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Vaccine-Preventable Diseases, Immunizations, and MMWR --- 1961--2011

Supplements

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Introduction

In the 50 years since *MMWR* became a responsibility of CDC, understanding has been enhanced of diseases now prevented by vaccines, many new vaccines have been introduced, the occurrence of most of these diseases has been dramatically reduced, and some challenges not previously anticipated have appeared. This article summarizes some of these changes over three periods: 1961--1988, 1989--1999, and 2000--2010.

In 1961, children in the United States received vaccines to prevent five diseases: diphtheria, tetanus, pertussis, poliomyelitis, and smallpox. Now children receive vaccines to prevent 16 conditions: diphtheria; *Haemophilus influenza* type b, hepatitis A, hepatitis B, and human papillomavirus infections; influenza, measles, meningococcal disease, mumps, pertussis, pneumococcal disease, poliomyelitis, rotavirus infections, rubella, tetanus, and varicella (Table 1). Immunization coverage rates among preschool-aged children are high (Figure 1), and most diseases have declined to historically low levels (Table 2).

1961--1988: Establishment of a Nationwide Immunization Program

Vaccination Assistance Act

Before 1962, no formal nationwide immunization program existed. Vaccines were administered in private practices and local health departments and paid for out of pocket or provided by using state or local government funds with some support from federal Maternal and Child Health Block Grant funds. In 1962, the Vaccination Assistance Act (Section 317 of the Public Health Service Act) was passed to "achieve as quickly as possible the protection of the population, especially of all preschool children...through intensive immunization activity over a limited period of time..." The initial intention was to allow CDC to support mass, intensive vaccination campaigns. However, the Vaccination Assistance Act also established a mechanism to provide ongoing financial support to state or local health departments and direct support "in lieu of cash." The direct support included provision of vaccines and of CDC Public Health Advisors to assist in managing the programs. Section 317 has been reauthorized repeatedly since 1962 and remains one of the most important means of supporting health department immunization activities with federal funds (*1*).

At the initiation of the 317 funding program in 1963, the only vaccines routinely recommended for children were diphtheria and tetanus toxoids and pertussis vaccine (DTP), polio, and smallpox. Measles vaccine was licensed in 1963, and in 1966, a goal was set to eradicate measles from the United States (*2*). Measles incidence declined dramatically after large vaccination campaigns, but transmission was not interrupted. The licensure of rubella vaccine in 1969 led to mass campaigns to immunize children to avert an anticipated repeat of the tragic epidemic of 1964--65, which resulted in the births of approximately 20,000 infants with congenital rubella syndrome. The rubella campaigns diverted attention and funding from measles, resulting in a resurgence of measles. Federal funding for Section 317 declined during the early to mid-1970s. Immunization coverage fell, and disease increased.

In April 1977, a Childhood Immunization Initiative was announced with two goals: attainment of immunization levels of 90% in the nation's children by October 1979 and establishment of a permanent system to provide comprehensive immunization services to the 3 million children born each year in the United States. Increased funding was provided through Section 317, and a major effort was made to review vaccination records of school children and vaccinate those in need. State and local public health personnel reviewed >28 million records during a 2-year period. In addition, state and local authorities enacted and enforced school immunization requirements. By 1980, all 50 states had such laws, and since 1981, immunization levels of students entering schools have been ≥95%. Thus, the first target of the initiative was met. Achieving the second target would take considerably longer.

A major weakness of Section 317 in its early years was the assumption that state and local health departments could provide the infrastructure necessary to actually administer vaccines. Consequently, Section 317 funds were not authorized for paying salaries of persons who administered the vaccines. The result was that local health departments became increasingly unable to provide the services necessary to ensure that preschool-aged children received vaccines on time, and private sector clinicians were not filling this need, particularly in low-income communities. Additionally, no system was in place to monitor immunization coverage in preschool-aged children, so obtaining an accurate picture of population susceptibility was not possible. Inevitably, this situation led to an accumulation of susceptible children and a consequent resurgence of measles by the end of the decade.

Advisory Committee on Immunization Practices

Until 1964, recommendations about the use of vaccines in the United States were made by the American Academy of Pediatrics, the American Public Health Association, and other professional groups. The federal government's involvement occurred through convening ad hoc expert advisory groups to address individual issues, such as the results of the field trial of Jonas Salk's inactivated polio vaccine (IPV) and the subsequent incident of paralysis related to incompletely inactivated vaccine manufactured by Cutter Laboratories. Federal ad hoc groups also provided advice about the influenza pandemic of 1957, Albert Sabin's attenuated oral polio vaccine (OPV), and soon-to-be licensed measles vaccines. The frequency and complexity of issues led CDC to propose an ongoing Advisory Committee on Immunization Practices (ACIP), which was formally established in 1964. ACIP served as a technical advisory committee to the Public Health Service. It comprised eight members, including the CDC Director, who served as Chair. Today, ACIP continues to provide formal advice to CDC and the U.S. Department of Health and Human Services; after approval, ACIP recommendations are published in *MMWR* and are available on the Internet (*3,4*).

