

The ability of vaccines to protect others: Implications for vaccine mandates

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Abstract

Background: While the importance of vaccinations is currently undisputed, it remains legitimate to question whether vaccine mandates are consistent with respect for fundamental human rights. Vaccination mandates, in particular, limit one of the most intimate aspects of private life: The right to respect for bodily integrity. This restriction has often been justified by the need to protect others. In 2021, the European Court of Human Rights ruled in favour of compulsory vaccination for children. However, if the Court's decision had been based on the actual ability of vaccines to protect others, rather than on subjective value judgments, the outcome might have been different. Therefore, access to information about a vaccine's ability to protect others is crucial. To the best of our knowledge, this study is the only one that addresses this specific issue.

Methods: Vaccine efficacy, duration of protection and ability to prevent colonisation of mucosal membranes were all considered when assessing the capacity to protect others. Several official sources were consulted, including PubMed, the Cochrane Database, and the US Centers for Disease Control and Prevention, with priority given to systematic reviews.

Results: All inactivated vaccines (e.g., tetanus, diphtheria, acellular pertussis) have proven ineffective at efficiently blocking transmission of infection. Even live attenuated vaccines, such as the measles vaccine, have a considerable number of primary and secondary failures, leaving those who receive them at least partially susceptible to infection.

Conclusion: Vaccines are important preventive tools that primarily provide protection to individuals who receive them. However, given the uncertain ability of vaccines to protect others, compared to the clear sacrifice of a fundamental human right, this trade-off does not seem proportionate. A thorough assessment of a vaccine's capacity to protect others is essential when evaluating the appropriateness of vaccination mandates.

List of Abbreviations: ECHR: European Court of Human Rights; Hib: Haemophilus influenzae type b; HBV: Hepatitis B Vaccine; HZ: Herpes Zoster (shingles); IgA: Immunoglobulins A; IPV: Inactivated Polio Vaccine; MMR: Measles Mumps Rubella; NNV: Number Needed to Vaccinate; NP: Naso-Pharyngeal; OPV: Oral Polio Vaccine; R₀: Basic Reproduction Number; VZV: Varicella-Zoster Virus; WH1: Wuhan 1

Introduction

Vaccination is considered one of the greatest public health achievements of the 20th century and is believed to have saved more lives than any other medical intervention in history. While the importance of vaccinations is currently undisputed, it remains legitimate to question whether vaccine mandates are consistent with respect for fundamental human rights. Vaccine mandates involve limiting the right to bodily integrity, which is one of the most intimate aspects of private life (Article 8 of the European Convention on Human Rights), and thus require a justification proportionate to the sacrifice of that right.

The Constitutional and Supreme Courts of several Countries, as well as the European Court of Human Rights (ECHR), have justified this limitation on private life in the interest of protecting public health and the rights of others. Vaccination, they argue, protects both those who receive it and those who cannot be vaccinated for medical reasons, who rely on herd immunity for protection against contagious diseases. However, courts have not always thoroughly evaluated the actual ability of vaccines to protect others. For example, in the case of *Vavříčka and Others vs. the Czech Republic*, a dissenting opinion within the Court argued that the ECHR's ruling was based more on value judgments-such as a general trust in herd immunity-than on precise and comprehensive scientific data regarding the diseases and vaccines in question [1]. One consequence of the ECHR's en bloc value-based decision was

the legitimization of the tetanus vaccine mandate, despite the fact that tetanus is not transmissible from person to person. Therefore, the tetanus vaccine does not provide indirect protection to the community. Unnecessary government interference in the private sphere can cause psychological distress among citizens. To avoid imposing unnecessary obligations, it is essential to assess the actual ability of each vaccine to protect others.

This study examines the effectiveness of 15 widely used vaccines in preventing transmission: Tetanus, diphtheria, polio, pertussis, pneumococcus, Haemophilus influenzae type B, hepatitis B virus, meningococcus C, meningococcus B, measles, mumps, rubella, varicella, influenza, and COVID-19. To the best of our knowledge, there is currently no single document that compiles up-to-date, easily accessible information on this topic.

