Highlights of Historical Events Leading to National Surveillance of Vaccination Coverage in the United States

Philip J. Smith, PhD[a]
David Wood, MD, MPH[b]
Paul M. Darden, MD[c]

The articles published in this special supplement of *Public Health Reports* provide examples of only some of the current efforts in the United States for evaluating vaccination coverage. So, how did we get here? The history of vaccination and assessment of vaccination coverage in the U.S. has its roots in the pre-Revolutionary War era. In many cases, development of vaccines, and attention devoted to the assessment of vaccination coverage, has grown from the impact of infectious disease on major world events such as wars. The purpose of this commentary is to provide a brief overview of the key historical events in the U.S. that influenced the development of vaccines and the efforts to track vaccination coverage, which laid the foundation for contemporary vaccination assessment efforts.

HISTORICAL EVENTS INFLUENCING VACCINE DEVELOPMENT

Smallpox outbreaks in Boston

In the budding pre-revolution American colonies, smallpox posed a serious threat to the welfare of a developing nation: mortality from smallpox disproportionately affected Native Americans, and epidemics were recorded among Anglo-Americans in 1677, 1689–1690, and 1702.[1] By 1721, the city of Boston had become a prosperous port town of 11,000 residents. Many of those who were older than 20 years of age had contracted smallpox in the epidemic of 1702 and, therefore, were conferred lifelong immunity. However, each year between 1702 and 1721 brought with it a newly born cohort of residents that had not been exposed to the epidemic of 1702, and by 1721 the percentage of Bostonian residents who were susceptible to smallpox swelled.

On April 22, 1721, a British vessel arrived in Boston harbor, passed a quarantine inspection, and docked. Within one day, one of the ship's crew was diagnosed with smallpox and quarantined. By early May, nine more seamen from the ship were determined to have smallpox, and cases began to appear among Boston residents. As the number of smallpox cases mounted, approximately 1,000 residents fled Boston. Then, Onesimus, an African slave of the

[a]Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Diseases, Atlanta, GA

[b]University of Florida, College of Medicine, Community Pediatrics, Jacksonville, FL

[c]University of Oklahoma Health Sciences Center, General & Community Pediatrics, Oklahoma City, OK

Address correspondence to: Philip J. Smith, PhD, Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Diseases, MS E-62, 1600 Clifton Rd. NE, Atlanta, GA 30333; tel. 404-639-8729; fax 404-639-3266; e-mail <pzs6@cdc.gov>.

influential Bostonian Puritan minister Cotton Mather, informed Mather about variolation, a centuries-old procedure practiced throughout Africa[2] that protected against smallpox by cutaneous insertion of material from smallpox pustules.

Thereafter, Mather preached fervently in favor of variolation[3,4] and convinced a Boston physician, Zabdiel Boylston, to use variolation on 282 Boston residents.[5] Boylston kept records on 5,759 residents who were struck by smallpox and were not inoculated as well as the 282 residents on whom he had performed variolation. At that time, the commonly held view among Boston residents was that variolation ran counter to the will of God, and Boylston's work was met with strong opposition and, occasionally, outright violence.[6] Boylston was subsequently arrested and released on the condition that he would not inoculate anyone without governmental permission. However, Boylston's work showed that among the 5,759 residents who were struck by smallpox and were not inoculated, 884 (15.3%) died of smallpox, compared with just six (2.1%) who died from smallpox among the 282 who were inoculated. In July 1726, Boylston presented the results of his work[7] at a meeting of the Royal Society chaired by Sir Isaac Newton, representing the very first written record of work that focused on immunization coverage in the American colonies and its association with immunization efficacy.

Benjamin Franklin and assessment of variolation

Benjamin Franklin declared the "incontrovertible success" of variolation during the smallpox outbreaks of 1753–1754 in Boston.[8] In that study, 514 (9.3%) of 5,544 people infected with smallpox and not variolated died of smallpox, compared with 30 (1.4%) of 2,113 who were variolated. However, variolation had other drawbacks that included its cost and the labor time lost during the one- to two-month preparation for and recovery from the induced illness. In addition, inoculated individuals posed a clear transmission risk to the rest of the population. As a result of these concerns, every colony except Pennsylvania passed laws to restrict the practice.[9]

Compulsory variolation and the American Revolutionary War

Those laws would soon be tested during the American Revolutionary War (1775–1783).[10] During that war, most colonists were susceptible to smallpox, including recruits in the Continental Army. They faced British troops who were largely immune, as a result of either childhood exposure or army inoculation. The war brought men from diverse geographic locations into crowded camps and then exposed them to civilian populations in their travels, expanding smallpox transmission into vulnerable populations.[11] Major military campaigns conducted by the Continental Army were racked by smallpox. During the invasion of Canada beginning in December 1775, American forces conducting a siege of Quebec City while a smallpox epidemic swept through their camp failed to capture the city. In May of 1776, British and Hessian troops arrived to reinforce Quebec City. In the last two weeks of May alone, 1,800 of the 7,000 American troops died from smallpox.[12] A subsequent British and Hessian counteroffensive resulted in a rout of the weakened American troops, paving the way for an invasion by British General John Burgoyne's troops. Of the 10,000 troops of American General Horatio Gates' Northern Army that were to defend against the British invasion, 5,500 developed smallpox. Word of smallpox in the Northern Army spread, enlistments ceased, desertions became frequent, and Gates' army began to disintegrate.[10]

Both the Continental Congress and George Washington realized that preventing smallpox was of paramount importance, and the Continental Congress authorized Washington to order compulsory variolation for every recruit. As a result, by September 1776, the Northern Army was free of smallpox. A few months later, they defeated the British invasion and compelled Burgoyne's forces to surrender at Saratoga.[13] This victory and further subsequent successes of the Continental Army have been attributed in part to the fact that the American forces were free of smallpox because of compulsory variolation.[10] It would not be until World War I that American troops would be administered intradermal vaccinations for smallpox.[14]

State compulsory immunization requirements

In 1809, Massachusetts passed the first immunization law in the U.S. requiring smallpox vaccination for the general population, and, subsequently, other states enacted similar legislation.[15] Opposition to vaccination in the U.S. grew significantly as states started to enforce their compulsory vaccination requirements. In fact, compulsory vaccination laws were repealed in California, Illinois, Indiana, Minnesota, Utah, West Virginia, and Wisconsin.[16] Finally, in 1905 the U.S. Supreme Court upheld the authority of states to pass and enforce compulsory vaccination laws.[17] The Court's decision articulated the view that the freedom of the individual must sometimes be subordinated to the common welfare and subjected to the police power of the state. Also, in 1922 the court upheld the constitutionality of a city ordinance requiring smallpox vaccination as a prerequisite for attendance at school.[18] State and local laws that mandate vaccinations have been credited with having played a substantial role in improvements in immunization coverage and disease reduction.[19–22]

Typhoid fever and the Spanish American War

The U.S. fought the Spanish American War from April 25 to August 12, 1898, against Spain in support of Cuban independence. During the 10-week war, 243 soldiers were killed in action or died of wounds. However, 1,580 died of typhoid fever.[10] Learning from this experience, the U.S. Army commissioned development of a typhoid fever vaccine. The vaccine was successfully developed by 1911, when compulsory vaccination was ordered for all troops and for all service personnel younger than 45 years of age.