Initially ACIP directed its recommendations to public health agencies; recommendations for private practitioners were developed by the American Academy of Pediatrics and other professional societies. To improve consistency in recommendations, liaison members from the societies have been appointed, and since 1994, all childhood vaccination recommendations have been standardized and endorsed by the Public Health Service and by professional societies. ACIP recommendations have major impact on immunization policies and practice in the United States and in other countries.

Monitoring of Adverse Events

The importance of monitoring and investigating adverse events following immunization (AEFI) is exemplified by the Cutter incident of 1955 and investigations into paralysis associated with OPV during the early 1960s. Investigations into adverse events associated with routine smallpox vaccination contributed substantially to the U.S. decision to discontinue routine smallpox vaccination in 1972, years before smallpox was eradicated globally. Reports of Guillian-Barré syndrome after receipt of swine influenza vaccine in 1976 led to nationwide investigations and contributed greatly to the development of CDC's Monitoring System for Adverse Events Following Immunization. This system was the forerunner of the current Vaccine Adverse Event Reporting System (VAERS), which was established legislatively by the National Childhood Vaccine Injury Act of 1986. VAERS is a passive surveillance system receiving reports of AEFI from providers, parents, and others.

Approximately 30,000 such reports are received each year. VAERS reports describe a temporal association and cannot prove causal relationships. CDC and others have developed additional systems to permit investigation of causality. Premier among these is the Vaccine Safety Datalink, a network of eight large medical-care organizations that tracks all medical encounters (including receipt of vaccine) in approximately 9 million persons (approximately 3% of the U.S. population) (*5*).

Influenza

Surveillance of influenza disease activity and virologic characteristics are published regularly in *MMWR*, as are ACIP's recommendations for influenza vaccine use. The emergence of influenza A (H3N2) virus caused the influenza pandemic of 1968--69, and response to an A (H1N1) virus in 1976 led to the national "swine flu" vaccination program that year.

Vaccine Liability and the National Childhood Vaccine Injury Act

Manufacturers' concerns about their liability exposure to lawsuits related to AEFI (particularly paralysis after receipt of OPV) led them to transfer responsibility to the U.S. government for informing recipients of vaccine risks, as well as benefits, for vaccines administered in the public sector. The result was development of Vaccine Information Statements describing the risks and benefits and a federal requirement that each recipient (or parent) receive this notification for each dose of each vaccine. Lawsuits against manufacturers of DTP vaccine increased dramatically in the early 1980s after allegations that DTP caused permanent brain damage and sudden infant death syndrome. Some DTP manufacturers left the market, and prices of DTP from the remaining producers rose dramatically. In 1986, the National Childhood Vaccine Injury Act was enacted, which put in place a no-fault compensation program for persons who had been injured after receipt of a vaccine that was universally recommended for children (no matter the age of the recipient). This Act also formally established VAERS, the National Vaccine Program Office, the National Vaccine Advisory Committee, and the Advisory Commission on Childhood Vaccines. Lawsuits against manufacturers declined dramatically.

Introduction of New Vaccines and Reduction of Disease during the 1960s--1980s

The incidence of polio declined dramatically after introduction of IPV in 1955 and further after introduction of OPV in 1961. The last case of paralysis from indigenously acquired polio infection in the United States occurred in 1979; the entire region of the Americas was certified free of polio in 1994. Introduction of measles vaccine in 1963 led to calls for eradication in 1966 and subsequently for elimination by October 1, 1982. Neither target was met, but measles incidence declined greatly. Introduction of rubella vaccine in 1969 led to a dramatic decline in reported rubella and congenital rubella syndrome and interrupted the cycle of recurrent epidemics at 6--9-year intervals that preceded vaccine availability.

The Certification Panel declared eradication of smallpox on December 9, 1979, and the World Health Assembly adopted the resolution declaring eradication on May 8, 1980. The last naturally occurring case occurred in 1977. Smallpox remains the only disease of humans to have been eradicated from the world thus far, but polio and dracunculiasis are nearing their eradication goals.

