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# The global value of vaccination

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**Abstract**

While most agree that vaccination is one of the most important public health practices, vaccines continue to be underused and undervalued, and vaccine-preventable diseases remain a threat to world health. Perhaps one reason this gap remains is that decision-making generally is made on a vaccine-by-vaccine basis. There has been less attention to the value of vaccination in general. To more clearly identify this value, this paper reviews the cost-effectiveness literature and calculates the annual benefits of vaccination on a global scale.


*Keywords:* Cost-effectiveness; Burden of disease; Vaccination

## 1. Introduction

Vaccination is one of the most significant public health interventions in the past century, sparing millions of people from infectious diseases. Each year 130 million children are born, about 30 million of whom have no access to vaccinations. To improve access, this paper reviews the global value of vaccination, the effectiveness of vaccination initiatives, and the necessity of sustaining progress and overcoming the effects of under-valuation of vaccination on a global scale.

## 2. Methods

Estimates of vaccine-preventable cases world-wide, vaccine coverage levels, disease incidence, vaccine costs and cost-effectiveness were obtained through in a four-stage process. First, an electronic document search was conducted to obtain online references and statistics from public agencies and academic centres in the US (Centres for Disease Control, GAVI, National Institutes of Allergy and Infectious Diseases, United Nations/UNICEF, World Bank), the UK (Public Health Laboratory Service), France (INSERM), Australia (Australian Department of Health and Aged Care) and Switzerland (World Health Organisation). Second, government documents and academic publications were reviewed using the following search terms: vaccination, vaccine, immunisation, pertussis, diphtheria, DTaP/DTP, measles, mumps, rubella, MMR, polio/poliomyelitis, influenza, HiB/Hib, hepatitis, meningitis, meningococcal disease, pneumoccocal disease, tetanus, cost-effectiveness, quality-adjusted life year (QALY) and disability-adjusted life year (DALY). Third, academic and government experts in vaccine cost-effectiveness were contacted to obtain several estimates. Fourth, the epidemiological and economic data obtained from the first two stages were converted to the following common units: US$, life years saved (LSY), deaths prevented, quality-adjusted life years, and disability-adjusted life years (DALYs), to allow for further economic analyses of the value of vaccination.

## 3. The status of vaccination world-wide

World-wide average vaccination coverage of children under the age of five fell from 80% in 1990 to 74% in 1999. One in four children in the world remains without immunisation against the six diseases initially covered by EPI (measles, polio, pertussis, diphtheria, tetanus and tuberculosis). Moreover if vaccination is undervalued, there may be a lack of adequate investment in research and development for new vaccines to combat the diseases that are prevalent in developing countries: diarrheal diseases, malaria, tuberculosis, pneumonia and HIV/AIDS [1].

### 3.1. Industrialised countries

The under-utilisation of vaccines in industrialised countries is caused in part by underestimating the seriousness of vaccine-preventable diseases, underestimating the benefits of vaccination, and concerns regarding the side effects of vaccines [2]. Those who have witnessed the horrible disabilities and deaths caused by smallpox and polio often viewed

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Table 1
Estimated impact of increased vaccine coverage on vaccine-preventable diseases

| Disease | Annual number of deaths from vaccine-preventable disease: world-wide |
|---|---|
| Hepatitis B | 900,000 |
| Measles | 888,000 |
| *Haemophilus influenzae b* (Hib) | 400,000 |
| Pertussis (whooping cough) | 346,000 |
| Neonatal tetanus | 215,000 |
| Tetanus | 195,000 |
| Yellow fever | 30,000 |
| Diphtheria | 5,000 |
| Poliomyelitis | 720 |
| Total | 2,979,720 |

Sources: GAVI and WHO Department of Vaccines and Biologicals (http://www.vaccinealliance.org/press/press_disease.html) accessed June 2001; WHO World Health Report 1999 and WHO Department of Vaccines and Biologicals.

vaccines against these diseases as a miracle. However, much of today's population has never experienced the devastation caused by these and other vaccine-preventable diseases thanks to vaccination programs. When there is no longer an imminent fear of contracting a disease, the public may forget about the limitations of cures and can become apathetic about prevention.

### 3.2. Developing countries

There is great disparity throughout the world with regard to severity of disease, availability of vaccines, and the quality of vaccination programs. A child in a developing country has more than a 10-fold greater chance of dying of a vaccine-preventable disease than a child in an industrialised country. In some countries in sub-Saharan Africa, up to 70% of children do not receive the full set of vaccines [1].