The 1918–1919 influenza epidemic

The 1918–1919 influenza epidemic[23] remains an ominous warning to current-day public health. In the two decades preceding 1918, the U.S. had experienced influenza epidemics in 1889–1890,[24,25] 1890–1893,[25] and 1916.[26] Surveys conducted by the U.S. Public Health Service (PHS) during the 1918 pandemic showed a high incidence of death attributable to influenza among adults aged 20–44 years.[27] The deaths in the U.S. civilian population directly attributable to the pandemic were estimated at not less than 450,000, and the estimated death rate of four per 1,000 population was reported to have exceeded even liberal estimates of the preceding epidemics. At the time of the 1918 influenza pandemic, the U.S. was engaged in World War I, and many troops were engaged in brutal trench warfare in Europe. During the war, influenza swept through every camp, causing approximately 25,000 deaths among members of the Army expeditionary forces[28] and accounting for approximately 5,000 deaths among the 600,000 men enlisted in the Navy.[29] The development of a vaccine for influenza became a U.S. military priority. In 1944, research sponsored by the U.S. Army showed that effective vaccines for influenza A and influenza B could be developed.[30,31] In 1946 and 1947, compulsory influenza vaccination for all Army enlistees did not result in lower influenza incidence, an outcome revealing the ability of influenza A to undergo genetic shift.[32]

SCIENTIFIC STUDIES LEADING TO ASSESSMENT OF VACCINATION COVERAGE

The Hagerstown Morbidity Study

On December 1, 1921, the PHS launched the Hagerstown Morbidity Study,[33] the first comprehensive study for assessing the incidence of principal causes of illnesses. The study included data from 1,851 white families living in Hagerstown, Maryland, who were recruited using two criteria: (*1*) representativeness of different economic classes and (*2*) convenience for repeated visiting. After being recruited for the study, families were canvassed at six- to eight-week intervals for 28 months. Of the top 22 causes of household-reported illnesses in the first published report from the Hagerstown Study, four were illnesses that are considered to be vaccine-preventable diseases today. These included influenza (rank = 2, with 143.2 annual cases per 1,000 people), measles (rank = 8, with 34.2 annual cases per 1,000 people), whooping cough (rank = 9, with 22.6 annual cases per 1,000 people), and chickenpox (rank = 13, with 13.9 annual cases per 1,000 people). However, vaccines for those diseases had not yet been developed. Subsequent publications from the Hagerstown Morbidity Study included reports on notifiable diseases,[34] the use of medical and hospital services,[35] the association between age and illness,[36–38] a comparison of the incidence of illness and death by cause and age,[39] differences in illness rates by gender,[40,41] and the association between poverty and illness.[42] Because of the scope and depth of the public health topics covered, the Hagerstown Morbidity Study has been considered to be the precursor to the National Health Interview Survey (NHIS).[43]

The U.S. Morbidity Study

Subsequent to the Hagerstown Morbidity Study, the PHS conducted a second study between 1928 and 1931 that used the methodology of the Hagerstown study, but expanded its scope to observe 8,758 white families for 12 consecutive months in 130 localities in 18 states. This study came to be known as the U.S. Morbidity Study.[44] The U.S. Morbidity Study collected health outcomes similar to those collected by the Hagerstown Morbidity Study. For the first time in the history of public health surveillance in the United States, the U.S. Morbidity Study collected vaccination histories of family members in surveyed households, although a federal program to support immunization activities had not yet been developed.[45] Those histories were household-reported and not verified by vaccination providers, and included family members' histories for the four vaccines in use at that time: smallpox, diphtheria, typhoid fever, and scarlet fever vaccines.[46–49] Analyses included in the published reports described how vaccination coverage varied according to age; gender; marital status; city size; U.S. region; family income; and metropolitan, urban, and rural designations. Results from the survey showed that from 1928 to 1931, vaccination coverage among study participants across all age groups, and with no history of vaccine-specific disease, was 54.4% for smallpox, 15.8% for diphtheria, 7.5% for typhoid fever, and 2.0% for scarlet fever. For children younger than 15 years of age with no history of vaccine-specific disease, vaccination coverage rates were 40.9% for smallpox, 31.8% for diphtheria, 4.9% for typhoid fever, and 2.8% for scarlet fever.

The 1936 PHS study

In 1936, the PHS conducted a survey with a similar study design to the Hagerstown Morbidity Study. In the 1936 study, the PHS obtained information from 213,931 families in 28 cities of 100,000 population or more, located in 19 states. However, information was collected from white and black families, and families that were classified as belonging to an "other" race category. A total of 761,968 people were in the families canvassed, including 182,640 children younger than 15 years of age at the time of the survey. For each person younger than 25 years of age, data were recorded on the individual's history of an episode of the disease or immunization against smallpox, diphtheria, scarlet fever, and typhoid fever at any time since birth. Results showed that among children younger than 15 years of age, vaccination coverage rates were 62.7% for smallpox, 48.0% for diphtheria, 1.7% for typhoid fever, and 1.9% for scarlet fever.

The 1941 study of parents' attitudes toward immunizations

In 1941, with the U.S. on the verge of entering World War II, it was recognized that wars increased the hazard of spreading communicable diseases among not only the troops, but also the general population.[50] Immunization was compulsory in the armed forces, but not among civilians. Public immunization would prevent epidemics and preserve the civilian workforce that was needed to support the war effort.

In September 1941, a national survey examined the public's attitudes toward immunizations to learn whether the public was ready for compulsory immunizations.[50] The study showed that while the public was aware of the value of immunization and saw no specific drawbacks to being immunized, only slightly more than 50% of those in need of protection said that they might be willing to be immunized. Further, the study revealed that the public was not well-informed about when or how often to be immunized. People responsible for children were generally better informed concerning immunization procedures than adults not responsible for children.

Polio in the U.S.

