vaccinations.

The most reassuring evidence of the quality of the 1996 NIS data came from comparing the provider-adjusted national NIS estimates with the provider-adjusted estimates from the NHIS, which are inclusive of children from residences with and without telephones. The NIS provider-adjusted 4:3:1:3 vaccination level estimate for 1996 for the United States was 76.5% (95% confidence interval, 75.7% , 77.3%),[2] which was remarkably close to the 1996 NHIS provider-adjusted estimate of 77.1% (95% confidence interval, 73.4%, 80.8%).

OTHER USES OF THE NIS

In screening for children ages 19–35 months, the NIS samples a large number of households that include people of all ages. The NIS offers a cost-effective option for collecting vaccination information or other health- or welfare-related information about individuals in other age groups without increasing the size of its screening sample. Additional age groups of interest for vaccination coverage levels might include ages 12–18 months, 11–12 years, 18–64 years, and 65 years and older. Moreover, as health care markets respond to new incentives and states gain increasing responsibility for administering health and welfare programs through waivers and legislated reforms, high quality state-level data are recognized as increasingly important to the public health and health policy communities. Existing population surveys, such as the NHIS and the Medical Expenditure Panel Survey,[37,38] can provide relevant information at the national level on many important health-related issues. However, none of the major national surveys or other population-based data collection systems can provide the information needed to evaluate the performance and impact of various programs at the state level. Traditional surveillance systems monitor disease incidence by state; clearly, new and improved surveillance systems are needed to monitor the impact of various health, health-related (for example, insurance), and welfare programs.

As a cost-effective approach to providing needed data at the state level, NCHS is developing a new population-based, multipurpose survey as an expansion of the existing NIS. This new survey, the State and Local Area Integrated Telephone Survey (SLAITS), will provide useful monitoring and evaluation data at the state and sub-state levels. Various questionnaire modules (Health, Child Well-Being/Welfare, and Children's Health Insurance and Health Care) and strategies for oversampling high-risk population subdomains are being tested. The use of an existing survey, the NIS, rather than the development of a costly new data collection mechanism with a single focus, is consistent with the Department of Health and Human Service's survey integration plan.[39] SLAITS meets the goals of survey integration in three important areas. First, SLAITS makes use of the NIS, which already contacts and screens nearly one million households per year. Second, the questionnaire modules use questions from various national surveys such as the NHIS. Finally, as in the NIS, data from the NHIS can be used to adjust for households without telephones.

CONCLUSION

The NIS is the largest telephone survey ever undertaken. More than 1.6 million telephone numbers are called annually to identify the more than 33,000 children ages 19–35 months needed to monitor vaccination progress in all states as the nation moves toward the year 2000 and beyond. Telephone survey data combined with provider records and appropriate weighting adjustments for noncoverage and nonresponse yield the most accurate vaccination coverage estimates ever available at the state level. These estimates allow vaccination programs to evaluate the outcome of current and new vaccination delivery strategies, target limited resources, and monitor the introduction of new vaccines.

The largest source of error in the NIS is response error. Use of provider data in combination with household data significantly reduces response error; routine provider verification of self-reported vaccination data should be an integral component of household-based childhood vaccination surveys. However, provider-reported vaccination status is not without error and leads

Table 3. Effect of adjustment for reporting error on estimates of percentage of children ages 19–35 months up-to-date for 4:3:1:3 series, National Immunization Survey, 1996