1989--1999: Measles Resurgence and Response

In 1989, after almost a decade (1980--1988) during which an average of approximately 3,000 measles cases were reported annually, a major resurgence began that fundamentally changed the immunization program in the United States (*6*). During 1989--1991, approximately 55,000 measles cases were reported, resulting in approximately 11,000 hospitalizations and 123 deaths. Early in the outbreak, multiple outbreaks were identified among college and high school students for whom coverage with a single dose of measles vaccine was high. During the 1980s, recognizing that measles could be transmitted among the 2%--5% of persons who did not make a primary immune response to a first dose of measles vaccine, ACIP-recommended mass revaccination campaigns as part of measles outbreak control efforts. These emergency responses were costly and logistically difficult to implement and required major diversions of resources toward outbreak control from other immunization and public health priorities. Efforts to control the multiple outbreaks among college students brought this issue to a head, and in 1989, ACIP recommended a routine second dose of measles--mumps--rubella vaccine (MMR) be administered to all children, usually at entry to school (4--6 years of age).

The major problem with measles during the resurgence was disease, not in college students, but in unimmunized preschool-aged children, often living in inner cities, and disproportionately members of racial and ethnic minority groups (*7*). Initially, the cause of the lack of vaccination was believed to be lack of access to measles vaccine. A series of studies showed that most children had access to a provider and that many had seen a health-care provider during a time when they were eligible for measles vaccination but that vaccination was not offered. Reasons for health-care providers to fail to take advantage of opportunities to vaccinate children included adherence to presumed contraindications that were not valid,

reluctance to offer several vaccines simultaneously when multiple vaccines were indicated, and referral of children from private providers when parents could not pay for vaccines to public clinics where vaccines were free. The measles resurgence spurred efforts to develop comprehensive state- and community-based Immunization Action Plans that laid out the steps needed to achieve at least 90% immunization coverage of preschool-aged children for all recommended vaccines at the recommended ages during the first 2 years of life.

In 1991, the National Vaccine Advisory Committee issued recommendations laying out the blueprint for the future immunization program (*6,7*). Some of those recommendations included using federal Section 317 grant funds for actual delivery of vaccines and not simply for vaccine purchase and program administration; developing "Standards for Immunization Practice," guidelines to optimize vaccine delivery to reduce vaccine-preventable diseases; building coalitions of public and professional partners for immunization; ensuring children in other public programs (such as Women, Infants, and Children programs) were vaccinated; and enhancing assessment of immunization coverage of preschool-aged children to determine population susceptibility gaps so actions could be taken to prevent outbreaks of vaccine-preventable diseases.

Childhood Immunization Initiative and Development of the Vaccines for Children Program

In 1993, a second Childhood Immunization Initiative was undertaken with the goal of achieving, by 1996, 90% immunization coverage among preschool-aged children for vaccines recommended during the first 2 years of life. A critical part of the Childhood Immunization Initiative was to eliminate financial barriers to vaccination and ensure children could be vaccinated at their site of usual care ("medical home"), typically a private provider's office. The Vaccines for Children (VFC) program, established through the Omnibus Reconciliation Act of 1993, initiated an entitlement program for vaccines recommended by ACIP for children who were Medicaid eligible, completely uninsured, or American Indian/Alaska Native. In addition, VFC covered children whose insurance did not cover vaccinations ("underinsured")---but only if they received vaccines at Federally Qualified Health Centers (*8*). Importantly, VFC authorized ACIP to play the decisive role in which vaccines would be covered, automatically financing vaccines ACIP voted into the program. The VFC grew to cover approximately 45% of U.S. children, including about 70% of African-American and Hispanic children.

Another critical component of Childhood Immunization Initiative was the establishment of the National Immunization Survey (NIS). Starting in 1994, the NIS, through random-digit dialing surveys, obtained statistically valid immunization coverage rates for all 50 states and several urban areas, allowing tracking of progress toward meeting national goals and identification of problem areas for special interventions. The NIS documented that in 1996, ≥90% coverage was achieved for the following vaccines routinely recommended for preschool-aged children: DTP (three or more doses), polio (three or more doses), MMR (one dose), and *Haemophilus influenza* type b (Hib) (three or more doses). The Childhood Immunization Initiative goal of 70% coverage with three or more doses of hepatitis B vaccine also was met. Furthermore, racial and ethnic disparities in immunization rates, once as high as 20 percentage points for measles, had substantially narrowed (*9*).

Introduction of New Vaccines and Reduction of Disease, 1989--1999

During 1987--1999, several new vaccines were added to the childhood immunization schedule (Table 1), including Hib conjugate vaccines and hepatitis B vaccines for infants, IPV (replacing OPV), replacement of whole-cell pertussis vaccines with acellular vaccines, and varicella vaccine for all children during the second year of life.

Before the availability of Hib vaccine, an estimated 20,000 children each year developed invasive Hib disease, including 12,000 who developed meningitis. Extensive use of Hib vaccine markedly reduced these numbers and was associated with not only direct protection but with herd immunity as well (*10*).