The U.S. polio epidemic had a profound impact on the development of vaccines and the acceptance of universal vaccination by the American public.[51] The first documented outbreak of polio describes a cluster of eight to 10 cases of infantile paralysis in West Feliciana, Louisiana, in 1841.[52] Subsequent small outbreaks[53–56] in the U.S. were followed by an outbreak in New York City in 1907, where an estimated 2,500 cases and 125 deaths were recorded. Thereafter, surveillance of polio cases became routine for the PHS.[57–60]

From the early 1940s to 1952, annual incidence rates of polio surged[61,62] and the American public became terrified[63] by outbreaks that occurred in urban and rural areas throughout the U.S.[61] In 1954, the Salk poliomyelitis vaccine was field-tested. During the inoculation phase of the field test, approximately 400,000 second-grade children in 44 states were vaccinated. In 1955, the vaccine was declared to be safe and effective,[64,65] and three doses were recommended for routine administration. Also, in that year President Eisenhower signed the Polio Vaccine Assistance Act into law, marking the first time the U.S. government became involved in civilian immunization activities by allowing federal grants to states for the purchase of polio vaccine, for the costs of planning and conducting vaccination programs,[45] and for vaccination coverage assessment surveys to evaluate immunization needs.[66] However, for a brief period in 1955, the recommendation for routine polio administration was suspended because of contamination of 120,000 doses with live poliovirus that led to 40,000 cases of abortive poliomyelitis, 56 cases of paralytic poliomyelitis, and five deaths.[67,68]

Despite the temporary setback, when the suspension was lifted and routine administration was reinstated, an estimated six million children were reported to have been vaccinated by July 1955.[68] As the nationwide mass vaccination campaign progressed, the incidence rate of polio decreased quickly and dramatically. Attitudes and beliefs related to being vaccinated with the poliomyelitis vaccine were studied in California[69] and Georgia,[70] and the findings of several published and unpublished studies were analyzed in a systematic review of the existing literature.[71]

Surveillance of poliomyelitis vaccination coverage

At first, the PHS attempted to estimate poliomyelitis uptake by using information provided by manufacturers' records of domestic vaccine shipments, monthly state reports covering vaccine purchases with federal funds, and other reports submitted by states to the PHS. However, estimates of overall vaccination participation based on these reports provided little information on receipt of vaccines by age and number of inoculations received per person.

In the summer of 1957, the PHS contracted with the Bureau of the Census to add supplemental questions on poliomyelitis vaccination participation to the Current Population Survey.[66] In 1958, this survey became known as the U.S. Immunization Survey (USIS). Conducted annually, the USIS used household-reported vaccination histories to estimate national vaccination coverage rates. Details of the distribution and use of poliovirus vaccines in the U.S. can be found in the Communicable Disease Center's reports entitled *Poliomyelitis Surveillance Report,* in which the initial reports of vaccination coverage were published for selected years,[72–75] and in the annual reports entitled *United States Immunization Survey*[76–86] (for publication years 1967–1978). Although the USIS was conducted annually up to and including 1985, no annual reports were routinely published from data collected between 1979 and 1985 by the Centers for Disease Control (renamed the Centers for Disease Control and Prevention [CDC] in 1992), although retrospective reports on estimated coverage from USIS data were published.[87,88]

From 1955 to 1961, the estimated percentage of the U.S. civilian population that had received ≥ 3 doses of poliomyelitis vaccine reached 53.6%,[66] and the number of annual poliomyelitis cases (all types) declined from 28,985 to 1,327 nationally.[89] Over time, the USIS expanded vaccination coverage surveillance to new vaccines as they became recommended. In 1978, vaccination coverage estimates were published for children aged 1–4 years for each year between 1965 and 1978[86] and included vaccination coverage estimates for rubella, measles, diphtheria-tetanus-pertussis, poliomyelitis, influenza, and mumps vaccines.

A hiatus in federal vaccination coverage assessment, disease resurgence, and the Vaccines for Children (VFC) program

From 1986 to 1991, there was a hiatus in vaccination coverage assessment activities conducted by the U.S. government. During that time, there was a resurgence in the number of measles,[90,91] mumps,[92] and rubella[93] cases in the U.S. Research revealed that cases observed during the measles resurgence were disproportionately inner-city, preschool-aged, American Indian, Hispanic, or black children <5 years of age who had not been vaccinated[94–97] and who were living in poverty.[91] Data from retrospective immunization coverage surveys of children entering kindergarten or first grade in the 1990–1991 and 1991–1992 school years showed that vaccination levels of preschool- and school-aged children were low.[98] In response to this resurgence, the Childhood Immunization Initiative[99,100] was developed in 1993 to eliminate significant gaps in vaccination coverage among young children in the U.S. Among the strategies for achieving this goal was eliminating the cost of vaccines as a barrier to being vaccinated. In October 1994, the Vaccines for Children (VFC) program[101] was established to achieve this goal by providing financially vulnerable children with publicly purchased vaccines at no cost at the offices and clinics of vaccination providers who are enrolled in the VFC program.

Recommencement of federal vaccination coverage assessment

In 1991, CDC recommenced assessment of national vaccination coverage in the U.S. using the NHIS.[102] From 1991 to 1993, household-reported vaccination histories were collected for children aged <6 years in sampled households; between 1994 and 1999, the household used vaccination provider-reported vaccination histories from sampled children.[103] Data from the 1992 NHIS provided estimates for the first published reports of national vaccination coverage that followed the measles, mumps, and rubella resurgence.[104]

RECENT EFFORTS FOR ASSESSING VACCINATION COVERAGE IN THE U.S.

The National Immunization Survey (NIS) and the NIS-Teen

In 1994, CDC launched the NIS, which has since been conducted annually to date. The NIS was originally designed to obtain accurate and precise estimates of vaccination coverage in states and local areas that were affected the most by the resurgence. The NIS is a landline telephone survey of households with children aged 19–35 months.[105–107] Among households for which consent is obtained, a mail survey is sent to vaccination providers to obtain sampled children's provider-reported vaccination histories that are used to estimate vaccination coverage rates. Currently, the NIS collects provider-reported vaccination histories for the following vaccines: diphtheria-tetanus-acellular pertussis (DTaP), polio, measles-mumps-rubella (MMR), hepatitis B (Hep B), *Haemophilus influenzae* type b (Hib), varicella (VAR), heptavalent and 13-valent pneumococcal conjugate (PCV7 and PCV13), hepatitis A (Hep A), seasonal influenza, and rotavirus. In 2009, data from a completed telephone interview and an adequately reported provider-reported vaccination history were obtained for 17,313 children aged 19–35 months.