Although vaccination saves up to three million children's lives each year, another three million lives are lost world-wide from diseases that are preventable with existing vaccines (Table 1). More widespread use of vaccines could prevent an additional 1.6 million deaths a year among children under the age of five [1].

## 4. The world-wide benefits of vaccination

Vaccination is a collective activity in the sense that the act of immunising one person can lead to the protection of an entire group of people and can cross boundaries between countries and continents resulting in a global impact. High vaccination rates benefit all as the spread of infection declines [3]. High rates in one country benefit other countries; and high rates in one generation benefit the next generation.

The benefits of smallpox and polio eradication and measles and tetanus control through immunisation, in terms of annual life years saved (LYS) and disability-adjusted life years (DALYs) saved in the US, Africa and globally, is shown in Table 2.

WHO made an enormous eradication effort and invested more than 300 million dollars over 11 years in the Intensified Smallpox Eradication Program. This cost has been repaid many times in saving human lives and in the elimination of costs for vaccines, treatment and international surveillance activities [4].

Table 2
Benefits disease eradication and control by vaccination, in terms of annual life years saved (LYS) and disability-adjusted life years (DALYs) saved

| Disease | US | | Africa | | Global | |
|---|---|---|---|---|---|---|
| | LYS | DALY | LYS | DALY | LYS | DALY |
| Smallpox[a] | 1,685,740 | NA | 933,065 | NA | 5,000,000 | NA |
| Polio[b] | 212,690 | NA | 484,230 | 279,000 | 35,750,000 | 1,725,000 |
| Measles[c] | 5,811,852 | 26 | 2,125,500 | 17,463,000 | 71,500,000 | 29,838,000 |
| Tetanus[d] | 42,705 | 9 | 2,801,500 | 3,039,000 | 56,030,000 | 12,020,000 |

NA: not available.

[a] Children's Vaccine Initiative, World Health Organization, 1995 MMWR, 2 April 1999. Note that the estimate of life years saved in the US is based upon 48,164 average deaths between 1900–1904 multiplied by 35-year life expectancy. JW Hopkins, The Eradication of Smallpox. Westview Press: San Francisco, CA, 1989. Estimate of life years saved in Africa based upon 26,659 deaths reported in 1971 multiplied by 35-year life expectancy.

[b] Dr. Matthew McKenna at CDC; Murray and Lopez, *Global Burden of Disease, 1999*; Children's Vaccine Initiative, World Health Organization, 1995 Note: estimate of US life years saved is based on 21,269—average number of paralytic polio cases times an assumed 50% mortality rate between 1951–1954 times an assumed 20-year life expectancy (source: MMWR, 2 April 1999). Estimate of African life years saved is based on difference between 1999 polio cases (http://www.polioeradication.org/pdfs/polio_news_no7.pdf, Page 3) and 1988 cases (http://www.ifrc.org/what/health/archi/fact/fpolerad.htm) of 35,000-2718 times assumed 15-year life expectancy.

[c] World Health Organization, 2000. Estimate of US life years saved based on 894,131 times a mortality rate at peak incidence of 10% times 65-year life expectancy. Estimate of African life years saved based upon estimate of 32,700 deaths prevented between 1998 and 2000 (http://www.whoafr.org/ddc/vpd/2000tfi/measlescontrol/acceleratedmeaslescontrol.pdf) times assumed 65-year life expectancy.

[d] MMWR, International Notes Progress Toward the Global Elimination of Neonatal Tetanus, 1989–1993, vol. 43(48), 1994: 885–94 estimate of tetanus life years saved in the US is based on assumed 657 deaths prevented from peak incidence of 1314 and 50% mortality rate times 65-year life expectancy. Estimate of tetanus life years saved in Africa in 1993 based on estimate that 5% of world-wide tetanus deaths and deaths prevented occurred in Africa times 65-year life expectancy.

Other than for concerns over bio-terrorism, the relative balance of benefits and risk mean there was no longer a need for smallpox vaccination thanks to this remarkable and unprecedented global vaccination campaign [5]. To date, eradication has spared the global community of some 350 million new smallpox victims and some 40 million deaths from the disease [6]. The annual savings as a result of vaccination being stopped and hospitals being able to be converted to other uses is estimated to be in excess of US$ 2000 million each year [7].

Vaccination has resulted in the elimination of wild poliovirus from the Western Hemisphere. Of the three types of wild polioviruses, type 2 was last seen in 1999 and appears to have been eradicated. More than 190 countries and territories are polio-free and the disease now exists in only about 20 countries, all in the regions of Southeast Asia and Sub-Sahara Africa. Since 1988, the number of cases reported to WHO has declined by 99%. In the year 2000, fewer than 3000 cases world-wide were reported compared with 35,000 cases reported in 1988 [8].

