Historical Comparisons of Morbidity and Mortality for Vaccine-Preventable Diseases in the United States

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VACCINES ARE AMONG THE greatest achievements of biomedical science and public health, stimulating protective immune responses against acute and chronic infectious diseases, as well as some infectious diseases that result in cancer. In the United States, vaccination programs have made a major contribution to the elimination of many vaccine-preventable diseases and significantly reduced the incidence of others. Vaccine-preventable diseases have societal and economic costs in addition to the morbidity and premature deaths resulting from these diseases—the costs include missed time from school and work, physician office visits, and hospitalizations.

National recommendations provide guidance for use of vaccines to prevent or eliminate 17 vaccine-preventable diseases, namely diphtheria, pertussis, tetanus, poliomyelitis, measles, mumps, rubella (including congenital rubella syndrome), influenza, invasive *Haemophilus influenzae* type b (Hib), hepatitis B, hepatitis A, rotavirus, varicella, herpes zoster (shingles), and disease caused by many of the most important types of *Streptococcus pneumoniae*, *Neisseria meningitidis*, and human papillomavirus (HPV).

This report summarizes the historical and current status of 12 of these diseases for which national recommendations were in place prior to 2005 (diphtheria, pertussis, tetanus, poliomyelitis, measles, mumps, rubella [including congenital rubella syndrome], invasive Hib, acute hepatitis B, hepatitis A, varicella, *S pneumoniae*), in addition to smallpox, for which vaccination has not been routinely recommended since 1971. Influenza is not covered in this study; assessing the effects of influenza vaccine requires a different approach than is used for other vaccine-preventable diseases because the prevalent influenza viruses and vaccine change annually, and yearly vaccination is required for protection.

To provide a context for viewing vaccine-preventable disease morbidity and mortality, we describe elements of the US national immunization program, including development of immunization policy, vaccine distribution and coverage assessment, vaccine safety monitoring, and surveillance.

**Context** National vaccine recommendations in the United States target an increasing number of vaccine-preventable diseases for reduction, elimination, or eradication.

**Objective** To compare morbidity and mortality before and after widespread implementation of national vaccine recommendations for 13 vaccine-preventable diseases for which recommendations were in place prior to 2005.

**Design, Setting, and Participants** For the United States, prevaccine baselines were assessed based on representative historical data from primary sources and were compared to the most recent morbidity (2006) and mortality (2004) data for diphtheria, pertussis, tetanus, poliomyelitis, measles, mumps, rubella (including congenital rubella syndrome), invasive *Haemophilus influenzae* type b (Hib), acute hepatitis B, hepatitis A, varicella, *Streptococcus pneumoniae*, and smallpox.

**Main Outcome Measures** Number of cases, deaths, and hospitalizations for 13 vaccine-preventable diseases. Estimates of the percent reductions from baseline to recent were made without adjustment for factors that could affect vaccine-preventable disease morbidity, mortality, or reporting.

**Results** A greater than 92% decline in cases and a 99% or greater decline in deaths due to diseases prevented by vaccines recommended before 1980 were shown for diphtheria, mumps, pertussis, and tetanus. Endemic transmission of poliovirus and measles and rubella viruses has been eliminated in the United States; smallpox has been eradicated worldwide. Declines were 80% or greater for cases and deaths of most vaccine-preventable diseases targeted since 1980 including hepatitis A, acute hepatitis B, Hib, and varicella. Declines in cases and deaths of invasive *S pneumoniae* were 34% and 25%, respectively.

**Conclusions** The number of cases of most vaccine-preventable diseases is at an all-time low; hospitalizations and deaths have also shown striking decreases.

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Vaccine Distribution and Coverage Assessment
Since the licensure of inactivated polio virus vaccine in 1955, the national immunization program, in partnership with state, local, and private providers, has taken a primary role in purchasing and distributing vaccines for the public sector. Vaccines through the Vaccines for Children program are available to clinicians at no charge for eligible children and adolescents. The program contributes to achieving high vaccination coverage levels and ensuring that children have access to newly recommended vaccines. There is no equivalent program for adults who are uninsured and of low-income status.