From 2005 to 2007, three new vaccines were recommended for adolescents. In response, CDC initiated the NIS-Teen in 2006. The design of the NIS-Teen is similar to that of the NIS: a landline telephone survey of households with adolescents aged 13–17 years is followed by a mail survey sent to vaccination providers to obtain sampled adolescents' provider-reported vaccination histories when consent is obtained to contact providers.[108] Currently, the NIS-Teen collects provider-reported coverage histories for the following: (*1*) vaccines that are recommended beginning at 11 years of age—tetanus-diphtheria-pertussis (Tdap), quadrivalent human papillomavirus (HPV4), and meningococcal conjugate (MCV4); the seasonal influenza vaccine that is recommended annually; vaccines for which catch-up doses are recommended—Hep B, inactivated poliovirus, MMR, and VAR; and vaccines recommended to certain high-risk groups—Hep A and pneumococcal conjugate. In 2009, data from a completed telephone interview and an adequately reported provider-reported vaccination history were obtained for 20,399 adolescents aged 11–17 years. Data from the NIS[109,110] and NIS-Teen[111,112] continue to be used to obtain routine annual reports on progress in national- and state-level vaccination coverage.

Both the NIS and NIS-Teen surveys are based on sampling households with landline telephones. In recent years, the number of households that use only cellular telephone service has increased dramatically.[113] However, recent studies suggest that bias in surveys that only sample households with landline telephones may be small.[114–116] CDC is currently experimenting with contacting homes that use cellular telephones to improve the coverage of the target populations of the NIS and NIS-Teen.

Recent assessment of adult vaccination coverage in the U.S.

The NHIS has been one of the main surveys used to assess national estimates of adult vaccination coverage. In 1989, an immunization supplement to the NHIS collected self-reported vaccination status for the seasonal influenza, pneumococcal, and tetanus vaccines.[117] In 2000, the NHIS again began collecting information annually on adult influenza and pneumococcal vaccinations. In 2009, the NHIS[118] collected self-reported adult vaccination histories for seasonal influenza, pneumococcal, tetanus (with reduced diphtheria [Td] and without), Hep A, Hep B, herpes zoster, and HPV4 vaccines.

The Behavioral Risk Factor Surveillance System (BRFSS) is a cross-sectional telephone survey conducted by state health departments with technical and methodological assistance from CDC.[119] Conducted annually since 1993, the BRFSS has collected self-reported adult vaccination histories for the seasonal influenza and pneumococcal vaccines.[120] Currently, CDC supports optional modules that states can use to assess Td/Tdap, herpes zoster, and HPV4 vaccinations among adults and influenza vaccination among children.

CDC conducted the National Adult Immunization Survey (NAIS) in 2003 and 2007 to gather timely data on newly licensed vaccinations. Data from the NAIS were used to examine racial/ethnic differences in seasonal influenza and pneumococcal vaccination coverage among adults aged ≥65 years;[121] evaluate behavior and beliefs about influenza vaccine among adults aged 50–64 years;[122] track uptake of herpes zoster vaccination among adults aged ≥60 years[123] and Hep A vaccination coverage among adults aged 18–49 years;[124] and learn about HPV4 awareness and vaccination initiation among women.[125]

Evaluation of influenza A (H1N1) vaccination coverage

The National 2009 H1N1 Flu Survey (NHFS) was conducted to provide weekly estimates of influenza A (H1N1) monovalent vaccination coverage. To estimate national- and state-level influenza vaccination coverage from August 2009 to May 2010, CDC combined data from the BRFSS and the 2009 NHFS. Interim reports that gave national[126] and state[127] estimates have been published along with final national estimates.[128] Final estimates using combined data from the NHFS and BRFSS showed that 2009–2010 seasonal influenza vaccination coverage among all people aged ≥6 months in the U.S. was 41.2% (95% confidence interval 40.8, 41.6).

Since 1986, the Healthcare Infection Control Practices Advisory Committee and the Advisory Committee on Immunization Practices (ACIP) have recommended that all health-care personnel be vaccinated annually for influenza.[129,130] To evaluate this recommendation, a population-based panel survey was administered via the Internet during January 2010 to a nationally representative sample of health-care personnel. The survey showed that estimated H1N1 coverage for this group was 37.1%.[131] Also, because pregnant women are at increased risk for severe disease associated with influenza infection, the American College of Obstetricians and Gynecologists and ACIP have recommended seasonal influenza vaccination for women while pregnant, regardless of trimester.[132,133] Self-reported H1N1 status from pregnant women in 10 states showed that estimated H1N1 coverage for this group was 46.6%.[134] In 2010 and 2011, provider-reported H1N1 vaccination status for children aged six months through 17 years has been collected in the NIS and NIS-Teen.

Local area approaches for assessing vaccination coverage

Although the NIS and the NIS-Teen provide national and state estimates of vaccination coverage that are useful for assessing state immunization program performance and achievement of national coverage objectives, assessing vaccination coverage in smaller geographic areas can pinpoint where coverage is low. Targeted interventions may be designed to increase coverage in those areas. A wide variety of methods have been used in the past to obtain coverage estimates in smaller locales.[88,135–137] In the U.S., each state has immunization requirements, sometimes called "school laws," that must be met before a child may enter school. In most states, a parent must bring written proof of a child's immunizations from the health provider or clinic at the time of school registration. State-based school surveys have been conducted regularly to assess vaccination coverage at school entry as well as the percentage of school-entry children whose parents take an exemption from the mandatory state immunization requirements.[138–141] Also, state-based Immunization Information Systems, also known as immunization registries,[142–146] are used to assess childhood vaccination coverage within states.

CONCLUSIONS

The number of cases of most vaccine-preventable diseases is at an all-time low,[147] and hospitalizations and deaths from these diseases have also shown striking decreases. Our national vaccine recommendations in the U.S. target an increasing number of vaccine-preventable diseases for reduction, elimination, or eradication.[148] This success has been achieved at least in part because vaccination coverage among young children in the U.S. has reached record highs with estimated national coverage that exceeds 90% for many recommended vaccines.[110] Achievement of this success has been due in part to the assessment of vaccination coverage. Assessment enables vaccination program managers to learn the extent to which their efforts have achieved vaccination coverage goals and to implement interventions or change policies to improve coverage. Also, assessment is an essential component in evaluating vaccine effectiveness, examining the relationship between increased coverage and population disease burden, monitoring vaccine safety, and studying public perceptions about vaccines.

Across the U.S., both the rich and poor[149] live with little concern for many infectious diseases because of the great effort and sacrifice that has been made to develop and implement vaccination programs.[150] For the first time in the history of mankind, there is a nation where there is freedom from the fear of illness or death from what were formerly endemic killer diseases. Maintenance of that freedom depends, in part, on remembering what has gone before us, removing the barriers that remain in affording access to safe and effective vaccines for all people, using science to discover ways to prevent other diseases we have not yet conquered, and remaining diligent about knowing where we are through continued assessment of how well the nation is protected from vaccine-preventable diseases.

