Forty Years and Four Surveys
How Does Our Measuring Measure Up?

Diane M. Simpson, MD, PhD, Trena M. Ezzati-Rice, MS, Elizabeth R. Zell, MStat

Objective: This article reviews four surveys methodologies that have been used over the past 40 years to assess immunization rates in young children in the United States. These methods include three national surveys: (1) United States Immunization Survey (1959–1985), which was first a household and then a telephone survey; (2) National Health Interview Survey (1991–present), which interviews people in their homes; and (3) National Immunization Survey (1994–present), a random-digit-dialing telephone survey. In addition, a series of retrospective school record surveys that used standard sampling and assessment methodologies were conducted nationally during 4 school years September 1990–May 1991.

Methods: Federal publications, National Immunization Conference proceedings, and Centers for Disease Control and Prevention (CDC) internal reports regarding national immunization surveys were reviewed. The methodology used in each survey is presented, and selected examples of previously tabulated results are presented.

Conclusions: The assessment of immunization coverage in American preschool children requires ongoing commitment and survey expertise. Over the past 40 years the CDC's efforts to determine vaccination coverage in young children has evolved from the comparatively simple United States Immunization Survey to the current National Immunization Survey that utilizes sophisticated statistical and survey techniques to obtain the most-accurate results yet available.

Medical Subject Headings (MeSH): child, preschool; health surveys; sampling studies; vaccines, data collection (Am J Prev Med 2001;20(4S):6–14) © 2001 American Journal of Preventive Medicine

Introduction

Vaccines have been heralded as the greatest public health achievement of the 20th century. Their effectiveness is apparent in the dramatic and rapid declines in morbidity and mortality that followed their introduction.[1] Vaccines are considered so important to the health of children in the United States that all state governments require them for entry into school and the federal government has established programs that provide for their administration at low or no cost to uninsured or underinsured children. High rates of vaccine coverage in young children are vital to the control of vaccine-preventable diseases, and public health systems need to assess a vaccine-preventable

disease's burden in a population related to its specific vaccine coverage.

The accurate assessment of vaccine coverage in preschool children is, however, logistically challenging and expensive. Surveys are the most widely used means to measure coverage but in order to minimize bias and produce reliable and valid estimates, very large samples and supplementary data collection are needed. Nevertheless, the federal government has had a commitment to a series of national childhood immunization surveys. Regular assessments of vaccination coverage allow our immunization programs to discern and correct problems before an outbreak of a vaccine-preventable disease occurs.

Over the past 40 years, four different systems to assess vaccine coverage in preschool children have been attempted. Three national immunization surveys interviewed parents about their children's immunizations and the fourth assessment retrospectively analyzed school records. The first of the three interview surveys was the U.S. Immunization Survey (USIS), conducted from 1959 through 1985. The second is the immunization component of the National Health Interview Survey (NHIS), which has been in place since 1991 and the

From the National Immunization Program (Simpson), National Center for Health Statistics (Ezzati-Rice), and National Center for Infectious Diseases (Zell), Centers for Disease Control and Prevention, Atlanta, Georgia

Address correspondence to: Diane M. Simpson, MD, PhD, Centers for Disease Control and Prevention, 1600 Clifton Road, Mailstop E-62, Atlanta, GA 30333.

Address reprint requests to: Centers for Disease Control and Prevention, National Immunization Program Resource Center, 1600 Clifton Road NE, Mailstop E-34, Atlanta, GA 30333. Fax: (404) 639-8828.
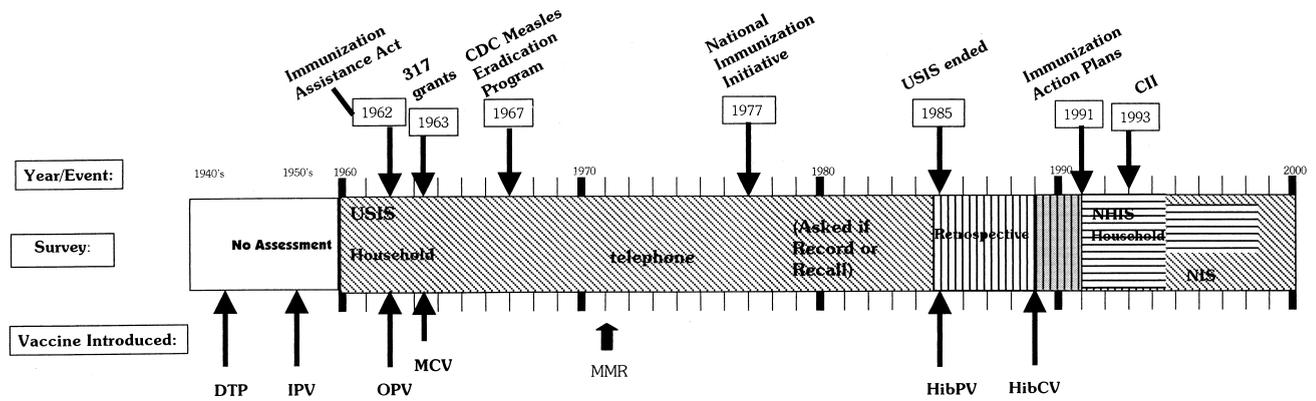
Figure 1. Time line of immunization surveys as they relate to the introduction of vaccines and immunization initiatives. USIS, U.S. Immunization Survey; CII, Childhood Immunization Initiative; NHIS, National Health Interview Survey.

