Benefits of Mass Vaccination Programs

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Since the late 1940s, mass vaccination programs in the USA have contributed to the significantly reduced morbidity and mortality of infectious diseases. To assist the evaluation of the benefits of mass vaccination programs, the number of individuals who would have suffered death or permanent disability in the USA in 2014, had mass vaccination never been implemented, was estimated for measles, mumps, rubella, tetanus, diphtheria, pertussis, polio, Haemophilus influenzae type b (Hib), hepatitis B, varicella, and human papillomavirus (HPV). The estimates accounted for mortality and morbidity trends observed for these infections prior to mass vaccination and the impact of advances in standard of living and health care. The estimates also considered populations with and without known factors leading to an elevated risk of permanent injury from infection. Mass vaccination prevented an estimated 20 million infections and 12,000 deaths and permanent disabilities in 2014, including 10,800 deaths and permanent disabilities in persons at elevated risk. Though 9000 of the estimated prevented deaths were from liver cirrhosis and cancer, mass vaccination programs have not, at this point, shown empirical impacts on the prevalence of those conditions. Future studies can refine these estimates, assess the impact of adjusting estimation assumptions, and consider additional risk factors that lead to heightened risk of permanent harm from infection.

Keywords: vaccination ; disease ; mortality ; disability ; risk

1. Introduction

To measure the benefit of a mass vaccination program targeting an infectious disease, it is useful to assess what the risk of death or permanent injury would be from the disease in the absence of the mass vaccination program. There is an abundance of medical literature detailing the risks associated with infectious diseases; however, the information is scattered through dozens of sources that are often lengthy and consider only a narrow scope of the risks involved. For example, some sources describe the symptoms of a disease without specifying how many patients fully recover [1]; other sources describe the number of deaths from an infection without addressing permanent disability in survivors [2][3]. Moreover, some sources do not account for the pre-vaccine rates of decline in mortality for some infectious diseases [3][4][5].

2. Discussion

Based on population data for 2014, it was estimated that mass vaccination programs against measles, mumps, rubella, tetanus, diphtheria, pertussis, polio, Hib, hepatitis B, varicella, and HPV could prevent 20 million infections and 12,000 deaths and permanent disabilities annually.

Individuals who have conditions or behaviors that would put them at higher risk of permanent injury from infectious diseases (e.g., insufficient vitamin A, absence of tonsils, breastfed <13 weeks, injection-drug use, and smoking) were found to comprise 90% (≈ 10,800/12,000) of all the estimated cases of prevented death and permanent disability, with the remaining 1200 cases in persons at normal risk (or with risk factors excluded from this report). It is possible that the high risk conditions described in this report might expose individuals to permanent harm from other causes. More research in this arena would be useful.

Pre-vaccine declines in mortality rates recorded for measles, tetanus, diphtheria, and pertussis were not unique to those infections. In the early 20th century, significant declines in mortality rates were recorded for numerous infectious diseases that were not targeted by mass vaccination programs, such as those for tuberculosis, syphilis, typhoid fever, and dysentery [6]. The human immune system is evidently remarkably efficient when coupled with treatments for severe cases of diseases, such as antibiotics and when not hampered by factors like poor nutrition, poor sanitation, or limited access to health care.

Mass vaccination programs are best known for preventing deaths and permanent disabilities that occur a relatively short time after infection. However, 75% (≈ 9000/12,000) of the estimated cases of death and permanent disability prevented in this report would be from conditions occurring much later in life—liver cirrhosis and cancer. Though hepatitis B and HPV are the causes of these conditions, the hepatitis B and HPV mass vaccination programs have not, at this point, shown empirical impacts on the prevalence of liver cirrhosis and cancer. In spite of the significant reduction in acute cases of hepatitis B, the prevalence of chronic hepatitis B has remained practically unchanged since 1976 [7]. As for the HPV vaccine, although the prevention of HPV infections that are necessary for the potential development of cancer has been observed [8], cancer protection has not yet been empirically documented and uncertainties remain. Among these, a minimum protective antibody titer has not been determined [8], and the duration of antibody response has only been measured for eight-to-nine years [9]. Since most HPV-attributable cancers occur in the population >50 years of age, it may be that to most successfully prevent HPV-attributable cancer, either an HPV vaccine needs to provide lifetime immunity or booster doses need to be introduced into the mass vaccination program.

This report had other limitations. The accuracy of our estimates depended on the quality of the available evidence concerning the risks and effects of the diseases, which could have been imperfect. In many instances, we projected to 2014 from statistics recorded decades earlier. The accuracy of such projections could have been affected by changes in the organisms targeted by vaccines, changes in host resilience, or changes in health care practices deviating from pre-vaccine trends, among other factors. In addition, inaccuracies can propagate from one estimate to another when an estimate is used to derive the other. For example, the case fatality rate of a disease is sometimes used to estimate the total number of cases of that disease based on its estimated number of fatalities. Another limitation was related to the potential aggregate impact of risk factors that were not considered in generating our estimates, either because they are (individually) less commonly implicated or are undiscovered or inadequately studied. The comprehensive consideration of such factors might shift more of the vaccine-averted deaths and disability to the high-risk category. The same limitations might apply to the long term effects of some of the diseases. It is also possible that relevant information was missed in our literature review. We sought to convey the challenges surrounding some of the available data in the discussion of each disease and have tried to be explicit about assumptions made. We explained our choices in relation to the application of pre-vaccine trends and in gauging expected disease outcomes as a function of whether an individual is at higher risk. Furthermore, this study only estimated the number of deaths and permanent disabilities prevented by mass vaccination programs. It did not consider similar outcomes that may be caused by these programs.

Despite these limitations, we believe this report employed the best processes among the available data and studies for estimating the numbers of deaths and permanent disabilities that would have occurred (here estimated for 2014) in the absence of mass vaccination programs. Though other studies have presented estimates of the benefits of mass vaccination programs, they have not accounted for disease risk factors, cases of nonfatal permanent disability, pre-vaccine trends in mortality, post-vaccine improvements in factors tied to disease outcomes resulting in improved case fatality rates in unvaccinated populations (such as improved nutrition, sanitation, hygiene, indoor temperature control, health care, and the treatment of disease), and adjustments of pre-vaccine estimates using data recorded after vaccine licensure [3][4][5]. Furthermore, some studies have not provided an explanation for the data used as the basis of their estimates [4][5]. We have tried to rectify these omissions in the present report.

3. Conclusion

Despite the decline in mortality rates of infectious diseases recorded since the late 19th century, the data in this report indicate that mass vaccination programs may still have prevented 20 million infections and 12,000 deaths and permanent disabilities in 2014. In addition, mass vaccination programs have reduced the burden on health services, hospitals, intensive care, and the economy caused by the diseases they target. Put another way, measuring the number of deaths and cases of permanent disability prevented by mass vaccination programs is not the only way to measure the benefit of those programs, as those benefits can also be measured by other outcomes such as hospitalizations or the economic burden associated with a disease. However, those outcomes may be more greatly influenced by a range of factors beyond the impact of the vaccine and the disease, such as shifts in approaches to and costs of hospitalization over time. Nonetheless, because such outcomes are generally a function of the morbidity and mortality of the disease, the data in this report might also be useful in generating estimates for those outcomes.

We believe this report provides a useful reference for the effect of mass vaccination programs on the most serious complications of the diseases they target. Future studies can seek to further refine these estimates and use these estimates in risk-benefit analyses.

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