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Achievements in Public Health, 1900-1999 Impact of Vaccines Universally Recommended for Children -- United States, 1990-1998

At the beginning of the 20th century, infectious diseases were widely prevalent in the United States and exacted an enormous toll on the population. For example, in 1900, 21,064 smallpox cases were reported, and 894 patients died (1). In 1920, 469,924 measles cases were reported, and 7575 patients died; 147,991 diphtheria cases were reported, and 13,170 patients died. In 1922, 107,473 pertussis cases were reported, and 5099 patients died (2,3).

In 1900, few effective treatment and preventive measures existed to prevent infectious diseases. Although the first vaccine against smallpox was developed in 1796, greater than 100 years later its use had not been widespread enough to fully control the disease (4). Four other vaccines -- against rabies, typhoid, cholera, and plague -- had been developed late in the 19th century but were not used widely by 1900.

Since 1900, vaccines have been developed or licensed against 21 other diseases (5) (Table_1). Ten of these vaccines have been recommended for use only in selected populations at high risk because of area of residence, age, medical condition, or risk behaviors. The other 11 have been recommended for use in all U.S. children (6).

During the 20th century, substantial achievements have been made in the control of many vaccine-preventable diseases. This report documents the decline in morbidity from nine vaccine-preventable diseases and their complications -- smallpox, along with the eight diseases for which vaccines had been recommended for universal use in children as of 1990 (Table_2). Four of these diseases are detailed: smallpox has been eradicated, poliomyelitis caused by wild-type viruses has been eliminated, and measles and Haemophilus influenzae type b (Hib) invasive disease among children aged less than 5 years have been reduced to record low numbers of cases.

Information about disease and death during the 20th century was obtained from the MMWR annual summaries of notifiable diseases and reports by the U.S. Department of Health, Education, and Welfare. For smallpox, Hib, and congenital rubella syndrome (CRS), published studies were used (2,3,7-14).

Current Delivery and Use of Vaccines

National efforts to promote vaccine use among all children began with the appropriation of federal funds for polio vaccination after introduction of the vaccine in 1955 (5). Since then, federal, state, and local governments and public and private health-care providers have collaborated to develop and maintain the vaccine-delivery system in the United States.

Overall, U.S. vaccination coverage is at record high levels. In 1997, coverage among children aged 19-35 months (median age: 27 months) exceeded 90% for three or more doses of diphtheria and tetanus toxoids and pertussis vaccine (DTP), three or more doses of poliovirus vaccine, three or more doses of Hib vaccine, and one or more doses of measles-containing vaccine. Coverage with four doses of DTP was 81% and for three doses of hepatitis B vaccine was 84%. Coverage was substantially lower for the recently introduced varicella vaccine (26%) and for the combined series of four DTP/three polio/one measles-containing vaccine/three Hib (76%) (15). Coverage for rotavirus vaccine, licensed in December 1998, has not yet been measured among children aged 19-35 months. Coverage among children aged 5-6 years has exceeded 95% each school year since 1980 for DTP; polio; and measles, mumps, and rubella vaccines (CDC, unpublished data, 1998).

Vaccine Impact

Dramatic declines in morbidity have been reported for the nine vaccine-preventable diseases for which vaccination was universally recommended for use in children before 1990 (excluding hepatitis B, rotavirus, and varicella) (Table_2). Morbidity associated with smallpox and polio caused by wild-type viruses has declined 100% and nearly 100% for each of the other seven diseases.

Smallpox. Smallpox is the only disease that has been eradicated. During 1900-1904, an average of 48,164 cases and 1528 deaths caused by both the severe (variola major) and milder (variola minor) forms of smallpox were reported each year in the United States (1). The pattern in the decline of smallpox was sporadic. Outbreaks of variola major occurred periodically in the first quarter of the 1900s and then ceased abruptly in 1929. Outbreaks of variola minor declined in the 1940s, and the last case in the United States was reported in 1949. The eradication of smallpox in 1977 enabled the discontinuation of prevention and treatment efforts, including routine vaccination. As a result, in 1985 the United States recouped its investment in worldwide eradication every 26 days (1).