The authors gratefully acknowledge the work of Pamela A. Martin, Jack F. Colbert, and Katherine L. Tucker at the Centers for Disease Control and Prevention's Public Health Library and Information Center; and Naomi House and Jennifer A. Turley at the U.S. Census Bureau, who labored to provide citations for many of the original data sources. Also, the authors thank David J. Sencer, James A. Singleton, Peng-Jun Lu, Tammy A. Santibanez, Amanda Bryant, Karen Cullen, Cindi Knighton, Bob Chen, and Gary Euler for guiding the authors to recent publications that document progress in vaccination coverage.

REFERENCES

1. Aronson SM, Newman L. God have mercy on this house: being a brief chronicle of smallpox in colonial New England. Providence: Brown University, John Carter Brown Library; 2002. Also available from: URL: http://www.brown.edu/Administration/News_Bureau/2002-03/02-017t.html [cited 2011 Mar 24].
2. Finch CS, editor. The African background in medical science: essays on African history, science and civilizations. London: Karnak House; 1990. Also available from: URL: http://blackhistorypages.net/pages/onesimus.php [cited 2011 Jan 17].
3. Mather C. Diary. Boston: Massachusetts Historical Society Collections, 7th series, vols. 7–8; 1911–1912.
4. Mather C. The way of proceeding in the smallpox inoculated in New England. Communicated by Henry Newman Esq of the Middle Temple. Philosophical Transactions XXXII (Jan, Feb, Mar 1722) 1722;370:33-5.
5. Woodward SB. The story of smallpox in Massachusetts. N Engl J Med 1932;206:1181-91.
6. Blake JB. Public health in the town of Boston, 1630–1822. Cambridge (MA): Harvard University Press; 1959.
7. Boylston Z. An historical account of the small-pox inoculated in New England upon all sorts of persons, whites, blacks and of all ages and constitution. London: S. Chandler; 1726.
8. Franklin B. Some account of the successes of inoculation for the small-pox in England and America. London: W. Strahan; 1759.
9. Hopkins DR. Princes and peasants: smallpox in history. Chicago: University of Chicago Press; 1983.

10. Benenson AS. Immunization and military medicine. Rev Infect Dis 1984;6:1-12.
11. Artenstein AW, Opal JM, Opal SM, Tramont EC, Peter G, Russell PK. History of U.S. military contributions to the study of vaccines against infectious diseases. Mil Med 2005;170(4 Suppl):3-11.
12. Taylor RJ, Lint GL, Walker C, editors. The Adams papers: papers of John Adams, vols. 3–4 (1775–1776). Cambridge (MA): The Belknap Press of Harvard University Press; 1979.
13. Bernstein SS. Smallpox and variolation: their historical significance in the American colonies. J Mt Sinai Hosp NY 1951;18:228-44.
14. Kenyon University. North by south [National Endowment for the Humanities seminar]: Louis T. Wright, MD [a brief biography] [cited 2011 Mar 23]. Available from: URL: http://northbysouth.kenyon.edu/1998/health/wright.htm
15. Jackson CL. State laws on compulsory immunization in the United States. Public Health Rep 1969;84:787-95.
16. Kaufman M. The American anti-vaccinationists and their arguments. Bull Hist Med 1967;41:463-78.
17. *Jacobson v Commonwealth of Massachusetts*, 197 U.S. 11 (l905).
18. *Zucht v King*, 260 U.S. 174, 43 S.Ct. 24, 67L (1922).
19. Orenstein WA, Halsey NA, Hayden GF, Eddins DL, Conrad JL, Witte JJ, et al. From the Center for Disease Control: current status of measles in the United States, 1973–1977. J Infect Dis 1978;137:847-53.
20. Orenstein WA, Hinman AR, Williams WW. The impact of legislation on immunisation in the United States. In: Hall R, Richters J, editors. Immunisation: the old and the new. Proceedings of the 2nd National Immunisation Conference, May 27–29, 1991. Canberra (Australia): Public Health Association of Australia; 1992. p. 58-62.
21. Robbins KB, Brandling-Bennett D, Hinman AR. Low measles incidence: association with enforcement of school immunization laws. Am J Public Health 1981;71:270-4.
22. Orenstein WA, Hinman AR. The immunization system in the United States—the role of school immunization laws. Vaccine 1999;17(Suppl 3):S19-24.
23. Sydenstricker E. Preliminary statistics of the influenza epidemic. Public Health Rep 1918;33:2305-21.
24. Public Health Service (US). United States: special reports: influenza and allied diseases. Wkly Abstr Sanit Rep 1890;5:39-40.
25. Frost WH. The epidemiology of influenza. Public Health Rep 1919;34:1823-36.
26. Influenza reported epidemic. Public Health Rep 1916;31:1,14-7.
27. Frost WH. Influenza in Maryland. Preliminary statistics of certain localities. Public Health Rep 1919;34:491-504.
28. Ayers LP. The war with Germany: a statistical summary. Chapter VIII: two hundred days of battle. Washington: Government Printing Office (US); 1919. Also available from: URL: http://net.lib.byu.edu/estu/wwi/memoir/docs/statistics/stats8on.htm#13 [cited 2011 Jan 23].
29. Byerly CR. The U.S. military and the influenza pandemic of 1918–1919. Public Health Rep 2010;125 Suppl 3:82-91.
30. Francis T, Pearson HE, Salk JE, Brown PN. Immunity in human subjects artificially infected with influenza virus type B. Am J Public Health Nations Health 1944;34:317-34.