third is the National Immunization Survey (NIS), which began in 1994. Both the NHIS and the NIS are ongoing. To fill the gap when no national survey was in process, immunization coverage at age 2 was estimated in Retrospective Surveys of School Enterers, which utilized a sample of children entering kindergarten or first grade during 4 school years (September 1990–May 1994). These school-based surveys estimated vaccination coverage when the school enterers were age 2 years in the mid-to-late 1980s (Figure 1).

This article describes and evaluates current and past efforts to measure immunization coverage in the nation's preschool population. The age groups covered in the different surveys varied as did each survey's methodology. These differences make a complete and consistent demonstration of coverage trends over time invalid.

Methods

Previously published tables and graphs of data from the different surveys were reviewed. Prior to 1990, most of the data were published in Department of Health and Human Services official publications or were presented at National Immunization Conferences. Early data files of the individual survey responses cannot be located and are not available for re-analysis. Consequently, coverage estimates are limited to age groups presented in previous publications. The four surveys are summarized below.

United States Immunization Survey (1957–1985)

History. The USIS evolved from two questions regarding receipt of the polio vaccine that were added to the Bureau of Census's ongoing Current Population Survey in 1957 at the request of the Communicable Disease Center (now the Centers for Disease Control and Prevention [CDC]). Polio immunization coverage among children was first published in 1959. The survey was renamed "the USIS" when questions on the combination vaccine—diphtheria, tetanus, and pertussis (DTP)—were added in 1962. Questions regarding the measles vaccine, rubella vaccine, and infections were added later.

Methodology. Initially, the USIS was conducted as an area-probability household survey using personal interviews. This methodology of home interviews became prohibitively expensive with the advent of the U.S. energy crisis of the 1970s. From 1971 to 1985, data were collected by telephone.

Based on information published in the mid 1970s, the USIS consisted of a 35,000-household sample spread over the 50 states and District of Columbia. All but approximately 1500 households were interviewed. Data were obtained on persons of all ages regarding receipt of influenza vaccine in the preceding 12 months. Parents of children were asked about their child's immunization history, and answers based on either memory (recall) or an immunization record kept in the home were accepted without further validation.

Vaccines measured. In 1959, the first year of the study, only coverage levels for three doses of polio vaccine (polio3) were assessed. Beginning in 1962, parents were asked about three doses of diphtheria and tetanus toxoids and pertussis vaccine (DTP3). A question on receipt of one dose of measles vaccine was added in 1964, and of one dose of rubella vaccine in 1970. An inquiry about one dose of mumps vaccine was added to the survey in 1973.

Prior to the introduction of these effective viral vaccines, there was a high incidence of measles and rubella infections in U.S. children. From 1965 to 1978, the USIS asked if the child had ever been diagnosed with measles disease. An inquiry into a history of rubella disease was added in 1970. Results regarding rates of prior infection are not available after 1978. These additional disease history questions allowed the program to determine the proportion of children who were no longer susceptible to these two viral diseases either because they were immunized or because they had had the infection.

Information on vaccination with polio vaccine; DTP; measles, mumps, and rubella vaccines; and history of measles, rubella, and mumps infections was limited to children and teens. The USIS also collected data on age, race, poverty status, and whether the child lived in a central city area of a Standard Metropolitan Statistical Area. Concerns over the accuracy of the results, which were substantially different from vaccination coverage estimates based on school-entry

data, and the cost of the survey caused the USIS to be dropped after 1985.[2]

Limitations. The USIS was limited in several respects. The USIS provided national estimates of vaccination coverage in the population but could not provide state or local coverage data. When the USIS changed from a household survey to a telephone survey, no statistical adjustments were made to account for differences in vaccine coverage in households without telephones. In addition, after the measles, mumps, and rubella vaccine (MMR) was first licensed in 1971, concerns were raised about respondents' abilities to know which antigens their children had received if a combination vaccine had been administered. A medical-provider survey to assess the validity of the self-reports of vaccination was never implemented.