Children who acquire chronic hepatitis B virus inf ection in early life have a 15%--25% lifetime risk for early death from liver failure and liver cancer. Before hepatitis B vaccine was available, >25,000 cases of acute hepatitis B virus infection were reported to CDC annually, and an estimated 30%--40% of chronic infections resulted from perinatal or early childhood infections. Initial efforts to reduce the lifetime burden of hepatitis B infection acquired in early life focused on screening high-risk (1984) and then all pregnant women (1988) for chronic hepatitis B virus infection and timely postexposure vaccination and hepatitis B immunoglobulin for their infants. Since 1991, hepatitis B vaccination has been recommended for all infants to reduce their lifetime risk for hepatitis B virus infection and to provide a safety net for infants who might otherwise not receive timely postexposure prophylaxis. In a strategy to eventually eliminate transmission of hepatitis B virus infection in the United States, vaccination has been recommended for adults at high risk

for hepatitis B infection (since 1982) and all unvaccinated children and adolescents 0--18 years (since 1999). By 2000, at least 90% of infants were being vaccinated annually. In 2007, declines in reported cases of acute hepatitis B since 1998 were 92% for persons aged <20 years, 59% for persons 20-49 years, and 46% for persons ≥50 years (*11*).

During the early 1980s, allegations surfaced that whole-cell pertussis vaccines, the standard vaccines in use in the United States at the time, caused serious adverse reactions, including permanent brain damage. Although studies did not confirm these allegations, extensive efforts were made to develop acellular pertussis vaccines. These acellular vaccines were associated with substantially lower rates of fever and local reactions than were whole-cell vaccines. In 1991, acellular vaccines became available for the fourth and fifth doses of the five-dose DTP series; in 1997, acellular vaccines were recommended for the first three doses as well.

In 1995, varicella vaccine was licensed. Varicella accounted for an estimated 10,000 hospitalizations and 100 deaths each year in the United States. In 1996, ACIP recommended that all children be vaccinated against varicella with a single dose of vaccine. A universal two-dose regimen was recommended in 2006.

The last outbreak of wild-virus polio occurred in the United States in 1979. However, as a result of the exclusive use of OPV, approximately seven to eight cases of polio caused by the vaccine were reported each year (vaccine-associated paralytic polio [VAPP]). These cases occurred in OPV recipients and in contacts of recipients. Persons with immune defects (primarily B cell) were at highest risk. With progress in the worldwide effort to eradicate polio, ACIP recommendations were updated in January 1997 to promote a sequential schedule of two doses of IPV followed by two doses of OPV to reduce the occurrence of VAPP. Because VAPP continued to occur in contacts of vaccine recipients, in June 1999, ACIP recommended that an all-IPV schedule be implemented no later than 2000. The all-IPV schedule has resulted in the near elimination of VAPP in the United States (*12*).

Diarrhea and dehydration caused by rotavirus accounted for an estimated >400,000 health-care provider visits, 55,000--70,000 hospitalizations, and 20--60 deaths annually in the United States. In 1998, RotaShield (Wyeth Laboratories, Marietta, Pennsylvania), a rotavirus vaccine derived from a strain isolated from rhesus monkeys and reassorted with three other (human) strains, was licensed. The vaccine was recommended universally for young infants. However, postlicensure surveillance documented a clustering of intussusception cases, primarily within the 3--14 days after the first dose. ACIP recommended routine vaccination stop pending further studies. A subsequent large case--control study confirmed an attributable risk for intussuception of approximately one in 10,000 first doses associated with the rhesus reassortant vaccine, and RotaShield vaccine was withdrawn (*13*). No documented cases of intussuception were reported following vaccine administered after July 16, the date of the *MMWR* publication, suggesting that the notice in *MMWR* led to marked reductions in rotavirus vaccine use.

Thimerosal

Thimerosal, an ethyl mercury--containing preservative, was added to several inactivated vaccines in multidose vials to avoid bacterial overgrowth of those vials should bacteria be introduced on repeated entry to withdraw additional doses. Before 1990, the only thimerosal-containing vaccine recommended for infants was DTP. However, recommendations for Hib and hepatitis B vaccines increased the amount of thimerosal to which infants were exposed. Overall, during the first 6 months of life, the amount of ethyl mercury in vaccines recommended for infants could exceed the levels recommended for safety by the U.S. Environmental Protection Agency for methyl mercury (a more toxic compound) but not the safety levels recommended by the Agency for Toxic Substances and Disease Registry or the Food and Drug Administration. At the time this level was recognized in 1999, no data existed to suggest any harm from the amount of ethyl mercury in vaccines. However, as a precaution, CDC recommended in 1999 that manufacturers work to decrease the amount of thimerosal in their vaccine products as soon as feasible (*14*). Use of thimerosal-containing vaccines was still recommended, until an adequate supply of vaccines not requiring a thimerosal preservative was available, to avoid the known consequences of a potential resurgence of serious vaccine-preventable diseases. Thimerosal as a preservative was generally removed by adopting single-dose packaging. Subsequent studies, including extensive research on an alleged link of thimerosal in vaccines with autism, have not supported a causal role of thimerosal in a variety of neurodevelopmental disorders, including autism (*15*).

