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# Current Estimates of the Impact of Routine Childhood Immunizations in Reducing Vaccine-Preventable Diseases in the United States

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## BACKGROUND

- Routine immunization recommendations in the United States (US) for children aged 10 years and younger currently target 14 different diseases.[1]
- Previous studies have highlighted the public health and economic impact of the childhood vaccination program,[2,3] but updated estimates are needed given changes in disease epidemiology over time, evolving vaccine recommendations, and varying compliance rates.

## OBJECTIVE

- To estimate the public health gains associated with the US childhood vaccination program, focusing on reductions in overall and age-specific disease incidence and corresponding cases of disease.

## METHODS

- A targeted literature review was conducted to obtain estimates of disease incidence with and without the childhood immunization program, accounting for herd immunity. These estimates were used in a Microsoft Excel–based model that was developed to evaluate reductions in cases of vaccine-preventable diseases associated with immunization in a single calendar year population.
  - Pre-vaccine disease incidence was estimated before each routine vaccine was recommended, with average values across multiple years obtained from the literature or calculated based on disease surveillance data or annual case estimates from the literature (Table 1).
  - Current incidence was generally calculated as average values over the most recent 5 years of available data (Table 1).
- Because childhood immunizations provide protection against diseases beyond ages 0 to 10 years, overall incidence estimates and estimates by age group were calculated across all ages (or for a subset of ages to account for disease epidemiology, available data, and/or to focus on the effects of childhood immunization).
- Differences in pre- and post-vaccine age-specific incidence rates were then compared and used to calculate the annual number of cases averted based on 2019 US population estimates (i.e., the analytic framework estimates the impact of the immunization program if there was no vaccination and incidence was at pre-vaccine era rates).

**Table 1. Summary of Pre- and Post-Vaccine Disease Incidence Sources**

| Disease | Dates of Vaccination Program Initiation[a] | Pre-Vaccine Source | Post-Vaccine Source |
|---|---|---|---|
| Diphtheria | 1928-1943 | Calculated based on 1936-1945 cases before widespread vaccination in late 1940s[3] | 2014-2018 NNDSS[4] |
| Hepatitis A | 1995 | 1990-1994 NNDSS[4] | 2014-2018 NNDSS[4] |
| Hepatitis B | 1981, 1986 | 1976-1980 NNDSS[4] | 2014-2018 NNDSS[4] |
| Hib | 1985, 1987, 1990 | Zhou et al.,[5] based on data from 1976-1984 | 2013-2017 ABCs[6] |
| Influenza | 1945 | Calculated based on CDC estimated cases and cases averted for seasons 2014-2015 through 2018-2019[7,8] | Calculated based on CDC estimated cases for seasons 2014-2015 through 2018-2019[7] |
| IPD | 2000 | 1997-1999 ABCs[6] | 2013-2017 ABCs[6] |
| Measles | 1963, 1967, 1968 | Zhou et al.[9] | 2014-2018 NNDSS[4] |
| Mumps | 1940s, 1967 | Zhou et al.[9] | 2014-2018 NNDSS[4] |
| Pertussis | 1914-1941 | Calculated based on 1934-1943 cases before routine vaccination in late 1940s[3] | 2014-2018 NNDSS[4] |
| Polio | 1955, 1961-1963, 1987 | Calculated based on 1951-1954 cases[3] | 2014-2018 NNDSS[4] |
| Rotavirus | 1998 (first licensed but withdrawn); 2006 | Calculated based on 1993-2002 cumulative risk of event by age 59 months without vaccine[10] | Calculated based on pre-vaccine incidence and % reduction in events with vaccine[10] |
| Rubella | 1969 | Zhou et al.[9] | 2014-2018 NNDSS[4] |
| Tetanus | 1933-1949 | Calculated based on 1947-1949 cases before routine vaccination in late 1940s[3] | 2014-2018 NNDSS[4] |
| Varicella | 1995 | 1990-1994 NNDSS[4] | 2014-2018 NNDSS[4] |