Based on the recommendations of an outside review in 1975, the questionnaire was changed in 1976 to allow for a "don't know" response. Results from 1976 showed that non-responders and parents who answered "don't know" accounted for approximately 6% to 7% of the sample. Consequently, results obtained before 1976 were not considered directly comparable to those obtained in later years.[3]

After the implementation of state immunization laws for school entry in the late 1970s, it became apparent that the immunization rates calculated from kindergarten and first-grade student vaccine records provided to the schools were higher than those obtained from the USIS for children aged 5 years to 6 years. This observation provoked an evaluation of the accuracy of the responses provided to the USIS. In 1979, a question was added that asked if the parent were reading from the child's immunization record or recalling the child's immunization history from memory. Comparisons between rates obtained from immunization records versus the total sample (records and recall) conducted on data collected between 1979 and 1983 showed that the USIS, which accepted parental recall, underestimated the true vaccination rate in preschoolers by as much as 23% for some antigens. USIS coverage rates restricted to children who had immunization records were similar to rates obtained from school-entry data. Although the survey results based on parents with immunization records were thought to reflect immunization coverage trends, it was discontinued after 1985.[4]

Retrospective Surveys of School Enterers' Immunization Records (1991–1994)

History. During the measles resurgence of 1989–1991, the lack of current, accurate data on the immunization status of preschool children became apparent. A survey that could provide population-based state or area-specific coverage estimates for preschool children was needed. Federal, state, and local health agencies were struggling with the financial and human resources needed to curtail the measles epidemics occurring around the country. Thus, the surveys needed to be easy to implement, inexpensive, and able to provide valid estimates of vaccination levels. To respond to this need, CDC's Immunization Division (now the National Immunization Program [NIP]) published in July 1990 a standardized method for conducting retrospective school-entrant surveys. While some states had been conducting retrospective surveys prior to 1990, all state and local health departments that received federal immunization grants were directed to con-duct these surveys from school year 1990–1991 through school year 1993–1994.

Methodology. The retrospective school-entrant surveys were relatively simple and inexpensive. During the 1991 to 1993 school years, state and local grantees collected a multistage cluster sample of school immunization records of kindergarten or first-grade children. The goal was to assess retrospectively children's vaccination status at their second birthday.

The standard method used to conduct these surveys was as follows: Within the state or local health department's area 35 schools were selected. The probability of being selected was proportional to the estimated number of kindergarten or first-grade children enrolled in the school. Twenty-five students were then randomly selected within each school. For these children, vaccination information was abstracted from the school's required records of student immunization status. Vaccination coverage levels of the selected students were calculated at each child's second birthday and when the child entered school. Given that immunizations were mandated for school entry, children without recorded immunization histories were assumed to be unimmunized. With this sampling plan, vaccination coverage estimates for states or local areas could be estimated. Immunization program officials were able to identify areas where preschool vaccination coverage had been low during the years 1984 to 1987.

Vaccines measured. Coverage rates for four doses of DTP (DTP4), three doses of DTP (DTP3), three doses of polio vaccines (polio3), and one dose of MMR, and the vaccine series 4:3:1 (DTP4, polio3, and 1 MMR) were calculated.

Limitations. The primary disadvantage of the retrospective school-entrant surveys was that they provided coverage level estimates as of the second birthday, a time 3 to 4 years in the past. These surveys could not provide current vaccination coverage—information necessary for health departments to plan and assess immunization initiatives. In addition, at the time of these surveys there was no assessment of the accuracy of the school-held vaccination records, many of which were transcribed by school personnel from parent-held immunization cards. Anecdotally, one urban area with low rates on their retrospective survey claimed that the estimated coverage was inaccurate. They argued that to save time, some school staff recorded only the immunizations the child needed for school entry and not each vaccine received. Consequently, many children may not have had all their DTP vaccinations listed on their school record, because the state accepted three DTPs at school entry if one of the three doses were given after the fourth birthday.

National Health Interview Survey (1991–Present)

History. The NHIS is one of the major data collection systems of the CDC's National Center for Health Statistics (NCHS). Through NHIS, information on the health and health care of the U.S. non-institutionalized civilian population is collected in face-to-face household interviews. The NHIS has been in continuous operation since 1957. The survey consists of a core set of questions to which supplemental questions on specific health topics may be added. National estimates of vaccination coverage have been available from the NHIS since 1991. Since 1994, parental responses regard-

ing immunizations administered to young children have been validated by the National Immunization Provider Record Check Survey (NIPRCS), which asks the child's healthcare provider to submit the child's immunization history.

Methodology. The survey methodology of the NHIS has changed over time. Originally, dates of vaccinations were collected as part of the Child Health Supplement from a written immunization record for one child aged <18 years per eligible family. If a written record were not available, parental history (recall), requiring the child's exact age at each vaccination, was used.

