Anti-vaccination: Past, Present, and Future Toll on Public Health

Antivakcinacija: praeities, dabarties ir ateities nuostoliai visuomenės sveikatai

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Summary

The toll of anti-vaccination in the public sphere is wide reaching and severely impactful. From continuing outbreaks of cases in communities previously thought to have eliminated the disease, the heightened demand of health care facilities, to the enormous economic burden that is brought on by these outbreaks. Although preventable via wide-spread use of vaccination, the increasing frequency of disease outbreaks is proving to be a major issue for healthcare systems worldwide. These problems are large in scope, and with the increase of skepticism towards healthcare and government officials via aggressive misinformation networks, along with the abandonment of the paternalistic model in patient- physician relationships are proving to be a major burden on medical systems worldwide. With the growing influence of social media in the public discourse, platforms such as Facebook and Twitter provide a host for multitude of vaccine critical outlooks and prove to be difficult to manage especially heading into the future. This paper aims to highlight three timeframes via a focus on the impact of anti-vaccination in their perspective disease: the role of anti-vaccination in its early start as panic towards the importation of foreign medical procedures as a preventative tool for smallpox outbreaks, the modern battle against MMR vaccine misinformation and its consequences, to the future of the problem approaching the era of postCovid life and the potential of future global pandemics along with potential biological warfare and its consequences.

Keywords: anti-vaccination movement, misinformation, vaccination.

Santrauka

Viešojoje erdvėje prieš skiepijimą nukreipta informacija yra plačiai paplitusi ir daro didelę įtaką visuomenei. Besitęsiantys infekcijų, kurios, kaip manyta, jau buvo išnykusios, protrūkiai bendruomenėse lemia padidėjusią sveikatos priežiūros įstaigų paklausą ir milžinišką ekonominę naštą. To galima išvengti plačiai naudojant vakcinas, tačiau vis didėjantis ligų protrūkių dažnis yra pagrindinė sveikatos priežiūros sistemų problema pasaulyje. Šios problemos yra didelės apimties, be to, didėjant skepticizmui prieš sveikatos priežiūros ir vyriausybės specialistus per agresyvius dezinformacijos tinklus, taip pat apleidžiant paternalistinį paciento ir gydytojo santykių modelį, daroma didelė našta medikams. Didėjant socialinių tinklų įtakai viešojoje erdvėje, įvairiose platformose, pavyzdžiui, *Facebook* ir *Twitter*, matoma daugybės svarbių vakcinų ateitis, kuri rodo, kad ligas bus sunku valdyti. Šiuo straipsniu siekiama pabrėžti 3 laikotarpius, sutelkiant dėmesį į antivakcinacijos poveikį ligų paplitimui: kovos su vakcinacija vaidmuo pradžioje kaip panika dėl užsienio medicininių procedūrų, tokių kaip raupų protrūkių prevencinės priemonės, importo, šiuolaikinė kova su MMR vakcina, dezinformacija ir jos padariniai bei problemos pokovidiniu laikotarpiu, kurios turės įtakos būsimų pasaulinių pandemijų potencialui, kartu su galimu biologiniu karu ir jo padariniais.

Raktažodžiai: antivakcininis judėjimas, dezinformacija, vakcinacija.

Introduction

The growing trend of anti-vaccination attitudes is an issue that is becoming more and more pressing to the global medical community. Vaccination is the process of providing immunity via a specially prepared antigen administered to a person [1]. As safe and effective vaccine methods are becoming more accessible to the world population, there seems to always be a pushback from certain sects of society. Although interest groups disregarding the validity of vaccination have been present since the time of the smallpox vaccine, the trend of skepticism towards vaccination seems to be at its most potent now. Whether it comes from the online spaces of Twitter or Facebook, or

news organizations validating the anti-vaccination position on the same scientific and ethical basis than that of vaccination, anti-vaccination attitudes are becoming a major issue affecting healthcare systems worldwide. This paper aims to focus on three viral epidemics across modern human history along with the public response to vaccination efforts and the effect that it had on disease occurrence and elimination. The goal of the paper is to evaluate the trend of anti-vaccination and the resulting effect that it has on disease control. A historical overview is significant in its ability to compare the phenomena of anti-vaccination as compared to different diseases in different points in time. The diseases and their vaccination that will be the topic of discussion are smallpox, measles, and COVID-19.