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Materials and methods

In analyzing the effectiveness, duration of protection, and ability to prevent transmission of the 15 vaccines studied, systematic reviews were prioritized, with preference given to those based on randomized controlled trials. Additional information was gathered from various scientific sources, including PubMed, the World Health Organization (WHO), the U.S. Centers for Disease Control and Prevention (CDC), and the Italian Istituto Superiore di Sanità (ISS). While studies from the past 20 years were primarily considered, some older milestone studies were also included to provide historical context. A few studies were not published in peer-reviewed journals but they were conducted by reputable institutions or scientists.

Here the broader term "protection of others" is preferred to "herd immunity." Herd immunity refers to a specific threshold proportion of immune individuals that leads to a decrease in the incidence of infection. According to the herd immunity theory, the incidence of infection decreases if the proportion of immune individuals exceeds $(R_0 - 1)/R_0$ (or $1 - 1/R_0$), where R_0 is the "basic reproduction number"-the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection [2]. This theoretical model assumes that the population mixes randomly and that immunity is randomly distributed, without other public health interventions (e.g., isolation, education). The herd immunity threshold has been used as a target for immunisation [3,4].

In assessing the ability of vaccines to protect others, factors such as vaccine effectiveness, duration of protection, and the ability to prevent colonisation of the mucous membranes were considered. If vaccine effectiveness is below $(1 - 1/R_0)$, eliminating an infection becomes impossible, even if the entire population is vaccinated [4]. Similarly, waning vaccine-induced immunity necessitates regular booster vaccinations or higher levels of coverage. If a vaccine allows pathogens to colonise the mucous membranes, transmission of infection will continue, meaning there can be no protection for others. Ability to protect others was assessed using the following scale: a) certain/complete, b) uncertain/incomplete (presence of consistent primary and secondary failures in the field), c) little/insufficient (in addition to previous point, the vaccine does not effectively prevent transmission or there is a shift towards non-vaccinable strains) and d) none.

Terminology: Mandatory or compulsory vaccination?

The terms "mandatory" and "compulsory" vaccination should not be treated as synonymous. While both imply restrictions imposed by rule or law, there is a subtle yet important distinction. Mandatory vaccination implies that those who choose not to be vaccinated will only face a fine, without further penalties. Compulsory vaccination, on the other hand, suggests that individuals may be forced to get vaccinated. We should not limit the meaning of "compulsory vaccination" solely to cases involving forced actions or criminal sanctions, such as imprisoning parents who refuse to vaccinate their children. Deprivation of fundamental rights, such as the right to work or to education, should also be considered a form of coercion, and in such cases, the term "compulsory" vaccination should be used rather than "mandatory."

Results

Table 1 summarises the effectiveness, duration of protection, and ability of the most common vaccines to protect others.

Tetanus

Tetanus vaccines produce antibodies against the toxin of *Clostridium tetani*. As a result, the tetanus toxoid vaccine does not affect the presence of clostridia, which remain ubiquitous and typically enter the body through poorly vascularised wounds with necrotic tissue. While the individual is protected from the harmful effects of the tetanus toxin, a person with tetanus is not infectious. Therefore, the tetanus vaccine cannot in any way protect the community.

Diphtheria

Diphtheria vaccines produce antibodies against the toxin of *Corynebacterium diphtheriae*. Diphtheria toxin is thought to help the bacterium invade the body, so the diphtheria toxoid vaccine protects the individual from symptomatic disease but does not prevent mucosal colonisation or transmission. Vaccination alone interrupts transmission in only 28% of outbreak settings, making isolation and antibiotics essential during epidemics [5]. The WHO recommends a three-dose primary vaccination series with a diphtheria-containing vaccine, followed by three booster doses. These booster doses should ideally be given during the second year of life (12-23 months), at ages 4-7 years, and 9-15 years. After this, protection wanes over time, leaving most

Table 1. Effectiveness, duration and protection of others of most common vaccines