In 1992, immunization information was collected only on one child aged <6 years per interviewed family. The total number of doses for each vaccine that the child received could be reported by recall or from a vaccination record; an unsolicited response of "all" was also accepted.

In 1994, NHIS again altered its methodology to include any child aged 19 to 35 months in the home as well as the one sample child aged <6 years. The names and addresses of the immunization provider(s) for the child aged 19 to 35 months were obtained along with written permission to contact these providers and obtain the child's immunization history as part of the NIPRCS.

In 1997, data collection in the NHIS was converted from paper and pencil to computer-assisted personal interviewing. Use of this system in the field provides automatic data quality checks and allows for a more accurate and consistent transition from one question to the next. In addition, since 1997, childhood immunization information has been collected for one sample child aged <18 years and all children aged 12 months to 35 months in a family.

A provider record check is conducted as part of NIPRCS on data obtained from the family on children aged 12 to 35 months. The NHIS bases its coverage estimates on these provider-verified data because submitted provider data have shown that coverage levels based only on parental response underestimated the DTP4:polio3:1 dose of MMR, and the three doses of *Haemophilus influenzae* type b (Hib3) by 11.5 percentage points. Details of the NIPRCS are described in an earlier publication.[5]

The current sampling method used in the NHIS is designed to yield information on approximately 40,000 households and about 100,000 people and includes an oversample of African-American and Hispanic people. Only a minority of these households, however, will have children aged 12 to 35 months.

Vaccines measured. The NHIS now measures coverage rates for diphtheria and tetanus toxoids (DT)/DTP, polio, MMR, Hib, hepatitis B (HepB), and varicella vaccines.

Limitations. The NHIS's primary limitation is one of sample size. Due to the cost of face-to-face interviews, the sample of households in the NHIS can produce reliable estimates of vaccination coverage only at the national level and is not sufficiently large to produce reliable state or local-area statistics.

Another disadvantage is the length of time required to collect and analyze the data. Data are compiled by calendar year and the results of the analyses are often not available for 12 to 18 months after the year of data collection. These two disadvantages make the information of limited use to state

and local health departments who must plan and implement interventions to increase immunization rates in preschoolers. However, the information obtained on differences between immunization rates in homes with and without telephones is invaluable to the NIS analyses.

Finally, the changes over time in the ages of the children surveyed and the use of provider verification of parental records and recall make it difficult to assess any trends in vaccine coverage.

National Immunization Survey

History. In 1993, the federal Childhood Immunization Initiative established coverage goals for preschool children. In response, the NIS, a national telephone survey that collects vaccination information on children aged 19 to 35 months, was established as a joint effort between two centers at the CDC—the NCHS and the NIP. The survey began in April 1994 and is ongoing. The NIS is sufficiently large and comprehensive to estimate coverage by state and 28 urban areas.

Methodology. The NIS is a random-digit-dialing (RDD) telephone survey that queries parents of children aged 19 to 35 months on their child's vaccination history and some demographic factors. Parents are also asked to provide consent for the CDC to contact their child's immunization provider(s) to obtain a written vaccination history.

The NIS is designed as an ongoing, independent, quarterly RDD survey that provides vaccination coverage–level estimates by state and the 28 urban areas for all recommended childhood vaccines. The NIS has a goal of 8580 completed interviews each quarter, or 34,320 each year.

RDD surveys can be conducted at a much lower cost than in-person household interviews. This is particularly important for surveys such as the NIS, which must contact hundreds of thousands of homes each year to find a relatively small group of the population, namely the 4% or 5% of households with telephones and children aged 19 to 35 months. Calls are made throughout the year.

An RDD survey methodology, coupled with computer-assisted telephone interviewing, which increases the interviewer's speed and accuracy during the call, was determined to be the only standard method available that could provide current national, state, and local vaccination coverage levels in children aged 2 years in a cost-effective and timely manner. However, a number of survey procedures and statistical estimation techniques were also incorporated into the NIS to produce more-accurate and reliable estimates.

The NIS first calls the sample of households to determine if there are eligible children (aged 19 to 35 months). If children in this age cohort reside in the home, the parents are interviewed to collect immunization histories with the parent using written records if available. The NIS then collects vaccination information from the children's immunization providers. The NIS also collects information from the parent on family income, race and ethnicity, age of child, marital status of mother, education of mother, household size, and a change in address since the child's birth.