2000--2010: New Century, New Vaccines, New Challenges

During the first decade of the 21st century, several new vaccines were introduced in the United States. Pneumococcal conjugate (PCV7 [2000]; PCV13 [2010]), meningococcal conjugate (2005), tetanus--diphtheria--acellular pertussis (Tdap, adult formulation, 2005), rotavirus (2006), human papillomavirus (2006), and zoster (2006) vaccines were recommended

for routine use during this period (Table 1). Recommendations for influenza vaccines were incrementally expanded; this trend culminated in a universal influenza vaccination policy adopted in 2010. The vaccines licensed during this decade were substantially more expensive than were earlier vaccines, and consideration of the cost-effectiveness of each new vaccine became a major component of ACIP's deliberations related to routine use. During this decade, disease was substantially reduced within the vaccination-targeted age groups, as well as within unvaccinated populations. Major herd immunity benefits were associated with use of pneumococcal conjugate (*16*) and hepatitis A vaccines, in particular. Immunization coverage for the infant vaccination series (DTap--IPV--MMR--Hib--hepatitis B--varicella) neared the Healthy People 2010 target of 80% (*17*). For each birth cohort vaccinated with this series, an estimated 20 million fewer illnesses occur, 42,000 premature deaths are prevented, and $13.6 billion in direct medical costs are saved. Direct and indirect savings to society are estimated to total $69 billion (*18*).

The Changing Epidemiology of Vaccine-Preventable Disease

Although most vaccine-preventable diseases were at record low levels during this decade, several communities or institutions experienced resurgences of some vaccine-preventable diseases, especially pertussis, mumps, and varicella. Certain factors associated with resurgent disease prompted new immunization policies (*19*). Waning immunity associated with pertussis vaccines administered during childhood prompted development of pertussis vaccine formulations that were suitable for older age groups and led to Tdap recommendations for routine adolescent and adult immunization. A single dose of varicella vaccine proved to be 85% effective, not sufficient to prevent varicella outbreaks; this finding prompted the 2006 recommendation for a routine two-dose series. Outbreaks of mumps concentrated in the midwestern United States during 2006 and the northeastern United States during 2009--2010 occurred in colleges or religious schools, despite high two-dose coverage. Indigenous measles and rubella were declared eliminated in 2000 and 2004, respectively. After elimination of endemic transmission of measles in the United States in 2000, importation of measles virus continued in low numbers annually, with limited spread. However, in 2008 more than twice the average number of annual cases occurred, associated with clustering of unimmunized children whose parents had intentionally avoided vaccinating their children (*20*). In some states, the rate of personal belief exemptions from school requirements for measles vaccine increased. Recognition of parental concerns about the number and timing of early childhood vaccines has renewed efforts to address communication needs of both providers and parents (*21*) and strengthen understanding of changing attitudes associated with immunization decisions.

Public Health Emergencies and a Pandemic

Public health emergencies during the 2000s led to some extraordinary mass vaccination efforts. The 2001 bioterrorist anthrax attack resulted in postexposure antimicrobial prophylaxis followed by voluntary vaccination of approximately 1,700 persons who had occupational exposure to envelopes contaminated with Bacillus anthracis spores. Preparedness for additional bioterrorist threats led the federal government to implement a smallpox vaccination program for civilian public health responders that reached nearly 40,000 workers) (*22*). These emergency programs were dwarfed in magnitude by the immunization program mounted in response to the first influenza pandemic in 41 years. The vaccination program against 2009 pandemic influenza A (H1N1) resulted in vaccination of an estimated 80 million U.S. residents with >90 million doses of monovalent (H1N1) vaccine (*23*). The pandemic influenza immunization program in the United States was accompanied by unprecedented levels of public and media communication and enhanced vaccine safety monitoring to optimize public acceptance. Results available thus far suggest that the monovalent pandemic (H1N1) vaccine had similar safety performance to seasonal trivalent influenza vaccines and much lower risk for Guillain Barré syndrome than that seen with the 1976 swine influenza vaccination program (*24*).