IAP area	Household-based[a]	Provider-adjusted[b]	Difference
Alabama			
Rest of state	47.8	75.0	27.2
Jefferson County	45.2	77.4	32.2
Alaska	48.7	69.2	20.5
Arizona			
Rest of state	54.0	69.2	15.2
Maricopa County	49.7	70.8	21.1
Arkansas	51.2	71.7	20.5
California			
Rest of state	56.6	73.5	16.9
Los Angeles	53.2	79.2	26.0
Santa Clara	50.5	78.7	28.2
San Diego County	66.7	76.8	10.1
Colorado	53.7	76.2	22.5
Connecticut	47.2	87.3	40.1
Delaware	52.5	79.9	27.4
District of Columbia	45.1	78.2	33.1
Florida			
Rest of state	49.4	77.8	28.4
Duval County	49.2	75.8	26.6
Dade County	59.1	75.8	16.7
Georgia			
Rest of state	47.9	81.8	33.9
Fulton/DeKalb	42.1	74.4	32.3
Hawaii	51.4	77.0	25.6
Idaho	52.7	65.7	13.0
Illinois			
Rest of state	51.9	75.3	23.4
City of Chicago	45.8	73.7	27.9
Indiana			
Rest of state	56.5	70.0	13.5
Marion County	51.4	72.1	20.7
Iowa	57.1	80.4	23.3
Kansas	60.1	73.4	13.3
Kentucky	50.1	76.1	26.0
Louisiana			
Rest of state	60.5	80.3	19.8
Orleans Parish	54.5	71.4	16.9
Maine	54.6	84.7	30.1
Maryland			
Rest of state	54.3	77.9	23.6
Baltimore City	52.7	80.5	27.8
Massachusetts			
Rest of state	56.2	85.9	29.7
City of Boston	49.7	83.7	34.0
Michigan			
Rest of state	59.6	76.1	16.5
Detroit	50.8	62.6	11.8
Minnesota	54.6	82.5	27.9
Mississippi	54.7	79.4	24.7
Missouri	61.4	73.7	12.3
Montana	53.7	76.7	23.0
Nebraska	58.5	80.2	21.7
Nevada	52.5	69.6	17.1
New Hampshire	51.4	82.8	31.4
New Jersey			
Rest of state	51.6	77.6	26.0
City of Newark	50.3	62.3	12.0
New Mexico	49.8	79.1	29.3
New York			
Rest of state	40.0	81.5	41.5
Metro New York City (5 counties)	57.4	75.4	18.0
North Carolina	55.1	76.6	21.5
North Dakota	53.7	80.5	26.8
Ohio			
Rest of state	50.7	76.7	26.0
Cuyahoga County	56.6	79.7	23.1
Franklin County	51.6	78.4	26.8
Oklahoma	49.2	72.6	23.4
Oregon	46.3	70.4	24.1
Pennsylvania			
Rest of state	42.6	80.3	37.7
Philadelphia	41.0	75.1	34.1
Rhode Island	49.4	84.5	35.1
South Carolina	59.6	84.4	24.8
South Dakota	62.3	80.5	18.2
Tennessee			
Rest of state	58.7	79.6	20.9
Shelby County	49.4	70.1	20.7
Davidson County	54.2	77.4	23.2
Texas			
Rest of state	44.2	73.9	29.7
Dallas County	41.1	71.5	30.4
El Paso County	45.3	62.2	16.9
City of Houston	42.1	68.1	26.0
Bexar County	48.7	73.8	25.1
Utah	56.8	63.2	6.4
Vermont	58.2	84.9	26.7
Virginia	45.7	76.8	31.1
Washington			
Rest of state	53.1	76.6	23.5
King County	58.2	81.4	23.2
West Virginia	53.5	70.7	17.2
Wisconsin			
Rest of state	56.4	78.0	21.6
Milwaukee County	47.2	70.1	20.9
Wyoming	58.5	77.5	19.0
United States	51.6	76.5	24.9

[a]Percentage of children ages 19–35 months up to date for 4:3:1:3 series by household report

[b]Percentage of children ages 19–35 months up to date for 4:3:1:3 series by household report, adjusted by provider record data

4:3:1:3 series = ≥4 diphtheria and tetanus toxoids and pertussis vaccine, ≥3 poliovirus vaccine, ≥1 measles-mumps-rubella vaccine, and ≥3 *Haemophilus influenzae* type b vaccine

to a slight underreporting of "true" vaccination coverage levels.[12]

Until vaccination registries are widely in place, the NIS will provide information about areas and subpopulations at high risk for outbreaks of disease (low vaccination levels) and areas with model vaccination programs (high vaccination levels) and will be used to track the implementation of new vaccines. For the future, the NIS may also be used to monitor other health-related issues to help meet the ever-increasing need for state-level and urban area data.

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(Continued from p. 6)

ple to stretch their available food dollars, and involve "consumers" in the process of food distribution. An empowered low-income family can use these programs, together with what is left of the Food Stamp program, and eat adequately 365 days a year without visiting a pantry or meal site.

We have the understanding and the resources to end poverty, but we are so invested in taking care of the poor that we ignore opportunities. If the minimum wage and the standard for self-sufficiency were the same, the relationship among low-income people, the government, and nonprofit charities would change.

Until business, labor, government, faith organizations, and secular nonprofits start to work in partnership with low-income people to bring them out of poverty, those concerned with true social justice will continue to feel like Bill Murray's character in the movie *Groundhog Day*, who was cursed to spend his life repeating the same February 2 over and over again.

Erica Siegel Raine, MA LICSW
Community Projects Manager
Fair Foods, Inc.
Dorchester, MA ■