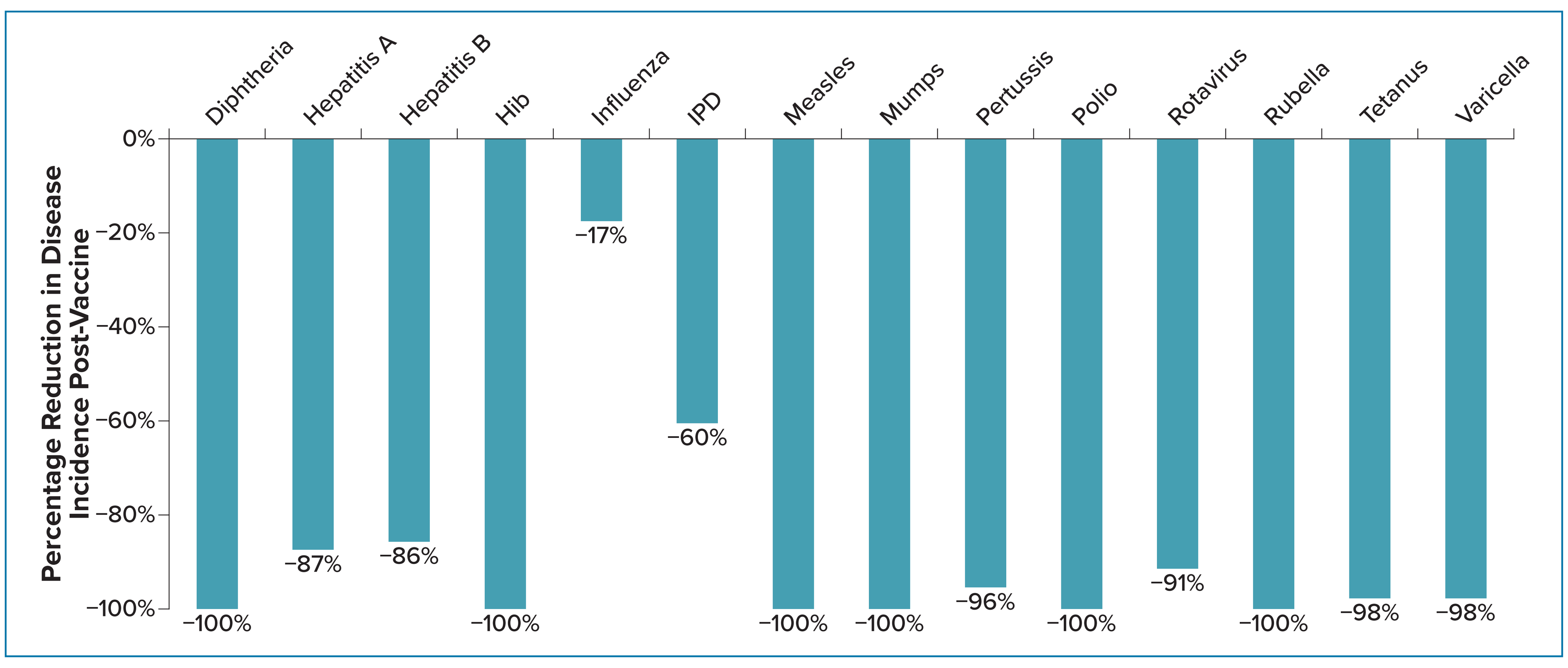
ABCs = Active Bacterial Core surveillance; CDC = Centers for Disease Control and Prevention; Hib = *Haemophilus influenzae* type B; IPD = invasive pneumococcal disease; NNDSS = National Notifiable Diseases Surveillance System.

[a] Dates of vaccination program initiation correspond to dates of vaccine licensure and/or routine use.[3,11] For additional details on vaccines with multiple dates listed, please see Roush et al.[3] and Widdowson et al.[10]

## RESULTS

- Incidence decreased for all diseases evaluated after vaccines were introduced (Table 2), with reductions ranging from 17.4% for influenza to 100.0% for polio (Figure 1).
  - More than 90% reduction in incidence was achieved for 10 of the 14 diseases evaluated (including reduction in incidence of rotavirus hospitalizations).
- Age-specific incidence estimates also decreased after vaccines were introduced (Supplementary Tables 3-5).
- Estimated annual cases averted by vaccination in 2019 ranged from approximately 1,000 for tetanus to more than 4.2 million for varicella (Table 2).

**Figure 1. Percentage Reduction in Disease Incidence Post-Vaccine, by Disease**




HiB = *Haemophilus influenzae* type b; IPD = invasive pneumococcal disease.

Note: Percentage reduction for rotavirus is hospitalizations. Percentage reductions in disease incidence round up to 100% for several diseases, although there are still some post-vaccine cases (Table 2).