Measles is one of the most contagious diseases known to man. It is a major childhood killer in developing countries, accounting for about 900,000 deaths a year. The American region reported the lowest incidence 1.6 cases per 100,000 persons, in 1998—a 75% decline from 1997. In the European Region there was a 59% decrease in reported cases from 1997 to 1998; however, 14 fewer countries in this region reported measles cases in 1998 so an actual decline may have been less. However, in the Eastern Mediterranean, the number of cases reported increased by 58% from 1997 to 1998. This increase was largely due to outbreaks that occurred in Islamic Republic of Iran, Morocco, Saudi Arabia and Syrian Arab Republic before implementation of measles elimination strategies [9].

Neonatal (new-born) tetanus is the most common form of tetanus in developing countries. The disease is caused by contamination of the umbilical stump with spores of *Clostridium tetani* following childbirth through cutting the cord with a non-sterile instrument or by application of animal dung to the cut cord. Neonatal tetanus (NT) is a major

Table 3
Comparison of savings for vaccine-preventable disease to other public health problems

| Disease: | Comparative savings | Direct or indirect savings |
|---|---|---|
| Smallpox[a,b] | Not available | US$ 300 million in direct costs per year |
| Polio[b,c] | Not available | US$ 13.6 billion in total savings world-wide by 2040[c] US$ 700 million in US between 1991 and 2000[d] |
| Measles[e] | One case of measles is 23 times the cost of vaccinating one child against measles[b] | US$ 10 per disability-adjusted life year (DALY) |
| Cholera[f] | Not available | US$ 770 million lost in seafood export Peru, 1991 |
| Malaria[f] | Not available | US$ 100 billion GDP lost annually in sub-Sahara Africa because of malaria[g] |
| MMR[h] | For every US$ 1 spent on MMR vaccine, more than US$ 21 is saved in direct medical care costs | US$ 100 million in direct medical costs from 1989 to 1991 measles outbreak[i] |
| DTPa[h] | For every US$ 1 spent on DTPa vaccine, US$ 24 is saved | US$ 23.6 billion in direct and indirect costs without DTP vaccines[j] |
| Hib[h] | For every US$ 1 spent on Hib vaccine, more than US$ 2 is saved | US$ 5 billion in direct costs and US$ 12 billion in indirect costs incurred in Us[k] |
| Other public health problems[l]: | | |
| Plague | Not available | US$ 1.7 billion lost tourist income and trade |
| AIDS | Not available | US$ 14 billion annual treatment cost in the US |
| Drug resistance | Not available | US$ 4 billion annual treatment cost in the US |

MMR: measles–mumps–rubella, DTPa: diphtheria–tetanus–acellular pertussis, Hib: *H. influenzae* type b.

[a] Based on eradication of smallpox in 1977.

[b] CDC, Immunization Services Div., Health Services Res. and Evaluation Branch, 1999.

[c] Based on eradication of polio by 2005. Bart Global eradication of poliomyelitis: benefit-cost analysis. Bull World Health Organ 1996;74(1):35–45.

[d] http://clinton1.nara.gov/white_house/eop/ostp/ciset/html/iintro.html.

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[f] GAVI fact sheet 169 March 2001.

[g] http://www.who.int/inf-pr-2000/en/pr2000-28.html.

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[k] http://www.ostp.gov/CISET/html/iintro.html#Table 1, US Government Accounting Office, Immunization: HHS could do more to increase vaccination among older adults (Washington, DC, June 1995), p. 11.

[l] WHO 1999 WHO Infectious Diseases Report: removing obstacles to healthy development. (http://www.who.int/infectious-disease-report/pages/graph24.html).

Table 4
Annual world-wide benefits of vaccination and global health improvements[a]

| Disease | Deaths prevented per year | Life years saved | Disability-adjusted life years saved |
|---|---|---|---|
| Varicella | 57,879 | 1,615,252[b] | NA |
| Diphtheria | 60,000 | 3,900,000[c] | 151,000 |
| Tetanus | 862,000 | 56,030,000[d] | 12,020,000 |
| Pertussis | 600,000 | 39,000,000[e] | 10,905,000 |
| *H. influenza* B (childhood) | 287,000 | 18,655,000[f] | 6,242,000 (bacterial meningitis) |
| Hepatitis B | 1,172,500 | 76,212,500[g] | 2,790,000 |
| Measles | 1,100,000 | 71,500,000 | 29,838,000 |
| Polio | 650,000 | 42,250,000[h] | 1,725,000 |
| Tuberculosis | 1,188,476 | 77,250,940[i] | 33,287,000 |
| Total | 5,977,855 | 386,413,692 | 96,958,000 |