Since 1994, the National Immunization Survey has provided national, state, and selected urban area estimates of vaccination coverage rates for US children between the ages of 19 and 35 months, including new vaccines as they are licensed and recommended for use. In 2004, the estimated vaccination coverage for children aged 19 to 35 months exceeded for the first time the Healthy People 2010 goal of 80% or greater for the proportion of children who receive all vaccines that have been recommended for universal administration for at least 5 years. Healthy People 2010 is a compendium of national health objectives designed to serve as a roadmap for improving the health of the people of the United States during the first decade of the 21st century. Since 1989, vaccination requirements have expanded to cover schools and day care settings, ensuring high vaccination coverage among infants and children in these environments. New systems are being developed to measure vaccine coverage rates among older children and adults. Assessing vaccination coverage identifies groups at risk of vaccine-preventable diseases, focuses efforts to improve uptake, and is a measure of the effectiveness of communicating immunization recommendations.

An increasing number of resources, including state-based immunization registries, for Disease Control and Prevention (CDC). The Advisory Committee on Immunization Practices reviews relevant scientific information and develops evidence-based recommendations for the use of licensed vaccines for infants and children, adolescents, and adults. Professional organizations also provide vaccination recommendations, which often are harmonized with the Advisory Committee on Immunization Practices recommendations. The Advisory Committee on Immunization Practices has responsibility for establishing the list of vaccines available to infants and children and to adolescents eligible to receive vaccines through the Vaccines for Children Program. Since 1994, the program, established by Section 1928 of the Social Security Act, has allowed children who are uninsured and from low-income families to receive vaccinations as part of routine care, supporting the integration of vaccination and primary care.

### Table 1. Historical Comparison of Morbidity and Mortality for Vaccine-Preventable Diseases With Vaccines Licensed or Recommended Before 1980: Diphtheria, Measles, Mumps, Pertussis, Poliomyelitis, Rubella, Smallpox, Tetanus

<table>
<thead>
<tr>
<th>Vaccine-Preventable Disease</th>
<th>Estimated Annual Average</th>
<th>Prevaccine No. (y)</th>
<th>Most Recent Postvaccine Reported No.</th>
<th>Prevaccine Estimated Annual No. vs Most Recent Reported No. (% Reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diphtheria</td>
<td>21,053</td>
<td>3508</td>
<td>0</td>
<td>21,053</td>
</tr>
<tr>
<td>(1936-1945)</td>
<td>(1938)</td>
<td>(1938)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Measles</td>
<td>532,217</td>
<td>763,094</td>
<td>0</td>
<td>530,162</td>
</tr>
<tr>
<td>Mumps</td>
<td>162,344</td>
<td>213,932</td>
<td>0</td>
<td>155,760</td>
</tr>
<tr>
<td>Pertussis</td>
<td>200,752</td>
<td>265,269</td>
<td>27</td>
<td>185,120</td>
</tr>
<tr>
<td>(1934-1943)</td>
<td>(1934)</td>
<td>(1934)</td>
<td>(99.3)</td>
<td></td>
</tr>
<tr>
<td>Poliomyelitis, acute</td>
<td>19,794</td>
<td>42,033</td>
<td>0</td>
<td>19,794</td>
</tr>
<tr>
<td>(1941-1950)</td>
<td>(1949)</td>
<td>(1949)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Poliomyelitis, paralytic</td>
<td>16,316</td>
<td>21,629</td>
<td>0</td>
<td>16,316</td>
</tr>
<tr>
<td>(1951-1964)</td>
<td>(1952)</td>
<td>(1952)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Rubella</td>
<td>47,745</td>
<td>24</td>
<td>11</td>
<td>47,734</td>
</tr>
<tr>
<td>Congenital rubella syndrome</td>
<td>152</td>
<td>Not available</td>
<td>1</td>
<td>151</td>
</tr>
<tr>
<td>(1966-1969)</td>
<td></td>
<td></td>
<td>(99.3)</td>
<td></td>
</tr>
<tr>
<td>Smallpox</td>
<td>29,005</td>
<td>110,672</td>
<td>0</td>
<td>29,005</td>
</tr>
<tr>
<td>(1900-1949)</td>
<td>(1920)</td>
<td>(1920)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Tetanus</td>
<td>580</td>
<td>601</td>
<td>41</td>
<td>539</td>
</tr>
<tr>
<td>(1947-1949)</td>
<td>(1948)</td>
<td>(1947)</td>
<td>(92.9)</td>
<td></td>
</tr>
</tbody>
</table>