The NIS vaccination coverage estimates are based on the provider data. To ensure that these estimates are representative of all children aged 19 to 35 months, and to reduce potential bias due to the exclusion of children living in

households without telephones, statistical adjustments are carried out using information from the NHIS that obtains immunization information on children in homes with or without telephone service. Further adjustments are made for provider nonresponse. Finally, an adjustment to known population totals is made to account for household nonresponses and population undercounts. Details of the NIS sample design and statistical estimation methodology are described elsewhere.[6–8]

Vaccines measured. The NIS inquires about every vaccine a child has received, but publishes coverage levels for only those vaccines recommended by national immunization advisory groups for universal routine administration. Currently, in 2001, coverage levels are determined for the DTP3, DTP4, MMR, polio3, Hib3, HepB3, varicella, and pneumococcal vaccines.

Limitations. Several limitations exist within the NIS methodology. The NIS relies on contacting homes with telephones. Children in homes without telephones are more likely to have inadequate immunizations[7] and, while an adjustment for nontelephone coverage is included in the NIS, some bias may still exist.

The NIS sample size cannot provide vaccination coverage estimates for many population subgroups or small areas within a local area. These subgroups and geographic areas of low coverage may be important to efficient program planning. For example, a local area may learn through the NIS that rates are low in white children whose family income is below established poverty levels. However, the NIS would not be able to discern if the children lived in one area of town, visited the same immunization providers, or were uninsured.

The current NIS estimation strategy assumes that the provider data are correct but a provider's record on a child may not always be complete. A provider may not have entire histories on children who have visited other clinics for their vaccinations. In these cases, the child's immunization status in the NIS will be misclassified.

The NIS determines vaccine coverage based only on the number of doses received. The NIS does not determine if children received their immunizations at the time intervals or ages recommended by vaccination advisory committees who set the national standards on which school laws are based. For example, a child with one dose of measles vaccine will be classified as up-to-date even if he or she received a measles vaccine at age 6 months and none thereafter. One dose of measles vaccine at age 6 months does not meet national recommendations or state mandates.

Results

Selected examples of earlier published tables and a graph that demonstrate useful and interesting insight into childhood immunization coverage are presented here. Although there were significant methodology problems with the USIS, its published rates of vaccination coverage are the only estimates available for much of the past 40 years. The NHIS produced relatively few years of vaccination coverage data in young children before the more inclusive and timely NIS was established. Results from the 1999 NIS are presented in the

Table 1. Vaccination coverage in children aged 1 to 4 years by antigen[a]

Year	Polio 3 (%)	DTP 3 (%)	Measles (%)	Mumps (%)	Rubella (%)
1959	65				
1960	72.2				
1961	74.3				
1962	78.4	67.8			
1963	84.1	72.9			
1964	87.6	76.0	24.0		
1965	73.9	73.9	33.2		
1966	70.2	74.5	45.4		
1967	70.9	77.9	56.4		
1968	68.3	76.5	58.8		
1969	67.7	77.4	61.4		
1970	65.9	76.1	57.2		37.2
1971	67.3	78.7	61.0		51.2
1972	62.9	75.6	62.2		56.9
1973	60.4	72.6	61.2	34.7	55.6
1974	63.1	73.9	64.5	39.4	59.8
1975	64.8	75.2	65.5	44.4	61.9
1976	61.6	71.4	65.9	48.3	61.7
1977	60.1	69.5	63.1	48.1	59.4
1978	61.4	68.0	62.8	51.1	61.7
1979	59.1	65.4	62.7	55.4	63.5
1980	58.8	66.3	63.7	56.6	63.5
1981	60.0	67.5	63.8	58.4	64.5
1982	58.0	66.3	64.0	58.9	62.8
1983	57.0	65.7	64.9	59.5	64.0
1984	54.8	65.7	62.8	58.7	60.9
1985	55.3	64.9	60.8	58.9	58.9

[a]U.S. Immunization Survey data were published previously and known to underestimate coverage rates.
DTP, diphtheria, tetanus, and pertussis.

tables published in this supplement.[9] Consequently most of the tables in this article are previously published data from the USIS.

Table 1 provides estimated coverage levels for children aged 1 year to 4 years in 1959 to 1985. Of interest is the slow uptake of new vaccines and the steady decrease in coverage with polio vaccine following a peak at 87.6% in 1964. Trivalent oral polio vaccine was introduced in the United States in 1963 and may explain this peak in coverage. Even if it is assumed that the USIS underestimated vaccination coverage by as much as 20%, the coverage levels in preschoolers in 1985, the last year of the USIS, had dropped to intolerable levels. Based on these data, coverage in young children with measles vaccine in 1985 was probably between 60% and 80%, levels which permitted the large outbreaks that occurred a few years later.