Vaccine	Effectiveness	Duration of protection	Protection of others
Tetanus (toxoid)	90% (3 doses)	Recommended booster dose after 10 years	None
Diphtheria (toxoid)	87% (3 doses)	Antibody levels decline by 0.8% per year	Insufficient
IPV	99% (3 doses)	?	Insufficient
Pertussis (acellular)	41%-85 %	10%-12% decline annually	Insufficient
Pneumococcus	57% (against NP carriage)	5-10 years	Insufficient
Haemophilus influenzae B	93% with three doses against confirmed Hib; 4% against clinical pneumonia	?	Insufficient
HBV	90% [29]	15 to 50% susceptible 5 to 15 years after vaccination	None (contagion only with blood or sexual intercourse)
Meningococcus C (ACWY)	69% [30]	1-5 years	Insufficient
Meningococcus B (4CMenB)	75% [30]	1-2 years	Insufficient
Measles	96% (2 doses)	33% may be susceptible after 20 years	Uncertain
Mumps	86% (2 doses)	Declining protection after 5-10 years	Uncertain
Influenza	40%-60% *30 NNV to avoid an influenza	3 months	Insufficient
COVID-19 mRNA	91% against WH1; very low against omicron sub-variants	3-6 months	Insufficient

Note: *reduction of risk of flu illness during seasons when most circulating flu viruses are well-matched to those used to make flu vaccines. **Abbreviation:** NNV: Number Needed to Vaccinate; IPV: Inactivated Polio Vaccine; HBV: Hepatitis B Vaccine; NP: Naso-Pharyngeal; WH1: Wuhan 1.

adults over the age of 40 unprotected. Since the 1990s, very few cases of diphtheria have been documented. However, in 2017, a diphtheria epidemic occurred among Rohingya refugees in the Kutupalong camp in Bangladesh due to poor sanitation, low socio-economic conditions, and a disruption of childhood vaccinations. Vaccination alone could not control the epidemic, and isolation and antibiotic treatment were necessary. Truelove et al. raised concerns about the overvaluation of the efficacy of the diphtheria toxoid vaccine: "Past research central to our understanding of diphtheria epidemic dynamics made inappropriate assumptions, including that vaccination confers immunity against colonisation, immunity is lifelong and does not wane, and only symptomatic individuals are infectious. This resulted in flawed estimates of key epidemiologic and disease control measures" [5].

Poliomyelitis

The Inactivated Poliovirus Vaccine (IPV) replaced the Oral Poliovirus Vaccine (OPV) in Western countries in the late 1980s, after cases of wild poliovirus were no longer detected. Although rare, OPV could cause poliomyelitis, and with no cases of wild poliovirus, continued use of OPV could no longer be justified. However, IPV does not prevent the colonisation of the intestinal mucosa by poliovirus, allowing the virus to be spread by vaccinated individuals [6].

Pertussis (Whooping cough)

Whooping cough remains one of the worst-controlled vaccine-preventable diseases globally [7]. Since the 1990s, whooping cough has resurged in highly vaccinated populations. According to a 2014 Cochrane review, the effectiveness of the acellular pertussis (aP) vaccine ranges from 41% to 85%, depending on the study design [8]. The duration of protection varies between 1 and 8 years, depending on the studies. The whole-cell pertussis vaccine was more effective but had a poor safety record and was replaced in Western countries by the acellular pertussis (aP) vaccine in the mid-1990s. The aP vaccine is active against *Bordetella pertussis* but not against *B. parapertussis*. Studies in primates have shown that pertussis vaccines do not prevent airway colonisation or transmission [7]. Due to its short duration and weak immunity produced, the aP vaccine cannot provide herd immunity [3]. Therefore, alternative strategies, such as education, early diagnosis, adequate isolation (at least 3-4 weeks), antibiotic treatment, and strengthening of cellular immunity, are needed.