31. Members of the Commission on Influenza, Board for the Investigation and Control of Influenza and Other Epidemic Diseases in the Army, Preventive Medicine Service, Office of the Surgeon General, United States Army. A clinical evaluation of vaccination against influenza. JAMA 1944;124:982-5.
32. Rasmussen AF Jr, Stokes JC, Smadel JE. The Army experience with influenza, 1946–1947; laboratory aspects. Am J Hyg 1948;47:142-9.
33. Sydenstricker E. A study of illness in a general population group. Public Health Rep 1926;41:2069-88.
34. Sydenstricker E. The reporting of notifiable diseases in a typical small city. Public Health Rep 1926;41:2186-91.
35. Sydenstricker E. The extent of medical and hospital service in a typical small city. Public Health Rep 1927;42:121-31.
36. Sydenstricker E. The age curve of illness. Public Health Rep 1927;42:1565-76.
37. Sydenstricker E. The cause of illness at different ages. Public Health Rep 1927;42:1067-74.
38. Sydenstricker E. The incidence of various diseases according to age. Public Health Rep 1928;43:1124-56.
39. Sydenstricker E. A comparision of the incidence of illness and death. Public Health Rep 1927;42:1689-701.
40. Sydenstricker E. Illness rates between males and females. Public Health Rep 1927;42:1939-57.
41. Sydenstricker E. Sex differences in the incidence of certain diseases at different ages. Public Health Rep 1928;43:1259-76.
42. Sydenstricker E. Economic status and the incidence of illness: total and specific rates for age and cause among persons classified according to family economic condition. Public Health Rep 1929;44:1821-33.
43. Breslow L, editor. Encyclopedia of public health: Sydenstricker, Edgar [cited 2011 Jan 5]. Available from: URL: http://www.enotes.com/public-health-encyclopedia/sydenstricker-edgar
44. Collins SD. Causes of illness in 9,000 families based on nationwide periodic canvasses, 1928–1931. Public Health Rep 1933;48:283-316.
45. Anderson OL. The Polio Vaccination Assistance Act of 1955. Am J Public Health Nations Health 1955;45:1349-50.
46. Collins SD. History and frequency of smallpox vaccinations and cases in 9,000 families. Public Health Rep 1936;51:443-79.
47. Collins SD. History and frequency of clinical scarlet fever cases and of injections for artificial immunization among 9,000 families, based on nation-wide periodic canvasses, 1928–31. Public Health Rep 1938;53:409-27.
48. Collins SD. History and frequency of diphtheria immunizations and cases in 9,000 families. Public Health Rep 1936;51:1736-73.
49. Collins SD. History and frequency of typhoid fever immunizations and cases in 9,000 families. Public Health Rep 1936;51:897-926.
50. Baumgartner L. Attitude of the nation toward immunization procedures: a study based on a public opinion poll made in 1941. Am J Public Health Nations Health 1943;33:256-60.
51. Paul JR. A history of poliomyelitis. New Haven (CT): Yale University Press; 1971.
52. Colmer G. Paralysis in teething children. Am J Med Sci 1843;5:248.
53. Holt LE, Bartlett FH. The epidemiology of acute poliomyelitis: a study of thirty-five epidemics. Am J Med Sci 1908;135:647-62.
54. Batten FE. The epidemiology of poliomyelitis. Proc R Soc Med 1911;4:198-226.
55. Lavinder CH, Freeman AW, Frost WH. Public Health Bulletin no. 91: epidemiologic studies of poliomyelitis in New York City and the Northeastern United States during the year 1916. Washington: Public Health Service (US); 1918.
56. Trevelyan B, Smallman-Raynor M, Cliff AD. The spatial dynamics of poliomyelitis in the United States: from epidemic emergence to vaccine-induced retreat, 1910–1971. Ann Assoc Am Geogr 2005;95:269-93.
57. Dauer CC. Studies on the epidemiology of poliomyelitis. Public Health Rep 1938;53:1003-20.
58. Dauer CC. Poliomyelitis in the United States in 1942, and a summary of its prevalence from 1933 to 1942, inclusive. Public Health Rep 1943;58:937-49.
59. Dauer CC. Incidence of poliomyelitis in the United States in 1945. Public Health Rep 1946;61:915-21.
60. Dauer CC. National morbidity reporting: revised system. Public Health Rep 1952;67:21-5.
61. Communicable Disease Center, Public Health Service (US). Surveillance of poliomyelitis in the United States, 1958–61. Public Health Rep 1962;77:1011-20.
62. Paul M. Safety of the poliomyelitis vaccine. Science 1957;125:1067-71.
63. O'Neill WL. American high: the years of confidence, 1945–1960. New York: The Free Press; 1986.
64. Francis T Jr, Korns RF. Evaluation of 1954 field trial of poliomyelitis vaccine: synopsis of summary report. Am J Med Sci 1955;229:603-12.
65. Langmuir AD, Nathanson N, Hall WJ. Surveillance of poliomyelitis in the United States in 1955. Am J Public Health Nations Health 1956;46:75-88.
66. Sirken MG, Brenner B. Population characteristics and participation in the poliomyelitis vaccination program. Public Health Monograph no. 61. Washington: Government Printing Office (US); 1960.
67. Nathanson N, Langmuir AD. The Cutter incident. Poliomyelitis following formaldehyde-inactivated poliovirus vaccination in the United States during the spring of 1955. II. Relationship of poliomyelitis to Cutter vaccine. Am J Hyg 1963;78:29-60.