Methods

The information for this paper was obtained via a broad search across sources providing medical articles, including PubMed, Google Scholar, Medscape, along with using the references used by theses medical articles to expand on their work. The key search words being *anti-vaccination*, *impact, effect, consequences, toll* along with the disease specifics such as *smallpox, measles, COVID-19*. The historical aspects of the paper were provided via written literature specific to the diseases discussed. Relevant information was further extrapolated on via news articles, publications and organizations focused on the disease-specific or vaccination-specific discussions.

Literature review

Past

Smallpox is the commonly referred name of the *variola* virus in its *major* subtype which has a fatality rate between 30–40% in those infected, while the minor subtype has a fatality of >1% [2]. Because of the significantly higher mortality rates of the variola major subtype of the virus, smallpox will most commonly be used as the name for the disease due to the widespread danger and its historic context, however it can refer to either subtypes, major or minor. *Sherris & Ryan's Medical Microbiology (8th Edition)* describes the virus:

Smallpox or variola virus is a poxvirus with a double-stranded linear DNA genome and a lipoprotein envelope that replicates in the cytoplasm by using its own viral RNA and DNA polymerases. Smallpox virus enters through inhalation and replicates in the upper respiratory tract epithelium, spreads to the regional lymph nodes, infects phagocytic cells followed by development of viremia and dissemination to various organs such as liver, spleen, and skin. Eosinophilic inclusions called Guarnieri bodies can be seen in the cytoplasm. Viral proteins such as complement regulatory and immunomodulatory proteins interfere with activities of Th1 response, cellular cytokines, chemokines, and other immune mediators. Enormous inflammatory responses were also accountable for main characteristics of illness. The incubation period is 12 to 14 days (occasional fulminant case; 4–5 days). Clinical manifestations are fever, chills, and malaise preceding lesions after 4 to 5 days. A dominant feature is a uniform papulovesicular rash that evolves to pustules over 1 to 2 weeks. Vesicles appear on face, arms, and lower extremities (all at the same time). Some cases are fulminant with a hemorrhagic rash. Complications include keratitis, encephalitis, pneumonia, and bacterial superinfections.

Vaccines, despite being perceived as a generally new advancement in the field of medicine, have been in the public conscience in one form or another for more than 400 years. One of the earliest forms of recorded variolation dates to 1500s China, where the dried scabs of smallpox pustules were nasally inhaled to inoculate the patient [3]. The very first instance of mention of smallpox inoculation in China was by author Wan Quan (1499–1582) in his *Douzhen xinfa* (痘疹心法) published in 1549 [4]. This practice spread throughout China during the Ming dynasty under Emperor Longqing (1567–1572) [5] and spread further west to the Ottoman Empire.

One of the first recoded instances of successful smallpox inoculation being brought to western Europe was via Mary Wortley Montagu, a British aristocrat and writer who spent time in the Ottoman Empire in the 1710's. Losing a brother to the disease in 1713, and surviving it herself, being left with facial scars, Lady Mary Wortley Montagu was exposed to the practice of what she called engrafting while spending time learning Turkish customs in religion-segregated housing in Constantinople known as *zenanas* [6]. The practice involved scraping the pus from an infected smallpox blister onto the arm or the leg of the uninflected individual [7]. This would result in a disease course much less severe than that of a normal smallpox infection [8]. In April of 1718, Montagu had the Embassy surgeon Charles Maitland perform the engrafting procedure on her fiveyear-old son, Edward, motivated to protect her child after seeing the benefits of the inoculation during her travels [9].