Polio. Polio vaccine was licensed in the United States in 1955. During 1951-1954, an average of 16,316 paralytic polio cases and 1879 deaths from polio were reported each year (9,10). Polio incidence declined sharply following the introduction of vaccine to less than 1000 cases in 1962 and remained below 100 cases after that year. In 1994, every dollar spent to administer oral poliovirus vaccine saved $3.40 in direct medical costs and $2.74 in indirect societal costs (14). The last documented indigenous transmission of wild poliovirus in the United States occurred in 1979. Since then, reported cases have been either vaccine-associated or imported. As of 1991, polio caused by wild-type viruses has been eliminated from the Western Hemisphere (16). Enhanced use of the inactivated polio vaccine is expected to reduce the number of vaccine-associated cases, which averaged eight cases per year during 1980-1994 (17).

Measles. Measles vaccine was licensed in the United States in 1963. During 1958-1962, an average of 503,282 measles cases and 432 measles-associated deaths were reported each year (9-11). Measles incidence and deaths began to decline in 1965 and continued a 33-year downward trend. This trend was interrupted by epidemics in 1970-1972, 1976-1978, and 1989-1991. In 1998, measles reached a provisional record low number of 89 cases with no measles-associated deaths (13). All cases in 1998 were either documented to be associated with international importations (69 cases) or believed to be associated with international importations (CDC, unpublished data, 1998). In 1994, every dollar spent to purchase measles-containing vaccine saved $10.30 in direct medical costs and $3.20 in indirect societal costs (7).

Hib. The first Hib vaccines were polysaccharide products licensed in 1985 for use in children aged 18-24 months. Polysaccharide-protein conjugate vaccines were licensed subsequently for use in children aged 18 months (in 1987) and later for use in children aged 2 months (in 1990). Before the first vaccine was licensed, an estimated 20,000 cases of Hib invasive disease occurred each year, and Hib was the leading cause of childhood bacterial meningitis and postnatal mental retardation (8,18). The incidence of disease declined

slowly after licensure of the polysaccharide vaccine; the decline accelerated after the 1987 introduction of polysaccharide-protein conjugate vaccines for toddlers and the 1990 recommendation to vaccinate infants. In 1998, 125 cases of Hib disease and Haemophilis influenzae invasive disease of unknown serotype among children aged less than 5 years were provisionally reported: 54 were Hib and 71 were of unknown serotype (CDC, unpublished data, 1998). In less than a decade, the use of the Hib conjugate vaccines nearly eliminated Hib invasive disease among children.

Future Direction

Vaccines are one of the greatest achievements of biomedical science and public health. Despite remarkable progress, several challenges face the U.S. vaccine-delivery system. The infrastructure of the system must be capable of successfully implementing an increasingly complex vaccination schedule. An estimated 11,000 children are born each day in the United States, each requiring 15-19 doses of vaccine by age 18 months to be protected against 11 childhood diseases (6). In addition, licensure of new vaccines is anticipated against pneumococcal and meningococcal infections, influenza, parainfluenza, respiratory syncytial virus (RSV), and against chronic diseases (e.g., gastric ulcers, cancer caused by Helicobacter pylori, cervical cancer caused by human papilloma virus, and rheumatic heart disease that occurs as a sequela of group A streptococcal infection). Clinical trials are under way for vaccines to prevent human immunodeficiency virus infection, the cause of acquired immunodeficiency syndrome.

To achieve the full potential of vaccines, parents must recognize vaccines as a means of mobilizing the body's natural defenses and be better prepared to seek vaccinations for their children; health-care providers must be aware of the latest developments and recommendations; vaccine supplies and financing must be made more secure, especially for new vaccines; researchers must address increasingly complex questions about safety, efficacy, and vaccine delivery and pursue new approaches to vaccine administration more aggressively; and information technology to support timely vaccinations must be harnessed more effectively. In addition, the vaccine-delivery system must be extended to new populations of adolescents and adults. Each year, thousands of cases of potentially preventable influenza, pneumococcal disease, and hepatitis B occur in these populations. Many of the new vaccines will be targeted at these age groups. The U.S. vaccine-delivery system must routinely include these populations to optimally prevent disease, disability, and death.