[a] Source: DALYs from (82); Cochrane Vaccinology review as of 5/1/01; Miller and McCann, 2000.
[b] Life years saved estimate for Varicella is an extrapolation of 57,879 prevented deaths and 9538 life years saved in 800,000 German children, which was extrapolated to the global population using 1995 population of 5,716,426,000 and a crude birth rate of 23.7/1000. This represents a lower bound, since the incidence of Varicella is likely to be higher in developing countries.
[c] Life years saved estimate for diphtheria is based on an estimate of 60,000 prevented deaths times the assumption of 65-year life expectancy. Source for deaths prevented (81) and (82).
[d] Life years saved estimate for tetanus is based on an estimate of 862,000 prevented deaths from 1998 World Health Report times assumption of 65-year life expectancy. Estimate of 862,000 deaths prevented is drawn from estimate of 724,000 neonatal deaths prevented in 1993 plus the 138,000 (515,000–377,000) additional deaths prevented per annum between 1993 and 1999. Estimates of 724,000 and 515,000 derived from (81) and estimate of 377,000 tetanus deaths world-wide from (82).
[e] Life years saved estimate for pertussis based on average of 600,000 deaths prevented annually in 1992 times assumption of 65-year life expectancy.
[f] Life years saved estimate for Hib was based on average of 287,000 deaths prevented annually (average of 257,000 and 317,000) for children (age) <5 times assumption of 65-year life expectancy.
[g] Life years saved estimate for hepatitis B is based on an estimate of 1,172,500 prevented deaths (1,296,500 expected deaths in 1985 to 124,000 hepatitis deaths in 1999) times an assumed 65-year life expectancy. Source for 1983 expected deaths (83).
[h] Life years saved estimate for polio is based on an estimate of 650,000 prevented deaths (250,000 from developed world and China (84) and 400,000 from developing world (85)) times assumption of 65-year life expectancy.
[i] Life years saved estimate for tuberculosis is based on an estimated 1,188,476 deaths averted times the assumption of 65-year life expectancy. A number of 1,188,476 death averted based upon a pre-vaccination incidence rate of 65 per 100,000 population from France before 1950 and 1995 mortality rate. It is assumed that vaccination reduces incidence rates but has no effect on mortality rates.

cause of mortality in developing countries, with over 400,000 deaths estimated to occur annually [10].

## 5. Economic burden of vaccine-preventable diseases

The rationale for investing in immunisation programs in developing countries is clear. These programs represent a low risk investment in human capital development with a proven impact. They are highly cost effective, have significant economies of scale, and can be financially sustained by developing countries [11]. The World Bank considers that a health care intervention is cost-effective if it buys a year of healthy life for less than the per-capita gross national product (GNP) of the country. Most immunisations cost less than US$ 50 per healthy life year saved. This is compared to the cost of treating a disease such as hypertension, which is estimated in the US to be between US$ 4340 and 87,940 per healthy life year saved [12]. When infectious diseases are not controlled they can place a tremendous burden on the economy of communities and regions. A few assessments from the literature are as shown in Table 3.

Vaccination is one of the few preventive public health measures that directly saves money. Table 4 summarises, in terms of lives, what vaccination gives to the world annually. An American Journal of Public Health study documented a 14:1 return on investment for the MMR vaccine. For every dollar spent, US$ 3.94–4.91 was saved; not including reduced absenteeism or improved productivity [13].

In the developing world, the annual cost of immunising millions of children against six infectious diseases is equivalent to the cost of a single day of health care in the USA. For less than US$ 20 in vaccine and administration costs, a child can be immunised against polio, diphtheria, pertussis, measles and tetanus. Additional “life-saving” vaccines could be added for approximately US$ 10 per vaccine. If it costs around US$ 30 to immunise one child, that is equal to about US$ 3–4 billion a year to immunise 100–120 million children [14]. At a cost of US$ 2.9 billion, measles vaccination coverage could be increased to 95% in low-income countries, resulting in an estimate of 579,000 child deaths averted per year [15].

## 6. Conclusion

Vaccines are unquestionably one of the most cost-effective public health measures available, yet they are undervalued and under-utilised throughout the world. It is important for international agencies, governments, and health policy

makers to keep this preventive measure in the spotlight. Ultimately, it is the global society and future generations that benefit when all countries make the effort to protect their populations from vaccine-preventable diseases.

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