aFootnote letters correspond to Box 1.
Box 1. Explanation of Variables for Table 1

Footnote letters correspond to Table 1.

**Diphtheria**
- b Number of reported cases from 1936-1945
- c,e Reported number of deaths, 1936-1945
- d Vaccine dates: the Children’s Vaccine Initiative
- e Cases reported to the National Notifiable Diseases Surveillance Systems (NNDSS) for 2006
- f Deaths reported in 2004

**Measles**
- b Number of reported cases for 1953-1962
- c Average reported deaths 1953-1962 is 444
- d Peak reported deaths 1953-1962 was 552 (in 1958)
- e Vaccine dates: measles vaccines were first licensed March 21, 1963
- f More attenuated Moraten strain was licensed in 1968
- g Cases reported to NNDSS for 2006
- h Deaths reported in 2004

**Mumps**
- b Number of reported cases, 1963-1968
- c,e Reported number of deaths, 1963-1968
- d Vaccine dates: inactivated mumps vaccine was available in the 1940s (no longer available); attenuated (Jeryl Lynn strain) was licensed in 1967
- e Cases reported to NNDSS for 2006
- f Deaths reported in 2004

**Pertussis**
- b Number of reported cases for 1934-1945
- c Reported number of deaths, 1934-1945
- d Peak reported deaths declined steadily during the 1920s
- e Vaccine dates: the Children’s Vaccine Initiative
- f Cases reported to NNDSS for 2006
- g Deaths reported to Centers for Disease Control and Prevention (CDC) in 2004

**Polio**
- b Number of reported cases, 1941-1950 and 1951-1954
- c Peak reported number of rubella cases, associated with the 1964-1965 epidemic
- d For rubella, number of reported cases for 1966-1968
- e Reported number of deaths for 1947-1949
- f Vaccine dates: inactivated polio vaccine (IPV) was used routinely
- g Cases reported to NNDSS for 2006
- h Deaths reported in 2004

**Smallpox**
- b Number of reported cases for all prevaccine years
- c,e,d For all prevaccine numbers, national reports only available during vaccine era and the smallpox endemic period 1900-1949; total number includes both variola major and variola minor
- d Vaccine dates: year smallpox vaccination widely known through publication; widespread vaccination use primarily due to establishment of school laws in the 1850s and routine universal vaccination at 1 year of age in the 1920s
- e Cases reported to NNDSS for 2006
- f Last reported case in the United States in 1949; worldwide eradication of smallpox was declared in 1980

**Tetanus**
- b Number of reported cases for 1947-1949
- c Incidence was steadily decreasing even before vaccine became available
- e Reported number of deaths for 1947-1949
- f Peak reported number of deaths for 1947
- g Peak reported number of deaths for 1947
- h Vaccine dates: the Children’s Vaccine Initiative
- i Cases reported to NNDSS for 2006
- j Between 1999-2004, the 5-year average number of reported tetanus cases was 31
- k Deaths reported in 2004

**Rubella and Congenital Rubella Syndrome (CRS)**
- b For rubella, number of reported cases for 1966-1968
- c For CRS, number is estimated, associated with the 1964-1965 epidemic
- d For rubella, peak reported number of deaths, 1968
- e For CRS, peak number is estimated, associated with the 1964-1965 epidemic
- f Vaccine dates: for rubella and CRS, the Children’s Vaccine Initiative
- g For rubella and CRS, cases reported to NNDSS for 2006
- h For rubella and CRS, among the cases reported in 2004, no deaths were reported to the CDC