Immunization Information Systems

Immunization information systems (IIS, immunization registries) are confidential, population-based, computerized databases that record all vaccine doses administered by participating providers to persons residing within a given geopolitical area. IIS have been under development since the early 1990s and now are in place in 48 of 50 states. As of December 31, 2008, 75% of children aged <6 years were enrolled in an IIS, with at least two vaccinations recorded. An increasing proportion of IIS now cover the lifespan of the individual. The Task Force on Community Preventive Services recently reviewed the evidence base for the effectiveness of IIS and recommended IIS on the basis of strong evidence of effectiveness in increasing vaccination rates. Public health efforts are under way to improve interoperability between IIS and electronic medical records.

Global Efforts

Global efforts to reduce vaccine-preventable disease accelerated during this period, aided by catalytic investments of the Bill & Melinda Gates Foundation (www.gatesfoundation.org), as well as the formation in 2000 of the Global Alliance for Vaccines and Immunization and the associated Vaccine Fund (now GAVI Alliance) (www.gavialliance.org). Use of hepatitis B and Hib vaccines in resource-poor countries increased markedly. The World Health Organization (WHO) now recommends all infants receive hepatitis B vaccine as soon as possible after birth and all regions and associated countries develop goals for hepatitis B control. The Measles Initiative, a partnership of the American Red Cross, CDC, WHO, United Nations Children's Fund, and the United Nations Foundation, spearheaded efforts to reduce global deaths from measles by 90% from 2000 to 2010. Tremendous progress has been achieved, especially in the African region, through sustaining strong immunization services and second-dose opportunities through supplemental immunization activities (SIAs) or as a routine second dose. Maintenance of these activities will be vital to maintaining progress (*25*). Outbreaks of measles were reported in 30 countries in Africa during 2010 as a result of delays in carrying out SIAs.

During the second decade of the Global Polio Eradication Initiative (*26*), the number of countries in which endemic transmission had never been interrupted fell to four: Afghanistan, India, Nigeria, and Pakistan. However the program suffered a major setback in 2003 when Nigeria temporarily stopped polio vaccination. Cases increased substantially in Nigeria, and the virus was exported to 20 previously polio-free countries during 2003--2006, requiring major response efforts. By summer 2010, both Nigeria and India had documented substantial reductions in wild poliovirus infections compared with earlier years. However, a large outbreak of wild poliovirus type 1 in Tajikistan detected during spring 2010 emphasized the fragility of elimination efforts that have been achieved in some regions and the importance of supporting strong routine immunization efforts and sustaining heightened surveillance for poliovirus and acute flaccid paralysis. Attainment of Millennium Development Goal 4---to reduce child mortality by two thirds by 2015 from 1990---will depend in part on strengthening immunization systems and introducing pneumococcal and rotavirus vaccines to areas of high mortality in sub-Saharan Africa and Asia.

Vaccine-Preventable Diseases, Immunizations, and *MMWR*

MMWR has played a major role in chronicling key events related to vaccine-preventable diseases and immunization, carrying articles about outbreaks of vaccine-preventable diseases (even before vaccines were available for many of them), the effect of vaccines, vaccine coverage, AEFI, and the recommendations of ACIP. A review of the tables of contents of articles published in the *MMWR* weekly during 1965--2009 (tables of contents were not published before 1965) indicates >2,500 articles published---an average of approximately one article per week over the entire period (Table 3). Articles on influenza were most numerous (684), followed by measles (451), polio (249), "other" (238), and ACIP recommendations (237). Many of the episodes first reported in *MMWR* were subsequently published in peer-reviewed journals.

The Future

During the past 50 years, immunization has led to elimination or near elimination of several vaccine-preventable diseases in the United States and has substantially reduced deaths, disabilities, and illness. Maintaining success depends on sustaining a strong vaccine-delivery system in both public and private sectors, while ensuring adequate surveillance of disease and of vaccine coverage. Key opportunities for future progress in the United States include improved access to preventive services, such as vaccines among adults through implementation of the Patient Protection and Affordable Care Act of 2010, and performance improvements and efficiency that should result from enhanced interoperability of IIS and electronic health records. The health and economic benefits of vaccines and immunization already evident in wealthier countries are potentially achievable throughout the world through the introduction of new and underused vaccines reaching the 20% of children not yet covered through routine immunization efforts, and effectively integrating other interventions into routine immunization services. Research advances may bring new transformative interventions, such as an effective malaria vaccine, during what Bill Gates has dubbed the Decade of the Vaccine (*27*). The future could also implement a key lesson learned from the outbreak of 2009 pandemic influenza A (H1N1) by investing in innovative technologies that will permit faster production of large quantities of influenza vaccine, which could improve the effectiveness of response to the next influenza pandemic and improve the control of seasonal influenza. In future decades, the long-term benefits of vaccinating girls against human papillomavirus, both in developed countries and around the world, should be manifested by major reductions in cervical cancer and its precursors. Successful eradication of polio in the remaining reservoir countries will be a permanent gift from this generation to all future ones.