Despite the dramatic declines in vaccine-preventable diseases, such diseases persist, particularly in developing countries. The United States has joined many international partners, including the World Health Organization and Rotary International, in seeking to eradicate polio by the end of 2000. Efforts to accelerate control of measles, which causes approximately one million deaths each year (5), and to expand rubella vaccination programs also are under way around the world. Efforts are needed to expand the use of existing vaccines in routine childhood vaccination programs worldwide and to successfully introduce new vaccines as they are developed. Such efforts can benefit the United States and other developed countries by decreasing disease importations from developing countries.

Reported by: National Immunization Program, CDC.

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Table_1

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 1. Vaccine-preventable diseases, by year of vaccine development or licensure -- United States, 1798-1998

Disease	Year

Smallpox*	1798+
Rabies	1885+
Typhoid	1896+
Cholera	1896+
Plague	1897+
Diphtheria*	1923+
Pertussis*	1926+
Tetanus*	1927+
Tuberculosis	1927+
Influenza	1945&
Yellow fever	1953&
Poliomyelitis*	1955&
Measles*	1963&
Mumps*	1967&
Rubella*	1969&
Anthrax	1970&
Meningitis	1975&
Pneumonia	1977&
Adenovirus	1980&
Hepatitis B*	1981&
Haemophilus influenzae type b*	1985&
Japanese encephalitis	1992&
Hepatitis A	1995&
Varicella*	1995&
Lyme disease	1998&
Rotavirus*	1998&

* Vaccine recommended for universal use in U.S. children. For smallpox, routine vaccination was ended in 1971.
\+ Vaccine developed (i.e., first published results of vaccine usage).
& Vaccine licensed for use in United States.

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Table_2

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 2. Baseline 20th century annual morbidity and 1998 provisional morbidity from nine diseases with vaccines recommended before 1990 for universal use in children -- United States

Disease	Baseline 20th century annual morbidity	1998 Provisional morbidity	% Decrease
Smallpox	48,164*	0	100%
Diphtheria	175,885+	1	100%&
Pertussis	147,271@	6,279	95.7%
Tetanus	1,314**	34	97.4%
Poliomyelitis (paralytic)	16,316++	0&&	100%
Measles	503,282@@	89	100%&
Mumps	152,209***	606	99.6%
Rubella	47,745+++	345	99.3%
Congenital rubella syndrome	823&&&	5	99.4%
Haemophilus influenzae type b	20,000@@@	54****	99.7%

* Average annual number of cases during 1900-1904 (1).
\+ Average annual number of reported cases during 1920-1922, 3 years before vaccine development.
& Rounded to nearest tenth.
@ Average annual number of reported cases during 1922-1925, 4 years before vaccine development.
** Estimated number of cases based on reported number of deaths during 1922-1926 assuming a case-fatality rate of 90%.
++ Average annual number of reported cases during 1951-1954, 4 years before vaccine licensure.
&& Excludes one cases of vaccine-associated polio reported in 1998.
@@ Average annual number of reported cases during 1958-1962, 5 years before vaccine licensure.
*** Number of reported cases in 1968, the first year reporting began and the first year after vaccine licensure.
+++ Average annual number of reported cases during 1966-1968, 3 years before vaccine licensure.
&&& Estimated number of cases based on seroprevalence data in the population and on the risk that women infected during a childbearing year would have a fetus with congenital rubella syndrome (7).
@@@ Estimated number of cases from population-based surveillance studies before vaccine licensure in 1985 (8).

**** Excludes 71 cases of Haemophilus influenzae disease of unknown serotype.

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