68. Offit PA. The Cutter incident, 50 years later. N Engl J Med 2005;352:1411-2.
69. Merrill MH, Hollister AC, Gibbens SF, Hayes AW. Attitudes of Californians toward poliomyelitis vaccination. Am J Public Health Nations Health 1958;48:146-52.
70. Belcher JC. Acceptance of the Salk polio vaccine. Rural Sociol 1958;23:158-70.
71. Rosenstock IM, Derryberry M, Carriger BK. Why people fail to seek poliomyelitis vaccination. Public Health Rep 1959;74:98-103.
72. Communicable Disease Center (US). Supplement to poliomyelitis surveillance. Report no. 276. Washington: Department of Health, Education, and Welfare, Public Health Service (US); March 29, 1963.
73. Communicable Disease Center (US). Supplement to poliomyelitis surveillance. Report no. 284. Washington: Department of Health, Education, and Welfare, Public Health Service (US); April 20, 1964.
74. Communicable Disease Center (US). Supplement to poliomyelitis surveillance. Report no. 287. Washington: Department of Health, Education, and Welfare, Public Health Service (US); June 1, 1965.
75. Communicable Disease Center (US). Supplement to poliomyelitis surveillance. Report no. 288. Washington: Department of Health, Education, and Welfare, Public Health Service (US); June 1, 1966.
76. National Communicable Disease Center (US). United States immunization survey—1967, 1968. Washington: Department of Health, Education, and Welfare (US); December 1968.
77. National Communicable Disease Center (US). United States immunization survey—1969. Washington: Department of Health, Education, and Welfare (US); February 1970.
78. National Communicable Disease Center (US). United States immunization survey—1970. Washington: Department of Health, Education, and Welfare (US); April 1971.
79. National Communicable Disease Center (US). United States immunization survey—1971. Washington: Department of Health, Education, and Welfare (US); December 1971.
80. Center for Disease Control (US). United States immunization survey: 1972. Atlanta: Department of Health, Education and Welfare (US); 1973.
81. Center for Disease Control (US). United States immunization survey: 1973. Atlanta: Department of Health, Education and Welfare (US); 1974.
82. Center for Disease Control (US). United States immunization survey: 1974. Atlanta: Department of Health, Education and Welfare (US); 1975.
83. Center for Disease Control (US). United States immunization survey: 1975. Atlanta: Department of Health, Education and Welfare (US); 1976.
84. Center for Disease Control (US). United States immunization survey: 1976 Atlanta: Department of Health, Education and Welfare (US); 1977.
85. Center for Disease Control (US). United States immunization survey: 1977. Atlanta: Department of Health, Education and Welfare (US); 1978.
86. Center for Disease Control (US). United States immunization survey: 1978. Atlanta: Department of Health, Education and Welfare (US); 1979.
87. Influenza and pneumococcal vaccination coverage levels among persons aged greater than or equal to 65 years—United States, 1973–1993. MMWR Morb Mortal Wkly Rep 1995;44(27):506-7, 513-5.
88. Simpson DM, Ezzati-Rice TM, Zell ER. Forty years and four surveys: how does our measuring measure up? Am J Prev Med 2001;20(4 Suppl):6-14.
89. Provisional information on selected notifiable diseases in the United States and on deaths in selected cities for week ended December 30, 1961. MMWR Morb Mortal Wkly Rep 1962;10(62):1-8.
90. Measles—United States, first 26 weeks, 1989. MMWR Morb Mortal Wkly Rep 1989;38(50):863-6, 871-2.
91. Measles—United States, 1992. MMWR Morb Mortal Wkly Rep 1993;42(19):378-81.
92. Van Loon FP, Holmes SJ, Sirotkin BI, Williams WW, Cochi SL, Hadler SC, et al. Mumps surveillance—United States, 1988–1993. MMWR CDC Surveill Summ 1995;44(3):1-14.
93. Increase in rubella and congenital rubella syndrome—United States, 1988–1990. MMWR Morb Mortal Wkly Rep 1991;40(6):93-9.
94. Atkinson WL, Orenstein WA, Krugman S. The resurgence of measles in the United States, 1989–1990. Annu Rev Med 1992;43:451-63.
95. Cutts FT, Orenstein WA, Bernier RH. Causes of low preschool immunization coverage in the United States. Annu Rev Public Health 1992;13:385-98.
96. Hutchins SS, Escolan J, Markowitz LE, Hawkins C, Kimbler A, Morgan RA, et al. Measles outbreak among unvaccinated preschool-aged children: opportunities missed by health care providers to administer measles vaccine. Pediatrics 1989;83:369-74.
97. Grindler JS, Atkinson WL, Markowitz LE, Hutchins SS. Epidemiology of measles in the United States in 1989 and 1990. Pediatr Infect Dis J 1992;11:841-6.
98. Zell ER, Dietz V, Stevenson J, Cochi S, Bruce RH. Low vaccination levels of US preschool and school-age children. Retrospective assessments of vaccination coverage, 1991–1992. JAMA 1994;271:833-9.
99. Reported vaccine-preventable diseases—United States, 1993, and the Childhood Immunization Initiative. MMWR Morb Mortal Wkly Rep 1994;43(4):57-60.
100. Department of Health and Human Services (US). Healthy people 2010. 2nd ed. With understanding and improving health and objectives for improving health. 2 vols. Washington: Government Printing Office (US); November 2000.
101. Social Security Administration (US). Compilation of the Social Security laws: program for distribution of pediatric vaccines: Sec. 1928. [42 U.S.C. 1396s] [cited 2011 Mar 23]. Available from: URL: http://www.ssa.gov/OP_Home/ssact/title19/1928.htm
102. Blackwell DL, Tonthat L. Summary health statistics for the U.S. population: National Health Interview Survey, 1999. Vital Health Stat 10 2003(211).
103. Bartlett DL, Ezzati-Rice TM, Stokley S, Zhao Z. Comparison of NIS and NHIS/NIPRCS vaccination coverage estimates. National Immunization Survey. National Health Interview Survey/National Immunization Provider Record Check Study. Am J Prev Med 2001;20(4 Suppl):25-7.
104. Vaccination coverage of 2-year-old children—United States, 1992–1993. MMWR Morb Mortal Wkly Rep 1994;43(15):282-3.
105. Zell ER, Ezzati-Rice TM, Battaglia MP, Wright RA. The National Immunization Survey: the methodology of a vaccination surveillance system. Public Health Rep 2000;115:65-77.
106. Smith PJ, Battaglia MP, Huggins VJ, Hoaglin DC, Roden A, Khare M, et al. Overview of the sampling design and statistical methods used in the National Immunization Survey. Am J Prev Med 2001;20(4 Suppl):17-24.
107. Smith PJ, Hoaglin DC, Battaglia MP, Khare M, Barker LE. Statistical methodology of the National Immunization Survey, 1994–2002. Vital Health Stat 2 2005(138).
108. Jain N, Singleton JA, Montgomery M, Skalland B. Determining accurate vaccination coverage rates for adolescents: the National Immunization Survey-Teen, 2006. Public Health Rep 2009;124:642-51.
109. State and national vaccination coverage levels among children aged 19–35 months—United States, April–December 1994. MMWR Morb Mortal Wkly Rep 1995;44(33):613, 619, 621-3.
110. National, state, and local area vaccination coverage among children aged 19–35 months—United States, 2009. MMWR Morb Mortal Wkly Rep 2010;59(36):1171-7.
111. National vaccination coverage among adolescents aged 13–17 years—United States, 2006. MMWR Morb Mortal Wkly Rep 2007;56(34):885-8.
112. National, state, and local area vaccination coverage among adolescents aged 13–17 years—United States, 2009. MMWR Morb Mortal Wkly Rep 2010;59(32):1018-23.
113. Blumberg SJ, Luke JV; National Center for Health Statistics (US). Wireless substitution: early release of estimates from the National Health Interview Survey, July–December 2008 [cited 2010 Feb]. Available from: URL: http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200905.htm
114. Blumberg SJ, Luke JV. Coverage bias in traditional telephone surveys of low-income and young adults. Public Opin Q 2007;71:734-49.
115. Blumberg SJ, Luke JV. Reevaluating the need for concern regarding noncoverage bias in landline surveys. Am J Public Health 2009;99:1806-10.
116. Molinari NM, Wolter KM, Skalland B, Montgomery R, Khare M,