Table 2 looks at rates in children aged around 2 years. Tables of USIS data presented vaccination levels in children in the second year of life (i.e., 24 months to 35 months). The NHIS also presented data for this same age group but the NIS slightly expanded the age group to include children as young as 19 months. Again, taking into account the negative bias in the USIS estimates of vaccination coverage, it is clear that re-

Table 2. USIS-reported coverage rates for children aged 24 to 35 months for 1979–1985, NHIS-reported coverage rates for children aged 24 to 35 months for 1991–1993, and NIS-reported coverage rates for children aged 19 to 35 months for 1994–1999[a]

Survey	Year[b]	DTP3 (%)	Polio3 (%)	Measles (%)	Mumps (%)	Rubella (%)
USIS	1979	64.4	59.7	66.5	55.9	65.9
	1980	66.0	58.9	66.6	59.9	67.5
	1981	68.1	59.2	66.8	60.4	68.8
	1982	67.1	57.0	67.6	61.5	66.7
	1983	65.4	56.9	66.3	59.2	65.9
	1984	65.0	53.2	65.8	60.0	62.1
	1985	63.6	53.6	61.2	58.8	59.0
NHIS	1991	68.8	53.2	82.0		
	1992	83.0	72.4	82.5		
	1993	88.2	78.9	84.1		
NIS	1994	93	83	89		
	1995	94.7	87.9	89.9		
	1996	95.0	91.1	90.7		
	1997	95.5	90.8	90.5		
	1998	95.6	90.8	92.1		
	1999	95.9	89.6	91.5		

[a]These data were tabulated and reported previously. The USIS data are known to be inaccurate.
[b]No nation-level data are available for 1986 through 1990.
NHIS, National Health Interview Survey; NIS, National Immunization Survey; USIS, U.S. Immunization Survey.

Table 4. Percent of children aged 1 to 4 years whose parents reported that these children had measles or rubella immunization or disease previously, U.S. Immunization Survey, 1965–1978

Year	Measles vaccine (%)	Measles infection (%)	Rubella vaccine (%)	Rubella infection (%)
1965	32.0	19.7		
1966	45.4	16.7		
1967	56.4	12.8		
1968	58.8	9.7		
1969	61.4	8.3		
1970	57.2	8.1	37.2	14.4
1971	61.0	8.7	51.2	13.9
1972	62.2	7.4	56.9	12.3
1973	61.2	6.3	55.6	12.8
1974	64.5	5.1	59.8	12.2
1975	65.5	4.8	61.9	11.3
1976	65.9	4.3	61.7	10.0
1977	63.1	3.8	59.4	10.0
1978	62.8	3.3	61.7	7.8

markable progress in achieving high rates of immunization for children aged <3 years has been accomplished in the last 10 years.

Table 3 shows the difference in coverage levels between rates calculated from the total sample of children whose parents either read from an immunization record or recalled their child's immunization history and the subset of these children whose parents had a written record of their child's vaccination. As noted, coverage levels increased by 14% to 23% when results excluded data based on parental recall.

Table 4 supports the importance of immunizations. As new immunizations are introduced and

their coverage levels increase, the percent of children aged 1 year to 4 years who had these diseases also decreased.

Some parents do not support all or specific immunizations and refuse to vaccinate their children; other children have medical contraindications to certain vaccines. As shown in Table 5, the percent of parents who reported that their child had not received any doses of DTP and the percent who responded that their child had not received polio vaccine have decreased over 12 years, as school laws took effect. Interestingly, in all but one of the years for which data are available, more children lacked polio vaccine than DTP vaccine. The reasons for this are unclear, but it is possible that parents did not realize that orally administered polio vaccine was a vaccination or that, due to known paralytic adverse events associated with oral polio vaccines, parents are more fearful of the vaccine. In 1999, NIS data show that 2.5% of parents reported either no DTPs or no OPVs (Table 6).

Table 3. Coverage rate of a total sample of 2-year-old children whose parents stated that they had received a vaccine or vaccine series and responded either from memory or from a vaccine record compared to the coverage rate in a subset of the total sample of parents who had their child's immunization record

Year	DTP3 total sample (%)	DTP3 record (%)	Polio3 total sample (%)	Polio record (%)	Measles total sample (%)	Measles record (%)	Mumps total sample (%)	Mumps record (%)	Rubella total sample (%)	Rubella record (%)
1979	64.4	82.1	59.7	76.3	66.5	80.8	55.9	70.1	65.9	80.0
1980	66.0	87.0	58.9	80.7	66.6	83.0	59.9	80.2	67.5	83.2
1981	68.1	87.6	59.2	80.9	66.8	81.5	60.4	79.1	68.8	83.9
1982	67.1	88.4	57.0	78.6	67.6	84.3	61.5	79.0	66.7	81.1
1983	65.4	88.4	56.9	78.6	66.3	83.9	59.2	78.1	65.9	81.9
1984	65.0	85.8	53.2	74.2	65.8	81.7	60.0	78.4	62.1	76.7
1985	63.6	85.8	53.6	76.7	61.2	81.7	58.8	78.9	59.0	77.3

DTP, diphtheria, tetanus, and pertussis.