**Vaccine Safety Monitoring**

Ensurance of vaccine safety is a core function related to the national immunization program and is a shared responsibility involving the CDC, the US Food and Drug Administration, other federal agencies, and vaccine resources in the public and private sectors. Reporting through the Vaccine Adverse Events Reporting System and increasing use of postlicensure monitoring is essential to determine whether the safety profiles established in prelicensing studies are reflected during use in the general population, and to detect previously unrecognized or rare adverse events. New scientific approaches are being used to identify rare, serious adverse events that might be associated with a vaccine and may be detectable only after widespread use in the population. The National Childhood Vaccine Injury Act of 1986 (Pub L No. 99-660) established the National Vaccine Injury Compensation Program, which provides recourse for individuals who believe they were injured by recommended vaccination.
Survival
Assessing the impact of the national immunization program on disease morbidity and mortality requires assessments of both vaccination coverage and the burden of disease. In national disease surveillance, state and local public health officials rely on health care providers, laboratories, and other public health personnel to report notifiable diseases to state and local health departments. In the United States, requirements for reporting diseases and conditions are mandated by state laws or regulations. The list of reportable diseases in each state differs, although there are certain diseases reported in common by all states. The CDC and the Council of State and Territorial Epidemiologists have established guidelines for state health departments’ reporting cases of selected diseases to CDC’s National Notifiable Diseases Surveillance System. To improve the specificity and enhance the comparability of state-reported cases of vaccine-preventable diseases, case definitions for surveillance have been developed. Enhanced surveillance systems have also been designed to provide public health data for monitoring disease patterns and the effectiveness of the national immunization program. Characterizing the impact of vaccines on chronic disease (e.g., hepatitis B and liver cancer, HPV and cervical cancer) requires surveillance designed to capture changes over extended periods of time.

Deaths attributed to vaccine-preventable diseases are another indicator of the impact of vaccination programs. Deaths are reported to the National Notifiable Diseases Surveillance System. In addition, the National Center for Health Statistics, National Vital Statistics System, provides data used to monitor the number of deaths, including deaths due to vaccine-preventable diseases. National Notifiable Diseases Surveillance System death reports, with the vital statistics data based on registration of birth and death events at the state and local level, allow monitoring of the impact of vaccination on the most serious outcomes of vaccine-preventable diseases.

**METHODS**

We established prevaccine estimated annual averages and determined the number of (reported or estimated) cases, deaths, and hospitalizations (when available) for vaccine-preventable diseases. The prevaccine information was from a wide variety of historical reporting sources. We sought to identify the most comprehensive and credible of these sources. The historical average number of cases and deaths per year were taken from the number reported or estimated for a representative time period before vaccine licensure, or before widespread implementation of the vaccine-specific immunization program. To give a wider context for the historical baseline (annual average), we also determined the peak numbers of cases and deaths, and indicated the period covered. The vaccine dates on the tables are either the date of license (approved for use) in the United States or the date of routine use (year the vaccine was recommended for routine use for any or all of the target age groups).

The most current available reported or estimated numbers of cases (mostly 2006), deaths (2004-2006), and hospitalizations (2006) were determined using sources most representative of the burden of disease. Reported cases and deaths (Table 1 and Box 1) were used for those diseases for which the national passive surveillance system served as the primary resource. Current estimates (rather than reports) were used for diseases for which active surveillance or modeling provided the most representative indication of disease impact (Table 2 and Box 2).