Smith PJ, et al. Quantifying bias in a health survey: modeling total survey error in the National Immunization Survey. Stat Med 2011;30:505-14.
117. Centers for Disease Control and Prevention (US). National Health Interview Survey. Questionnaires, data sets, and related documentation. 1989 NHIS [cited 2011 Jan 25]. Available from: URL: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/1989/IMMUNIZE.PDF
118. Centers for Disease Control and Prevention (US). Vaccines and immunizations: statistics and surveillance: 2009 adult vaccination coverage, NHIS [cited 2011 Mar 23]. Available from: URL: http://www.cdc.gov/vaccines/stats-surv/nhis/2009-nhis.htm
119. Chowdhury P, Balluz L, Town M, Chowdhury FM, Bartolis W, Garvin W, et al. Surveillance of certain health behaviors and conditions among states and selected local areas—Behavioral Risk Factor Surveillance System, United States, 2007. MMWR Surveill Summ 2010;59(1):1-220.
120. Centers for Disease Control and Prevention (US). Behavioral Risk Factor Surveillance System. BRFSS annual survey data: survey data and documentation. 2009 survey data [cited 2011 Jan 25]. Available from: URL: http://www.cdc.gov/brfss/technical_infodata/surveydata/2009.htm
121. Singleton JA, Santibanez TA, Wortley PM. Influenza and pneumococcal vaccination of adults aged ≥65: racial/ethnic differences. Am J Prev Med 2005;29:412-20.
122. Santibanez TA, Mootrey GT, Euler GL, Janssen AP. Behavior and beliefs about influenza vaccine among adults aged 50–64 years. Am J Health Behav 2010;34:77-89.
123. Lu PJ, Euler GL, Harpaz R. Herpes zoster vaccination among adults aged 60 years and older, in the U.S., 2008. Am J Prev Med 2011;40:e1-6.
124. Lu PJ, Euler GL, Hennessey KA, Weinbaum CM. Hepatitis A vaccination coverage among adults aged 18–49 years in the United States. Vaccine 2009;27:1301-5.
125. Jain N, Euler GL, Shefer A, Lu P, Yankey D, Markowitz L. Human papillomavirus (HPV) awareness and vaccination initiation among women in the United States, National Immunization Survey–Adult 2007. Am J Prev Med 2009;48:426-31.
126. Interim results: influenza A (H1N1) 2009 monovalent vaccination coverage—United States, October–December 2009. MMWR Morb Mortal Wkly Rep 2010;59(2):44-8.
127. Interim results: state-specific seasonal influenza vaccination coverage—United States, August 2009–January 2010 [published erratum appears in MMWR Morb Mortal Wkly Rep 2010;59(18):561]. MMWR Morb Mortal Wkly Rep 2010;59(16):477-84.
128. Centers for Disease Control and Prevention (US). Final estimates for 2009–10 seasonal influenza and influenza A (H1N1) 2009 monovalent vaccination coverage—United States, August 2009 through May 2010 [cited 2011 Feb 23]. Available from: URL: http://www.cdc.gov/flu/professionals/vaccination/coverage_0910estimates.htm
129. Pearson ML, Bridges CB, Harper SA. Influenza vaccination of health-care personnel: recommendations of the Healthcare Infection Control Practices Advisory Committee (HICPAC) and the Advisory Committee on Immunization Practices (ACIP) [published erratum appears in MMWR Recomm Rep 2006;55(9):252]. MMWR Recomm Rep 2006;55(RR-2):1-16.
130. Prevention and control of influenza. MMWR Morb Mortal Wkly Rep 1986;35(20):317-26, 331.
131. Interim results: influenza A (H1N1) 2009 monovalent and seasonal influenza vaccination coverage among health-care personnel—United States, August 2009–January 2010. MMWR Morb Mortal Wkly Rep 2010;59(12):357-62.
132. American College of Obstetricians and Gynecologists Committee on Obstetric Practice. ACOG committee opinion number 305, November 2004. Influenza vaccination and treatment during pregnancy. Obstet Gynecol 2004;104(5 pt 1):1125-6.
133. Fiore AE, Uyeki TM, Finelli L, Euler GL, Singleton JA, Iskander JK, et al. Prevention and control of influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2010 [published errata appear in MMWR Recomm Rep 2010;59(31):993 and 2010;59(35):1147]. MMWR Recomm Rep 2010;59(RR-8):1-62.
134. Seasonal influenza and 2009 H1N1 influenza vaccination coverage among pregnant women—10 states, 2009–10 influenza season. MMWR Morb Mortal Wkly Rep 2010;59(47):1541-5.
135. Rosenthal J, Raymond D, Morita J, McCauley M, Diaz P, David F, et al. African-American children are at risk of a measles outbreak in an inner-city community of Chicago, 2000. Am J Prev Med 2002;23:195-9.
136. LeBaron CW, Starnes DM, Rask KJ. The impact of reminder-recall interventions on low vaccination coverage in an inner-city population. Arch Pediatr Adolesc Med 2004;158:255-61.
137. Smith PJ, Singleton JA. Vaccination coverage for selected counties: achievement of Healthy People 2010 goals and association with indices of access to care, economic conditions, and demographic composition. Public Health Rep 2008;123:155-72.
138. Stanwyck C, Davila J, Wake L, Koshak M. Assessment of kindergarten immunization rates in Colorado: school self-reports vs. health department audits, 2004–2005. Public Health Rep 2007;122:461-5.
139. Ramirez E, Bulim ID, Kraus JM, Morita J. Use of public school immunization data to determine community-level immunization coverage. Public Health Rep 2006;121:189-96.
140. Rodewald LE, Roghmann KJ, Szilagyi PG, Winter NL, Campbell JR, Humiston SG. The school-based immunization survey: an inexpensive tool for measuring vaccine coverage. Am J Public Health 1993;83:1749-51.
141. Centers for Disease Control and Prevention (US), National Center for Immunization and Respiratory Diseases. School vaccination coverage reports [cited 2011 Feb 23]. Available from: URL: http://www2.cdc.gov/nip/schoolsurv/rptgmenu.asp
142. Wood D, Saarlas KN, Inkelas M, Matyas BT. Immunization registries in the United States: implications for the practice of public health in a changing health care system. Annu Rev Public Health 1999;20:231-55.
143. Immunization information systems progress—United States, 2005. MMWR Morb Mortal Wkly Rep 2006;55(49):1327-9.
144. Hinman AR, Urquhart GA, Strikas RA; National Vaccine Advisory Committee. Immunization information systems: National Vaccine Advisory Committee progress report, 2007. J Public Health Manag Pract 2007;13:553-8.
145. Centers for Disease Control and Prevention (US). Vaccines & immunizations: IIS interactive data query tool [cited 2011 Feb 23]. Available from: URL: http://www2a.cdc.gov/nip/registry/IISAR
146. White KE, Pabst LJ, Cullen KA. Up-to-date *haemophilus influenzae* type b vaccination coverage during a vaccine shortage. Pediatrics 2011;127:e707-12.
147. Notifiable diseases and mortality tables. MMWR Morb Mortal Wkly Rep 2011;59(52):1704-16.
148. Roush SW, Murphy TV; Vaccine-Preventable Disease Table Working Group. Historical comparisons of morbidity and mortality for vaccine-preventable diseases in the United States. JAMA 2007;298:2155-63.
149. Smith PJ, Lindley MC, Rodewald LE. Vaccination coverage among U.S. children aged 19–35 months entitled by the Vaccines for Children program, 2009. Public Health Rep 2011;126(Suppl 2):109-23.
150. Chen RT, Orenstein WA. Epidemiologic methods in immunization programs. Epidemiol Rev 1996;18:99-117.