**Table 2. Pre- and Post-Vaccine Disease Incidence Estimates, Annual Cases, and 2019 Cases Averted, by Disease**

| | Pre-Vaccine | | Post-Vaccine | | |
|---|---|---|---|---|---|
| Disease | Disease Incidence per 100,000[a] | Annual Cases[b] | Disease Incidence per 100,000[a] | Annual Cases[b] | Cases Averted |
| **Age < 5 years (n = 19,576,683)** | | | | | |
| Hib | 92 | 18,000 | < 1 | < 100 | 18,000 |
| Rotavirus[c] | | | | | |
| Hospitalizations | 340 | 67,000 | 29 | 6,000 | 61,000 |
| ED visits | 1,072 | 210,000 | 420 | 82,000 | 128,000 |
| Outpatient visits | 2,228 | 436,000 | 1,222 | 239,000 | 197,000 |
| NMA cases | 11,364 | 2,225,000 | 6,233 | 1,220,000 | 1,004,000 |
| **Age ≤ 10 years (n = 43,833,518)** | | | | | |
| Diphtheria | 89 | 39,000 | < 1 | < 1 | 39,000 |
| Influenza | 16,232 | 7,115,000 | 13,412 | 5,879,000 | 1,236,000 |
| **Age < 40 years (n = 170,936,198)** | | | | | |
| Measles | 2,129 | 3,639,000 | < 1 | < 1,000 | 3,639,000 |
| Mumps | 1,312 | 2,243,000 | 2 | 3,000 | 2,240,000 |
| Rubella | 1,124 | 1,921,000 | < 1 | < 10 | 1,921,000 |
| **All ages (n = 328,239,523)** | | | | | |
| Hepatitis A | 17 | 56,000 | 2 | 7,000 | 49,000 |
| Hepatitis B | 46 | 150,000 | 7 | 22,000 | 128,000 |
| IPD | 24 | 79,000 | 10 | 31,000 | 48,000 |
| Pertussis | 511 | 1,679,000 | 22 | 72,000 | 1,607,000 |
| Polio | 21 | 70,000 | 0 | 0 | 70,000 |
| Tetanus | < 1 | 1,000 | < 1 | < 100 | 1,000 |
| Varicella | 1,328 | 4,359,000 | 30 | 97,000 | 4,262,000 |

ED = emergency department; Hib = *Haemophilus influenzae* type b; IPD = invasive pneumococcal disease; NMA = nonmedically attended; US = United States.

[a] Incidence estimates are adjusted by underreporting factors of 1.7 for hepatitis A, 6.5 for hepatitis B, 3.3 for pertussis, 2.1 for polio pre-vaccine (to capture paralytic and nonparalytic cases), 22.2 for varicella pre-vaccine, and 10.4 for varicella post-vaccine (with all other diseases assumed fully reported and/or already adjusted to account for underreporting from the source data).

[b] Pre- and post-vaccine case estimates are calculated using 2019 US population estimates. For Hib, rotavirus, diphtheria, influenza, measles, mumps, and rubella, disease incidence and case estimates are based on age-defined population subsets, as outlined in the table, to account for disease epidemiology, available data, and/or focus on the effects of the childhood vaccination program.

[c] Rotavirus results are shown separately by health care resource use based on the available disease incidence data. Difference in averted NMA cases is due to rounding.

## LIMITATIONS

- Pre- and post-vaccine disease incidence estimates are generally based on multiple years of data and have been adjusted by underreporting factors as warranted; evolving understanding of the epidemiology of infectious diseases may alter the number of averted cases.
- Additional diseases prevented by pneumococcal vaccination, including pneumonia and acute otitis media, are not included in these estimates, which could cause an underestimation of the averted burden.
- This analysis did not estimate separately the proportion of disease incidence reduction that may be attributed to later childhood, adolescent, and adult vaccines or to booster doses. As a result, the analysis may overestimate reductions in burden associated with childhood immunization.

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## CONCLUSIONS

- Routine childhood immunization in the US continues to result in incidence reductions across all diseases and for all age groups evaluated, with reductions ranging from 17%-100% and corresponding to estimated reductions in cases ranging from 1,000 to 4.2 million cases of disease.
- The current study focused on the disease burden averted. An economic evaluation is necessary to fully understand the societal impact of vaccination.

## DISCLOSURES

Funding for this study was provided by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA. EL, JC, and ST are employed by RTI Health Solutions, which provides consulting and other research services to pharmaceutical, device, governmental, and nongovernment organizations. YC, MN, CC, and CR are employees of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA and shareholders in Merck & Co., Inc., Kenilworth, NJ, USA. GM has been an investigator on clinical trials funded by GlaxoSmithKline, Merck, Pfizer, Sanofi Pasteur, and Seqirus, and he has received honoraria from these companies for service on advisory boards and/or non-branded presentations.

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Presented at: IDWeek 2020; October 21-25, 2020