The percent reduction in the number of cases, deaths, and hospitalizations for each of the vaccine-preventable diseases was calculated as the difference between the baseline and the current numbers. The disease-specific numbers refer to the entire population unless a specific age group is indicated, although

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**Table 2.** Historical Comparison of Morbidity, Mortality, and Hospitalizations for Vaccine-Preventable Diseases With Vaccines Licensed or Recommended Between 1980 and 2005: Hepatitis A, Acute Hepatitis B, Haemophilus influenzae Type b, Pneumococcal Disease, Varicellaa

<table>
<thead>
<tr>
<th>Vaccine-Preventable Disease</th>
<th>Prevaccine Estimated Annual No. vs Most Recent Estimated No. (% Reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hepatitis A</strong></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>Hospitalizations</td>
</tr>
</tbody>
</table>

**Footnote letters correspond to Box 2.**
Box 2. Explanation of Variables for Table 2

Footnote letters correspond to Table 2.

**Hepatitis A**
- 

**Acute Hepatitis B**
- 

**Invasive Haemophilus influenzae type b (Hib)**
- 

**Invasive Pneumococcal Disease**
- 

**Varicella**
- 

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some vaccines may have targeted specific age or risk groups.

The data included here were collected for routine public health surveillance purposes, did not include linkages to personal identifiers, and thus were considered research not requiring institutional review for human subjects protections.

RESULTS

The prevaccine era number of cases and deaths and the most recent number (reported or estimated) of cases and deaths for 13 vaccine-preventable diseases are summarized in Table 1 and Box 1 and Table 2 and Box 2. The number of hospitalizations is shown for diseases and years with available information (Table 2 and Box 2).

Table 1 provides the historical comparison of 8 diseases for which a vaccine was licensed or recommended prior to 1980, including diphtheria,53-56 measles,53,54,56,60,61 mumps,54,57-59,61 pertussis,53-56,61 poliomyelitis,53-56 rubella and congenital rubella syndrome,54,57,58,60,62 smallpox,54,57,59,61 and tetanus.54,56,60,62,63 Our comparison of the period before national vaccination recommendations vs the 2006 number of reported cases shows greater than 99% declines in the number of cases for diphtheria (100%), measles (99.9%), paralytic poliomyelitis (100%), rubella (99.9%), congenital rubella syndrome (99.3%), and smallpox (100%) (Table 1 and Box 1). Smallpox has been eradicated worldwide,56 and endemic transmission of poliovirus,53-56 measles virus,54,57-59 and rubella virus has been eliminated in the United States. There were no reported deaths due to diphtheria, measles, mumps, paralytic poliomyelitis, or rubella; deaths due to congenital rubella syndrome are not reported. The decline in cases of mumps was 95.9%, of tetanus 92.9%, and of pertussis 92.2%. The decline in tetanus deaths was 99.2% and in pertussis deaths 99.3%.

Table 2 provides the historical comparison of the number of cases, deaths, and hospitalizations for diseases for which a vaccine was licensed or recommended after 1980 but before 2005 (including hepatitis A,33,38,68,69,94 acute hepatitis B,58,68,70 invasive Hib,58,71-73 invasive pneumococcal disease,58,73-75 and varicella).58-60,68,76,77,79-81,95 Our comparison of the period before national vaccination recommendations vs the most recent estimated number of cases and deaths shows declines in the estimated number of cases ranging from 34.1% to 99.8% or greater, and declines in the number of deaths ranging from 25.4% to 99.5% or greater. Cases of invasive Hib disease declined 99.8% or greater and deaths declined 99.5% or greater. Reduction in cases was 87.0% and in deaths 86.9% for hepatitis A; 80.1% in cases and 80.2% in deaths for acute hepatitis B; 34.1% in cases and 25.4% in deaths for invasive pneumococcal disease; and 85.0% in cases and 81.9% in deaths for varicella. Hospitalizations declined by 87.0% for hepatitis A, 80.1% for acute hepatitis B, and 88.0% for varicella.