Haemophilus influenzae and pneumococcus

Haemophilus influenzae type b (Hib) is present on the mucous membranes of the upper respiratory tract in 2%-5% of asymptomatic children. Hib is a leading cause of meningitis in children aged 0.1 to 5 years and occasionally causes pneumonia in children and adults. *Streptococcus pneumoniae* (pneumococcus) is present in the upper respiratory tract of up to 65% of asymptomatic children and around 10% of healthy adults. Pneumococcus is the most common bacterial cause of childhood pneumonia, especially in children under 5, and is the second leading cause of meningitis in adolescents. In adults, pneumococcus accounts for 10%-30% of community-acquired pneumonia. Both pneumococcus and Haemophilus influenzae are considered opportunistic pathogens that take advantage of weakened immune defences to invade the body. Antibacterial vaccines are effective at controlling specific bacterial strains but cover only a small fraction of the vast diversity of bacterial strains. As a result, "replacement" strains that are not susceptible to the vaccine can emerge. Pneumococcal vaccines are effective against a maximum of 23 strains out of a total of 94, and a shift towards strains not covered by the vaccine has been observed. In Germany and Japan, vaccination against pneumococcus did not reduce the incidence of pneumonia [9,10], and vaccinating

children has not provided benefits to the elderly [10]. There are six serotypes of *H. influenzae* (a-f), as well as non-typeable strains, but the vaccine only targets *H. influenzae* type b. Following widespread immunisation against Hib, there has been a decline in invasive diseases caused by *H. influenzae* type b, but this has been accompanied by an increase in invasive diseases caused by other *H. influenzae* types [11].

Measles, Mumps, and Rubella (MMR)

In the 1970s, measles was considered a minor concern in high-income countries, thanks to widespread improvements in living standards and nutrition. Nevertheless, many countries began elimination programmes through vaccination. Despite these efforts, several measles outbreaks have occurred in highly vaccinated populations [12]. Measles vaccination was introduced with the expectation that it would confer lifelong immunity, similar to natural infection. However, the protection it offers has proven to be short-lived in many cases. LeBaron et al. [13], in a post-elimination study, found that 4.7% of vaccinated individuals were potentially susceptible ten years after their booster dose (antibody titre ≤ 120 mIU/ml), with 20-year projections showing up to 33% of individuals becoming susceptible [13].

While vaccine refusal is often highlighted as a cause of measles outbreaks, vaccine failure is equally significant but has received less attention. Primary failure, in which no protective antibodies are formed after vaccination, occurs in 2%-10% of cases, even after two doses. Secondary failure, where immunity wanes over time, can result in additional infections. For example, during the 1989-1991 measles outbreak in the U.S., 20%-40% of those affected had already received one or two vaccine doses [12]. More recent examples of measles vaccine failure, with rates ranging from 7% to 20%, are reported in the medical literature [14]. Vaccinated mothers, unlike those who have had natural infections, do not transmit sufficient antibodies to protect newborns during the first six months of life. Poland and Jacobson have questioned whether it is time to develop a more effective vaccine [12]. The mumps vaccine reduces the severity of the disease and helps prevent complications, but it does not typically provide complete sterilising immunity, meaning that some vaccinated individuals may still become infected. A systematic review estimated the vaccine's effectiveness in preventing cases among household contacts to be 74% (RR= 0.26, 95% CI: 0.13-0.49) [15]. Due to the short duration of protection, susceptibility to mumps and rubella may simply be postponed. Mumps can be dangerous for males after puberty due to its potential to cause sterility, and rubella poses a risk for pregnant women, as it can cause birth defects in the developing foetus.

Chickenpox (Varicella)

Varicella is usually a mild disease, resolving in 7 to 10 days in most cases. After primary infection, either from wild or attenuated virus, the Varicella-Zoster Virus (VZV) becomes latent in cranial nerves, dorsal-root, and autonomic ganglia throughout the body. When VZV immunity declines below a certain threshold, it may reactivate as Herpes Zoster (HZ), characterised by pain and typical skin lesions (vesicles) confined to one to three adjacent dermatomes on one side of the body. In 20%-40% of cases, HZ can result in persistent debilitating pain (post-herpetic neuralgia), and HZ contributes to three times the morbidity and five times the mortality of varicella, with an HZ-to-varicella cost ratio of over 4 to 1 [16]. Universal childhood immunisation with the varicella vaccine led to a significant reduction in cases of chickenpox. However, a study of 300,000 residents in Antelope Valley, California, showed that the vaccine's effectiveness waned, leading to dangerous outbreaks of chickenpox in adults. Other studies confirmed an increased incidence of HZ in both children and adults following the introduction of universal varicella vaccination [16].