Upon her return to England, the Lady Montagu was an outspoken proponent of the medical practice, however, she was met with skepticism from the medical community due to the perception of the practice being performed by *illiterate old Greek and Armenian women* [10]. The backlash being severe enough to stop the Lady Montagu from inoculating her small daughter; that is, until 1721, when a vicious outbreak of the smallpox was targeting England [11]. With the help of surgeon Charles Maitland, the daughter of Lady Montagu was inoculated in a rather wellpublicized event, with many renowned physicians and upper-crust ladies in attendance. This experiment piqued the interest of at the time Princess of Wales, Caroline. The Princess, in August of 1721, permitted a group of seven prisoners at Newgate Prison in London to receive the inoculated in place of execution. All seven prisoners were released after surviving the experimental procedure [12]. Seeing the success of the operation, the Princess had her two daughters, Amelia and Caroline inoculated in April 1722 by surgeon Claudius Amyand.

At this time a general skepticism around the new practice was begging to gain momentum, with the conservative party (Torys) members and church leaders being openly against the foreign practice. This led to a media battle in newspapers and pamphlets, with criticism and defense of the practice being frequently discussed; and religious leaders such as Reverend Edmund Massey weighing in about the unnatural and dangerous procedure. The Reverend argued the practice was one of superstition and fatalism, criticizing vaccination as a being antithetical to a belief in a higher power [13]. The misinformation of the procedure led to a suboptimal process of inoculation. Classically (as performed in the Ottoman Empire) the procedure involved a period of self-isolation after the application of the infected material, along with a small dosing. This was however done incorrectly by ill-informed English physicians who took to blood letting their patients for the procedure, along with de-emphasizing the importance of the self-isolation period that should take place. This led to an increased spread of the disease, along with casualties from the extreme bloodletting involved.

Lady Montagu herself was on the frontlines of the public discourse, often visiting ill patients and speaking to the parents of those suffering. In September of 1722, the Lady Montagu wrote an essay under a pseudonym defending the practice. Being so outspoken made her an open target for the growing skeptic movement who were vindicated in the views, seeing a growing spread of the disease along with increased casualties from the suboptimal approach practiced by English physicians. Lady Montagu's prominence pushed her to the front of the controversy, with skeptic voices spreading enough where the common individual saw her *as an unnatural mother* who gambled with her children's lives [14]. Prominent figures at the time, including physician William Wagstaffe, were lamenting the royal family's acceptance of a practice attributed to *a few ignorant women*. On the topic, Wagstaffe wrote about the inoculation as *a method totally strange to English constitutions, imported from an illiterate and unthinking People*, living in a warm climate, but *on a spare Diet, and in the lowest manner, almost without the common Necessaries of Life* [15].

Not all efforts were in vain however, as word of the practice continued to spread throughout Great Britain and its isles' medical community into the 18th century. From Halifax Yorkshire's Thomas Nettleton [16] to the Shetland Isles' Johnnie Notions [17], a growing usage of the smallpox inoculation method was being spread through England. A significant proponent of the smallpox inoculation was a surgeon from Suffolk, Robert Sutton, who set out to perfect the procedure following the death of a son due to complications from the inoculation [18]. Sutton discovered that the optimal approach was not too dissimilar to the one practiced in the Ottoman Empire, with shallow cuts into the epidermis to deliver the infected pus, selecting mildly symptomatic donors, and no usage of bloodletting. This method was highly secretive, as Sutton kept the method to himself and his three sons. However, setting up inoculation clinics with franchisees being given the secret proved to be extremely successful, with as many as 300,000 successful inoculations being performed by the year 1770 [19].