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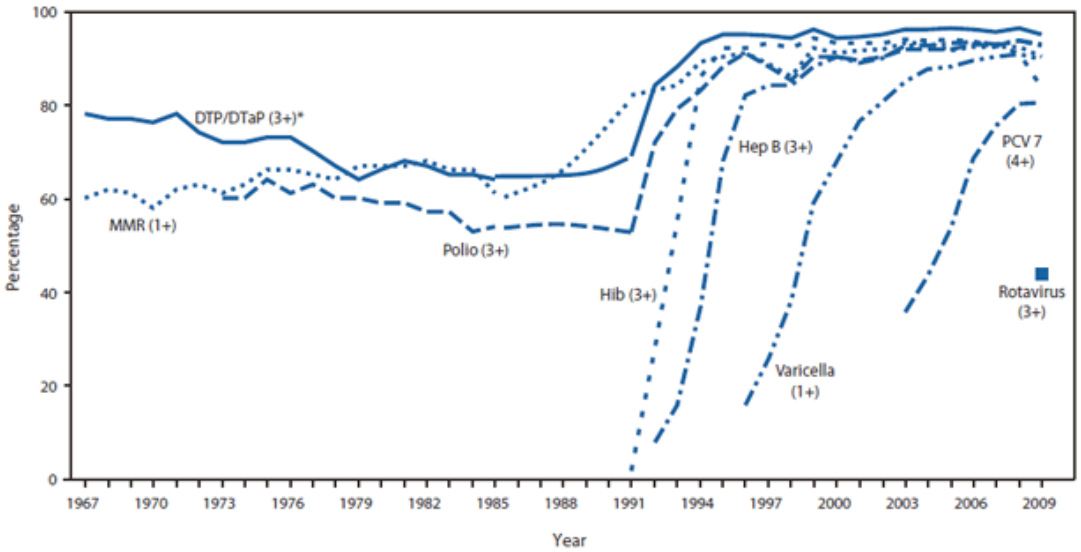
TABLE 1. Year of U.S. licensure of selected childhood vaccines

Vaccine	Year of first US licensure
Tetanus toxoid	1943
Trivalent inactivated influenza	1945
Tetanus and diphtheria toxoids	1953 for children aged >7 yrs; 1970 for children aged <7 yrs

Inactivated polio	1955
Oral polio	1963
Diphtheria--tetanus--pertussis	1970
Diphtheria--tetanus--acellular pertussis	1991
Measles--mumps--rubella	1963 (measles); 1967 (mumps); 1969 (rubella); 1971 (measles--mumps--rubella combined)
Hepatitis B	1981 (plasma derived); 1986 (recombinant)
Haemophilus influenzae type b conjugate	1987 for children aged ≥18 mos; 1990 for infants
Hepatitis A	1995
Varicella	1995
Pneumococcal conjugate	2000 (7-valent); 2010 (13-valent)
Live attenuated influenza	2003
Tetanus--diphtheria--acellular pertussis	2005
Meningococcal conjugate	2005
Rotavirus	2006
Human papillomavirus	2006

FIGURE. Increasing vaccine-specific coverage rates among preschool-aged children --- United States, 1967--2009



Abbreviations: MMR = measles-mumps-rubella; DTP/DTaP = diphtheria and tetanus and acellular pertussis; Hib = *Haemophilus influenza* type b; Heb B = heptatitis B;
PCV7 = 7-valent pneumococcal conjugate vaccine; USIS = United States Immunization Survey; NHIS = National Health

Interview Survey; NIS = National Immunization Survey; NCHS = National Center for Health Statistics; NIP = National Immunization Program; NCIRD = National Center for Immunization and Respiratory Diseases.

* DTP(3+) is not a *Healthy People 2010* objective. DTaP(4) is used to assess *Healthy People 2010* objectives.

Note: Children in the USIS and NHIS were 24--35 months of age. Children in the NIS were 19--35 months of age.

Source: USIS (1967--1985), NHIS (1991--1993) CDC, NCHS, and NIS (1994--2009), CDC, NIP and NCHS; No data during 1986--1990 due to cancellation of USIS because of budget reductions.

ALternate Text: The figure is a line graph presenting the increasing vaccine coverage rates among preschool-aged children in the United States during 1967-2009.