In some countries (e.g., the USA and Italy), varicella vaccination is mandatory, and it is included in national vaccine schedules elsewhere. However, since periodic re-exposure to the wild varicella virus plays a crucial role in boosting immunity and suppressing HZ reactivation, mandatory chickenpox vaccination may cause more problems than it solves for the community by reducing natural immune boosting. A limited vaccination strategy, allowing the wild VZV to circulate, could yield better outcomes in terms of vaccine longevity and reduction in HZ cases [16]. Therefore, mandatory vaccination for chickenpox does not seem justified at present.

Influenza

The effectiveness of the flu vaccine in healthy adults and the elderly is modest, reducing the risk of flu illness by 40%-60% during seasons when the circulating viruses are well-matched to those used in the vaccine. For people aged 65 and over, 30 individuals need to be vaccinated to prevent one case of influenza A or B [17]. Over 200 viruses can cause influenza-like illness, with symptoms such as fever, headache, body aches, cough, and runny nose. Flu vaccines are only effective against influenza A and B, which make up approximately 5% of all respiratory viruses in circulation.

In some states, hospitals require influenza vaccination for employees. However, a Cochrane review found that vaccinating healthcare workers in long-term care facilities for people aged 60 and over may have little to no effect on laboratory-confirmed influenza cases [18]. There is no clear evidence that influenza vaccination can prevent household transmission [19].

COVID-19

The mRNA COVID-19 vaccines serve as a notable example of how overestimating a vaccine's ability to stop transmission led to unnecessary mandates. The early pandemic belief that "no one is protected until everyone is vaccinated" was widespread. However, the mRNA COVID vaccine's risk management plan never stated that the vaccine could block transmission, as Phase III trials were not designed to measure that endpoint. Vaccinated individuals contracted COVID-19 at the same, if not higher, rates as unvaccinated individuals, based on antigen testing positivity rates [20]. COVID-19 vaccines induce low levels of IgA and are therefore unable to provide strong mucosal protection [21]. Additionally, the mRNA vaccines offer short-lived protection [22], and may create selective pressure, potentially leading to the development of resistant variants. Despite Italy's compulsory vaccination for healthcare workers, teachers, police officers, and those over 50-which required a COVID certificate for access to work, as well as to care homes, restaurants, and all sports and leisure activities-Italy saw no better health outcomes in terms of COVID mortality rates or excess deaths than Sweden, which had no mandates and a similar vaccination rate. In many countries, younger people were compelled to be vaccinated to attend university or participate in sports or work activities, even though the risk-benefit assessment of mRNA vaccines was unfavourable for this age group [23].

The pharmacokinetics of mRNA vaccines are not yet fully understood (e.g., the quantity of spike protein produced, its location, and duration) [24]. As it is well known, any compulsory medical intervention involving experimental drugs contradicts the Nuremberg Code and subsequent bioethics treaties.

Discussion

Mandatory or compulsory vaccination is a widely used strategy. In 2018, 105 countries (54%) out of a total of 193 had a vaccination

requirement for at least one vaccine: 43 nations imposed restricted access to education, and in 12 countries, those who refused vaccination were imprisoned [25]. Mandatory or compulsory vaccination, as an imposed medical intervention, constitutes an interference with the right to freedom of choice regarding one's own body, the most intimate aspect of private life. Such an obligation is justified if the vaccine not only protects those vaccinated but also safeguards the community, particularly those who cannot be vaccinated for medical reasons and are therefore reliant on "herd immunity" for protection. However, most inactivated or "dead" vaccines, such as diphtheria, tetanus, acellular pertussis, Hib, pneumococcal, and inactivated polio, are unable to efficiently block the transmission of infection, and consequently, they do not protect others. Doubts are also expressed regarding the ability of "live" attenuated vaccines to adequately protect others, as measles vaccine failure can be as high as 20%-40% in real life [26].

In this study, the term "protection of others" was used because it is more comprehensive than "herd immunity" (see Methods). In determining "protection of others," vaccine efficacy, duration of protection, and ability to prevent mucosal colonization were considered, whereas herd immunity refers only to the percentage of immune individuals in a community who can provide indirect protection once a certain threshold is reached.