COMMENT

The number of cases of most vaccine-preventable diseases is at an all-time low; hospitalizations and deaths from vaccine-preventable diseases have also shown striking decreases. These achievements are largely due to reaching and maintaining high vaccine coverage levels from infancy through childhood by successful implementation of the infant and childhood immunization program.1 It has been estimated that vaccination with 7 of the 12 routinely recommended childhood vaccines prevents an estimated 33,000 deaths and 14 million cases of disease in every birth cohort, saves $10 billion in direct costs in each birth cohort, and saves society an additional $33 billion in costs that include disability and lost productivity.14

There are important limitations to consider when reviewing the decrease in vaccine-preventable diseases over time. The number of cases and deaths reported to surveillance systems and the number of cases and deaths presented in the tables are likely to underestimate the number of cases and deaths throughout the reporting periods.96 Reporting and disease estimates from surveillance systems are affected by changes in disease awareness, tests and testing protocols, case definitions, reporting jurisdictions, and reporting practices over time.44,46,47,61,64 During the span of the national immunization program, changes have occurred in the population (eg, growth, racial/ethnic distribution, age structure), health care (eg, advances in treatment, vaccine formulations available), socioeconomic determinants (eg, education level, standard of living), vaccine practice (eg, early use of vaccines before national recommendations are made, vaccine coverage levels, inclusion of new vaccines in national recommendations), and other health predictors (eg, access to health care). Neither the historical nor current data are adjusted for these nonvaccine factors.46,97,98 Epidemiologic and economic analyses to further characterize vaccine impact will need to take into account the specific factors that have affected the burden of each disease over time.

The long-term health and economic benefits of vaccines are not included here, resulting in an underestimate of the true impact of vaccination programs. Current surveillance systems are not designed to measure the burden of chronic disease. No attempt was made to compile the rare but serious adverse events that have been causally associated with some vaccines or to weigh the risks and benefits of vaccination, which has been done elsewhere.98-104

The footnotes in Box 1 and Box 2 provide specific references for the historical and methodological details used to determine the prevaccine and most current disease numbers presented. Some of the recent data rely on estimates or statistical modeling to account for infections that are asymptomatic but infectious; these models are referenced in Table 1 and Box 1 and Table 2 and Box 2. Because the methodology for presenting historical and current numbers is specific to each disease, comparisons should not be made between diseases.
Added health benefits could be achieved by increasing vaccine uptake of currently recommended vaccines among adolescents and adults. An increasing number of vaccines that reduce the morbidity and mortality of disease in adolescents (eg, meningococcal; HPV; and new pertussis, tetanus, and diphtheria vaccines) create opportunities and challenges. Providing routine access to all vaccines recommended for adolescents will require different approaches for adolescents than for infants and children. Ensuring routine access to pertussis, influenza, pneumococcal, and zoster vaccines can reduce vaccine-preventable disease morbidity and mortality among adults, and may decrease disease transmission to other vulnerable populations. Achieving high vaccination uptake among adults will require a greater understanding of the benefits of vaccination by clinicians and patients, and adoption of vaccination provision as a part of adult preventive health care. Racial/ethnic disparities were not identified in the 2005 National Immunization Survey for vaccines that have been recommended for universal administration to children aged 19 to 35 months for at least 5 years. However, substantial racial/ethnic differences in adult vaccination uptake have been documented in national surveys, even among adults most likely to be vaccinated (eg, individuals with the highest education level and individuals who undergo frequent health care visits). The greatest additional gains are likely to come from achieving higher vaccination coverage among adolescents and adults. Vaccine-preventable diseases still exist, with 1 exception (smallpox). History demonstrates that because vaccine-preventable diseases and safety concerns, with safety concerns likely to emerge as first-hand experience with vaccine-preventable diseases decreases. The links between perception of benefits, perception of risks, and the decision to vacinate emphasize the importance of ensuring the safety of vaccines and clearly communicating their risks and benefits, especially when disease rates are low.

Vaccines are one of the greatest achievements of biomedical science and public health. Continued efforts to improve the efficacy and safety of vaccines and vaccine coverage among all age groups will provide overall public health benefit. The challenges in vaccine development, vaccine financing, surveillance, assessment, and vaccine delivery are opportunities for the future.

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