TABLE 2. Comparison of annual morbidity from vaccine-preventable diseases during the 20th century and 2009

Disease	20th Century*	2010†	% Reduction
Diphtheria	21,053	0	100
Hepatitis A	117,333	8,493§	93
Hepatitis B, acute	66,232	9,419§	86
Haemophilus influenzae type b in children aged <5 yrs.	20,000	240¶	99
Measles	530,217	63	>99
Mumps	162,344	2,612	98
Pertussis	200,752	27,538	86
Pneumococcus, invasive			
All ages	63,607	44,000††	30
<5 yrs	16,069	4,700††	72
Poliomyelitis, paralytic	16,316	0	100
Rotavirus, hospitalizations	62,500**	28,125§	55
Rubella	47,745	5	>99
Congenital rubella syndrome	152	0	100
Smallpox	29,005	0	100
Tetanus	580	26	96
Varicella	4,085,120	408,572§	90

* Estimated annual average number of cases in the prevaccine era for each disease. Source: JAMA 2007;298:2155--63.

† Source: MMWR 2011;60(32):1088--1101.

§ 2009 estimate.

¶ 23 type b and 223 unknown serotype (among children <5 years of age).

** Source: MMWR 2009;58(No. RR-2).

†† Source: http://www.cdc.gov/abcs/reports-findings/survreports/spneu09.html.

TABLE 3. *MMWR* articles in which vaccines and vaccine-preventable diseases are the sole or primary topic, 1965--2009*

Topic	1965--1969	1970--1974	1975--1979	1980--1984	1985--1989	1990--1994	1995--1999	2000--2004	2005--2009	Total	Grand total
Articles from ACIP	23	16	34	27	29	25	31	22	30	**237**	**237**
Diphtheria	19	20/2†	5/1†	1	0	0/1†	2/4†	2	0	**49/8†**	**57**
Hepatitis A	0	12/1†	4	4	1	3	7	3	8	**42/1†**	**43**
Hepatitis B	1	10	2	6	8	9	7	13	7/1†	**63/1†**	**64**
Hepatitis, other§	40/1†	18	10	2	4/1†	1	2	4/1†	10	**91/3†**	**94**
Hib	0	4	1/1†	0	3	4	5	2	5/1†	**24/2†**	**26**
HPV	0	0	0	0	0	0	0	0	0	**0**	**0**
Influenza	73/22†	63/21†	65/40†	86/10†	67/9†	29/4†	29/7†	48/4†	104/3†	**564/120†**	**684**
Measles	137	48/1†	48/3†	79/4†	36/3†	17/1†	10/11†	11/16†	9/17†	**395/56†**	**451**
Meningococcal disease	33/1†	10/2†	8/1†	1	1/1†	1/1†	5	3/1†	12	**74/7†**	**81**
Mumps	3	4	2	4/1†	4	0	1	0	8	**26/1†**	**27**
Pertussis	2	0	4/1†	5/1†	2	3	5	6	7	**34/2†**	**36**
Pneumococcal disease	0	0	1/3†	2	3	1	6	13	9/1†	**35/4†**	**39**
Poliomyelitis	27/3†	10/7†	12/11†	5/5†	2/6†	3/15†	3/45†	1/56†	4/34†	**67/182†**	**249**
Rotavirus	0	0	0/1†	0	0	0	4	2/1†	3/1†	**9/3†**	**12**
Rubella	4	17/2†	18	16	11	4	3	2	3/1†	**78/3†**	**81**
Smallpox	8/36†	3/36†	5/20†	7/4†	1/1†	0	0/2†	21	8	**53/99†**	**152**
Tetanus	5/1†	1	1	0	3	4/1†	4/1†	2	0	**20/3†**	**23**
Varicella	1	5	0/1†	2/1†	1	2	7	6	7	**31/2†**	**33**
Zoster	0	8	7	2	0	0	0	0	0	**17**	**17**
Other¶	1	3	7	4/1†	10	44¶/1†	68*/3†	57*/2†	33/4†	**227/11†**	**238**
Total	**377/64†**	**252/72†**	**234/83†**	**253/27†**	**186/21†**	**150/24†**	**199/73†**	**218/81†**	**267/63†**	**2,136/508†**	**2,644**

Grand total	**441**	**324**	**317**	**280**	**207**	**174**	**272**	**299**	**330**	**2,644**

Abbreviations: ACIP = Advisory Committee on Immunization Practices; Hib = *Haemophilus influenzae* type b; HPV = human papillomavirus.

* Includes years when monthly or quarterly immunization tables were printed.

† Cases from United States or US leads/cases from other countries or reported globally.

§ Hepatitis, other indicates viral hepatitis, hepatitis not otherwise specified, non-A non-B hepatitis, or hepatitis C.

¶ Other includes vaccination coverage surveys or multidisease or combination vaccine articles.

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