Herd immunity thresholds (which align with vaccination coverage thresholds) are calculated using a mathematical formula based on the basic reproduction number (R_0), i.e., the average number of secondary cases generated by a single infected individual in a fully susceptible population. Although R_0 may appear to be a straightforward measure of infectious disease transmission dynamics, its calculation relies on complex mathematical models, making it prone to misinterpretation. R_0 is influenced by numerous biological, behavioral, and environmental factors that govern pathogen transmission [2].

Likewise, the herd immunity threshold theory, which relies solely on R_0 , has significant limitations. It does not account for critical factors that can reduce the spread of infection, including public health interventions, socioeconomic determinants, and the role of the innate immune system in combating viral infections. According to the herd immunity threshold formula, if primary and secondary failures of the measles vaccine exceed 8.4% (assuming an R_0 of 12), eliminating the infection would be impossible, even with full population vaccination. However, real-world experience differs significantly. For example, in the wealthy province of Bolzano, Italy, in 1998, despite a measles vaccination coverage of only 28% at 24 months of age, public health interventions-such as early case identification, isolation, and contact vaccination-proved effective in containing measles outbreaks [26]. In contrast, in Sub-Saharan Africa, measles epidemics continued to occur despite vaccination coverage exceeding 90% [3].

Are current vaccination coverage targets unnecessarily high for high-income countries? A problem arises when herd immunity thresholds are equated with vaccination coverage targets. In this way, immunization targets may be overestimated, as only vaccinated individuals are considered protective for the community, while other critical factors such as natural immunity, socio-economic determinants and public health measures are ignored. It is important to remember that the dramatic reduction in morbidity and mortality from infectious diseases in high-income countries over the last two centuries cannot be attributed solely to vaccines, as routine paediatric vaccinations were introduced only after the Second World War. The reduction in infectious diseases is better explained by a combination of improved socioeconomic conditions and public health measures such as water treatment, food safety, organized solid waste disposal, and public

education about hygiene measures [27]. The claim that vaccines have saved more lives than any other intervention in history finds little supporting evidence in high-income countries [28]. As a result, establishing precise immunisation thresholds is challenging, given the wide margins of tolerance observed in high-income countries. Keeping this in mind, the accusation that the unvaccinated person can be a danger to others is unfounded.

Final observations

A 2022 WHO document, COVID-19 and Mandatory Vaccination: Ethical considerations, drafted by the COVID-19 Ethics and Governance Group, acknowledges the possibility of enforcing vaccination not only to protect others but also “to preserve the capacity of acute health care systems or other critical infrastructures”. Firstly, depriving individuals of basic human rights for economic reasons is ethically unacceptable, especially when policymakers fail to adequately fund the healthcare system to ensure its resilience. Furthermore, the claimed necessity of keeping hospital beds free for non-preventable diseases remains largely theoretical and requires substantiation. Most common childhood infections can be managed at home, with hospitalization needed only in rare cases of complications. In the event of new epidemics, by the time vaccines become available, viral diseases typically become less lethal, and the pressure on healthcare facilities subsides. Hospital burden can also be alleviated through appropriate home treatments, as observed during the COVID-19 pandemic. Vaccine refusal remains limited to a small percentage of the population (around 5% in Italy and 10% in the USA and UK for the MMR vaccine among children under two). The necessity of mandatory vaccination is further challenged by a European study, which found no clear association between vaccination mandates and childhood immunization rates across European countries (ASSET Reports, 2016). Finally, if we are concerned for the immunocompromised, passive immunisation with immunoglobulins (e.g., for measles virus) is available in case of close contact with contagious individuals.

Conclusion

Vaccine mandates, which involve the sacrifice of a fundamental human right, are generally justified with the goal of protecting public health. However, as shown here, most vaccines provide no or uncertain protection to others. Consequently, most vaccine mandates cannot be justified: The full loss of a fundamental human right in exchange for, at best, uncertain protection does not appear proportionate. Vaccines are important preventive tools that primarily protect the individuals who receive them. However, it is crucial to rigorously assess the actual effectiveness of each vaccine in protecting others to avoid imposing unnecessary vaccination mandates.

Conflicts of interest

I hereby declare that there are no conflicts of interest associated with this article.

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