Table 5. Percent of parents who said that their children aged 1 to 4 years had never received polio or DTP vaccine, U.S. Immunization Survey, 1965–1978

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
No polio	9.9	11.3	11.7	10.5	10.2	10.8	8.6	10.7	13.9	11.7	10.3	9.5	8.7	7.9
No DTP	10.9	10.8	9.3	8.6	7.2	7.0	5.8	6.9	6.2	5.2	4.5	3.7	3.3	3.8

DTP, diphtheria, tetanus, and pertussis.

Discussion

For over 40 years the federal public health sector has invested much money and effort to measure immunization rates in children, especially preschool children. These coverage estimates have allowed national programs to track major immunization initiatives such as the introduction of public funding for polio vaccine purchase, the establishment of grants to states for immunization services, school entry mandates, and the large Childhood Immunization Initiative of 1993 that targeted raising immunization rates to 90% in children aged 2 years. Studies have shown that it takes more than asking parents if their children are up to date on their immunizations to measure vaccine coverage accurately.[10,11] This review of the four methodologies used to measure vaccination coverage throughout the United States demonstrates some of the important lessons learned regarding these estimations.

One important lesson is that many parents cannot recall which immunizations their children have received. An accurate assessment of coverage must rely on written records—either immunization cards the parent maintains or the provider's office records. Either of these two sources may not be complete but are markedly better than parental memory.

Over 20 years of national immunization coverage rates (1959–1985) were estimated from information that was not verified. Coverage rates from the last several years of this time frame are known to be inaccurate, and it is probable that the rates from earlier years are also inaccurate. While these data are sometimes useful to provide historical perspective to national vaccination delivery efforts, their known inaccuracies must be acknowledged. Also to be acknowledged and avoided is the temptation to graph and assess coverage over time using data from different surveys. Age groups differed as did methodology, so results are not comparable over long periods of time.

Another lesson is to understand and statistically account for the many possible biases that are inherent in a survey. A careful inspection of general trends at the national level is no longer adequate. As public health workers attempt to understand groups who do or do not seek timely immunizations for their children, survey data must accurately reflect the population as a whole, reliably show differences among groups, and measure with reasonable certainty changes in coverage rates. The NIS provides the best coverage estimates obtained to date as it utilizes data from the NHIS to statistically account for nontelephone households and its estimates are based on provider-verified data.

Only the NIS has been able to provide relatively timely data and coverage estimates at the state and local levels. These data help state and local programs assess and evaluate ongoing initiatives to raise immunization rates in preschoolers. Most areas do not have the resources to perform their own coverage assessments and rely on the CDC and the NIS. The NIS ensures a consistent methodology throughout the nation and thus produces results comparable across states and local areas. However, the NIS does not have enough power to identify smaller, specific "pockets of need" within specific local communities. The cost to establish a national survey able to find these small areas or groups is prohibitive. As immunization rates increase, finding and assisting the few who still have difficulty obtaining early vaccinations for their children takes on increasing importance and difficulty.

Advances in information technology and the widespread use of computers within medicine may further improve our assessment capabilities, and immunization registries may eventually replace national surveys as the primary means to measure immunization coverage. Immunization registries are confidential computerized information systems that contain information on the vaccines administered to the population. All states are developing these registries to capture data on preschool immunizations. As these registries improve to include timely vaccination information on almost all children in their populations, these systems will be able to produce immediate coverage estimates for all or small subgroups of the included children. Although registries hold great promise as a means to assess coverage, and large amounts of resources have been directed to their implementation and use, immunization provider participation has been very slow. Without almost complete participation, the data in a registry will

Table 6. Percentage of parents of children aged 19 to 35 months from the National Immunization Survey who either report or their immunization providers report that the children had never received polio or DTP vaccines

Year	1995	1996	1997	1998	1999
No polio	1.3	1.5	3.5	3.2	2.5
No DTP	1.1	1.0	1.3	1.2	1.1

Table 7. Strengths and weaknesses of alternative methodologies for immunization surveillance