As England was facing its first historic struggle with vaccination, in the United States, a similar battle was being waged in Boston. On April 22, 1721, a British passenger ship HMS Seahorse arrived in Boston from Barbados [20]. The ship carried a crew of sailors exposed to the smallpox virus, and customs officials (experienced with coping with the disease from the previous year) sent the affected men to quarantine on a hospital established on Spectacle Island [21]. Despite the efforts to contain the disease, a single individual on board infected the crew the following day, leading to at least three infected individuals being found on board by a Bostonian water bailiff before the orders arrived for the ship to leave the harbor [22. Despite the efforts to quarantine the ill sailors in an isolated lodging, nine sailors were infected and became symptomatic in May 1721. The nine were quarantined at the hospital on Spectacle Island, however, the spartan conditions and lack of proper care led to the spread of the disease further out into Boston by the end of May 1721 [23].

The population was especially vulnerable due to the previous outbreak occurring in 1703, with younger age individuals being particularly at risk due to the limited immunity in that demographic. By June 1721, the disease was widespread enough to be the most significant public health crisis at the time [24]. The panic spread in the public well enough for religious leaders to regard it as divine punishment, and up to 900 individuals fleeing the city to the countryside in panic, spreading the disease further out into the rural areas [25]. The endemic's toll on the public peaked in October of 1721, with at least 400 casualties being recorded by The *New England Courant* newspaper [26]. According to some estimates, 8% of Boston's population died from the smallpox outbreak, and hundreds were left scarred, disfigured, and disabled [27].

The epidemic's toll on the city led Puritan clergyman and writer Cotton Mather to take steps to bring inoculation to the harrowed city. A prominent intellectual and leader in colonial Massachusetts, Mather was key in ousting King James II appointed governor Edmund Andros from the colony [28]. Mather was notorious for his leadership position during the Salem Witch Trials of 1692, along with publishing *The Wonders of the Invisible World*, his defense of the persecution as securing God's blessings for his colony [29] (a derivative of the concepts brought forth in Joseph Glanvill's *Saducismus Triumphatus*). Mather, having been exposed to the concept of inoculation in 1715 or 1716 from Onesimus, his gifted African slave, was intrigued with the concept. Onesimus is believed to be inoculated against smallpox at some point before coming to the city of Boston via the West Indies [30]. Due to the connection of African slave trade via the Caribbean, many slaves such as Onesimus arrived at the Colonies inoculated, letting the practice be spread to the New World. Having read the accounts of Emmanuel

Timoni, the Great British ambassador in Turkey who also witnessed a procedure like that described of Onesimus, Mather was convinced. In a 1716 letter to the Royal Society of London, Mather wrote:

Enquiring of my Negro-man Onesimus, who is a pretty Intelligent Fellow, Whether he ever had the Small-Pox; he answered, both, Yes, and No; and then told me, that he had undergone an Operation, which had given him something of the Small-Pox, and would forever preserve him from it, adding that it was often used among the Guramantese, & whoever had the Courage to use it, was forever free from the Fear of the Contagion. He described the Operation to me, and showed me in his Arm the Scar.

Believing smallpox to be a form of God's punishment, and the cure as *God's providential gift*, Mather followed the medical advice of Onesimus [31]. Mather's other motivation was to win back the influence among the New England society and regaining political power for religious figures [32]. In 1721, Mather wrote to 14 physicians in Boston, asking them to take up the mantle and inoculate their patients and workers [33]. The response to Mather was not positive, with all corners of high society exhibiting extreme skepticism. From the clergy and city officials, down to the normal man on the streets, the attitude was that inoculation would facilitate spread of the disease, along with being against divine providence. Being that Mather was advocating for an African practice, there was also a high degree of suspicion of the fact that the procedure was enabling African slaves to overthrow white society via poisoning masked as inoculation [34]. There was a marked skepticism of Mather due to the historic context of fear of conflict and conspiracy arising in the last part of the century in Boston. These fears escalated, and mob justices took hold of Boston, as inoculated individuals were forced out of the city and onto Spectacle Island's quarantine home. Following the inoculation of his nephew, Mather housed him during his recovery; hearing of this, a mob formed outside Mather's home, throwing a makeshift explosive through the window into the resting boy's room [35]. Although failing to go off, the bomb contained a note of harsh words towards Mather and his championing of the inoculation.