Surveillance system	Strengths	Weaknesses
Retrospective school entrant surveys	• A number of states have conducted these surveys in the past. • Surveys can be conducted at reasonable cost.	• Does not provide current vaccination status of 2-year-old population. Current data needed to target interventions that will improve coverage levels. • Accuracy of school-based immunization records is unknown. Previous studies have indicated that school records underestimate actual coverage levels.
Prospective birth certificate follow-up surveys	• Readily available sampling frame of 2-year-olds from state vital statistics records. • Some states have experience conducting prospective birth certificate follow-up surveys.	• Uniform methodology across all 78 IAPs not feasible in short time frame. • Tracking is difficult and costly in many IAPs. • Tracking required across IAPs to prevent undercoverage bias. • Quality of household reports unknown. Previous studies have shown that parents tend to underestimate the number of doses for multiple-dose vaccines and to overestimate single-dose vaccines. • Multiple modes of data collection (mail, telephone, face-to-face) required to ensure high response rate.
Face-to-face household survey	• Methodology already in place and tested at the national level (National Health Interview Survey [NHIS]).	• NHIS not large enough to produce IAP-level estimates. • Very expensive to screen for 2-year-olds. • Quality of household reports unknown. Previous studies have shown that parents tend to underestimate the number of doses for multiple-dose vaccines and to overestimate single-dose vaccines.
Random-digit-dialing (RDD) survey	• Lower cost than traditional area–probability-based household surveys with face-to-face interviewing. • Survey conducted in standardized manner from central location with continuous monitoring of the interviewing process and interviewing staff. • Data collection done quickly; editing done as part of Computer Assisted Telephone Interview; and results available in a timely manner. • Flexible.	• Reaches only households with 2-year-old children whose household has a telephone; therefore potential noncoverage bias. • Extensive number of dialings required to locate households with 2-year-old children. • Verbal consent to contact providers may not be acceptable to all providers. Quality of household reports unknown. Previous studies have shown that parents tend to underestimate the number of doses for multiple-dose vaccines and to overestimate single-dose vaccines.
Provider surveys	• Cost-effective method for children with regular source of medical care.	• No provider frame of private and public healthcare providers available. • Single provider's records may not contain all vaccinations a child has received. • Requires contacting household to get provider's names and addresses.
Immunization registries	• Provide measures of vaccination coverage at all population levels. • Ability to track individual children.	• Timely and costly to develop. • Costly to maintain. • Information may be out of date or inaccurate unless well maintained.

IAPs, Immunization Action Plan areas.

always be incomplete and/or delayed. Other problems associated with the full implementation of registries issues, such as choice, privacy, confidentiality, data security, and data accuracy, exist and are being addressed.

Vaccination coverage assessments remain an important component to immunization programs at all levels. However, the different methodologies used to assess coverage have strengths and weaknesses that must be considered when reviewing and using the data. Table 7

provides a synopsis of the strengths and weaknesses of the more commonly used means to assess vaccine coverage. Surveys remain our primary means to assess coverage and evaluate our progress toward preschool immunization goals. National surveys require an intensive commitment of expertise, time, and resources to conduct correctly. The NIS is the culmination of 40 years of experience providing useful, timely, and comparable data to federal, state, and local immunization programs.

References

1. Centers for Disease Control and Prevention. Ten Great Public Health Achievements, United States 1900–1999. MMWR Morb Mort Wkly Rep 1999 48(12):241–3.
2. Orenstein WA, Bernier RH. Surveillance information for action. Pediatr Clin North Am 1990 37:709–733.
3. U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control. United States Immunization Survey: 1976. Washington, DC: U.S. Department of Health, Education, and Welfare, 1976.
4. Eddins DL, Sirotkin BI, Holmgreen P, Russel S. Assessment and validation of immunization status in the U.S.: 20th immunization conference proceedings. Washington, DC: Department of Health and Human Services, Public Health Service, Centers for Disease Control, 1985.
5. Peak RR, Cadell DM. Overview of the National Immunization Provider Record Check Study. Proceedings of the section of survey research methods: Am Stat Assoc. 1996;332–4.
6. Smith PJ, Battaglia MP, Huggins VJ, et al. Overview of the sampling design and statistical methods used in the National Immunization Survey. Am J Prev Med 2001;20(suppl 4):17–24.
7. Zell ER, Ezzati-Rice TM, Battaglia MP, Wright RA. National Immunization Survey: the methodology of a vaccination surveillance system. Public Health Rep 2000;115:65–77.
8. Smith PJ, Rao JNK, Daniels D, Ezzati-Rice TM, Khare M. Compensating for nonresponse bias in the National Immunization Survey using response properties. NCHS Series 2 Report. Hyattsville, MD: National Center for Health Statistics. In press.
9. Luman ET, Barker LE, Simpson DM, Rodewald LE, Szilagyi PG, Zhao Z. National, state, and urban-area vaccination-coverage levels among children aged 19–35 months, United States, 1999. Am J Prev Med 2001;20(suppl 4):88–153.
10. Goldstein KP, Kviz FJ, Daum RS. Accuracy of immunization histories provided by adults accompanying preschool children to a pediatric emergency department. JAMA 1993;270:2190–4.
11. Suarez L, Simpson DM, Smith DR. Errors and correlates in parental recall of child immunizations: effects on vaccination coverage estimates. Pediatrics 1997;99(5). Available at: www.pediatrics.org/cgi/content/full/99/5/e3.