Of the 14 physicians Mather wrote to, only one, named Zabdiel Boylston, of Harvard University, took the call to action. On June 26, 1721, Boylston preformed the first inoculation in the colony on his six-year-old son, Thomas, his 36-year-old slave, and the two-year-old son of the slave [36]. All 3 survived the procedure with minor symptoms and no long-term side effect or damage. This bolstered the physician's confidence toward the procedure and over the next five months of the outbreak would lead to 247 individuals in the Boston area to be inoculated with 6 casualties (around 2%) [37]. This margin of error was fuel for the fire for skeptics at the *New England Courant* newspaper to attack Boylston. Among them, William Douglass, a physician who opposed Mather's procedure, believing that only educated physicians had a say in such dangerous practices [38]. Boylston was the target of many attacks from the newspaper doubting his validity as a physician from the likes of Douglass and others [39]. As controversy spread and word got around of Boylston's inoculation, Boston's City Council summoned Boylston in August 1721 for an explanation of the practices, resulting in him being asked to cease the in occupation, deeming it unsafe. However, after collecting support from clergy members such as Mather's father and others, Boylston resumed the inoculation two days later [40]. Following an assault in the streets of Boston, Boylston took a two-week hiatus from performing inoculations. On November 25, 1721, Boylston inoculated 15 individuals in Harvard, students, a professor, and a tutor. They all survived, and a collective enthusiasm and curiosity toward the procedure was begging to develop among the academia of the university [41]. With it, a growing acceptance of the practice arose, with word reaching colonial shores of similar practices taking place in England to great success.

Smallpox would become the only disease completely eradicated through the efforts of vaccination programs. In December of 1979, following two years of data analysis, a group of clinicians and scientists announced the eradication of smallpox virus. In May of the following year, the World Health Organization General Assembly endorsed this announcement [42]. This historic event was monumental in medicine, as less than 200 years prior, Edwards Jenner started inoculating against smallpox with infectious material from the cowpox virus [43]. Jenner's vaccine method was the first published, and clinically proven to be more effective than inoculating with smallpox and then cowpox vaccination protected against smallpox [44].

Jenner himself had an unfortunate experience with smallpox inoculation. Born in Gloucestershire, England as the eighth of nine children of the town's vicar, Jenner's education was doted over. Sent to schools in Wotten-under-Edge, and Cirencester, it was there that the young Jenner received an inoculation against smallpox that resulted in longer lasting side effects as normal (the safety of inoculation versus vaccination will/was mentioned) [45]. At 14 years old, Jenner began a sevenyear long apprenticeship under surgeon Mr Daniel Ludlow. In 1770, at the age of 21, Jenner joined St. George's Hospital in London, under John Hunter, who became a lifelong friend and mentor [46]. The following two years at St. George's, Jenner set out to practice medicine in his home of Berkeley in Gloucestershire. At the time, variolation was a normal procedure performed by Jenner and other doctors across the country. However, reminded of his youth-hood troubles with variolation, and armed with the country lore that individuals sick from cow pox did not perish from smallpox infections, Jenner set out to explore the topic further.

The Jenner Institute's website writes about the happenings of the first example of vaccination performed by Jenner as:

In May 1796 a dairymaid, Sarah Nelmes, consulted Jenner about a rash on her hand. He diagnosed cowpox rather than smallpox and Sarah confirmed that one of her

cows, a Gloucester cow called Blossom, had recently had cowpox. Edward Jenner realized that this was his opportunity to test the protective properties of cowpox by giving it to someone who had not yet suffered smallpox.

He chose James Phipps, the eight-year-old son of his gardener. On 14th May he made a few scratches on one of James' arms and rubbed into them some material from one of the pocks on Sarah's hand. A few days later James became mildly ill with cowpox but was well again a week later. So, Jenner knew that cowpox could pass from person to person as well as from cow to person. The next step was to test whether the cowpox would now protect James from smallpox. On 1st July Jenner variolated the boy. As Jenner anticipated, and undoubtedly to his great relief, James did not develop smallpox, either on this occasion or on the many subsequent ones when his immunity was tested again.

Jenner's success with this case bolstered his hypothesis, and he set out to replicate the results of his experiment and publish them. Jenner was able to test his hypothesis on more than 20 different patients and was able to release his results to the United Kingdom's national academy of sciences, the Royal Academy [47]. The Academy was skeptical to publish, however, after some revision and alternation from Jenner, the results were accepted despite some aspects of Jenner's more outlandish hypothesis (eg. the cause of smallpox being an illness specific to horses that was transferred to cows and then to humans) [48]. Jenner's new vaccine method and its safety and effectiveness rose to prominence; while variolation and its use experienced a decline, going as far as being banned in Russia in 1805 due to safety concerns [49]. This trend of banning variolation would continue across Europe, with the British government taking steps in establishing the Vaccination Acts of the 1800's.

Beyond the banning of variolation via smallpox infected material, the United Kingdom's Vaccination Acts of the 1800's took steps to mandate vaccinations in certain populations. The first of the Vaccination Acts were passed in 1840, banning variolation, and providing optional vaccinations free of charge [50]. The Act was justified by the fact that although there can be side effects due to vaccination, the approach pioneered by Jenner was always safer than that of the variolation methods practiced throughout the early 18th century.

The law was expanded upon more than a decade later in 1853, where the act made vaccination compulsory for all newborns at three or four months of age, with the parents or guardians reporting the vaccination status of the child to local government and the child being able to be evaluated by the appropriate bodies to ensure that vaccination was complete. With this new development, a new stipulation was included that that parents could be fined a £1 fee (and imprisoned for omission to meet the fee requirements) for refusing to vaccinate their newborn or allow an exception to take place to verify the child's vaccination [51]. With this inclusion, a wave of anti-vaccination sentiments grew among the populous, as individuals saw the fines as a violation of their civil liberties. The negative attitudes continued to escalate, leading to outbreaks of violent riots in multiple English cities, including Mitford, Henley, Ipswich, among others [52]. Later during the same year, 1853, the founding of the Anti-Vaccination League in London offered an organizational structure to the anti-vaccination movement growing in England. In 1867, additional laws were passed to add checks to the system of mandatory vaccination of newborns at 3 months of age and further specifying the fines and punishments for parents or guardians disobeying the parameters of the new law [53]. Although these extensions were consolidated and revised to be included in the National Health Service Act of 1946 (being technically repealed), the anti-vaccination groups (such as the newly formed Anti-Compulsory Vaccination League), seized the opportunity to attack the intrusion of government into civil liberties under the guise of public health [54]. Releasing a seven-point mission statement in its newsletter, *National Anti-Compulsory Vaccination Reporter* [55], the journal quoted the formation of the League *To overthrow this huge piece of physiological absurdity and medical tyranny* and quoted Richard Gibbs (the operator of the Free Hospital) as *I believe we have hundreds of cases here, from being poisoned with vaccination, I deem incurable. One member of a family dating syphilitic symptoms from the time of vaccination, when all the other members of the family have been clear. We strongly advise parents to go to prison, rather than submit to have their helpless offspring inoculated with scrofula, syphilis, and mania* [56]. By 1871, the Anti-Compulsory Vaccination League had 103 branches and more than 10,000 regular members [57]. Although the league would not remain in this form for long, continuing to expand and merge with other likeminded groups, the general ethos of the organization continued to thrive well into the 1970's in the form of the National Anti-Vaccination League, which was an amalgam of more than 100 years' worth of vaccine skepticism [58].

The outcry among the vaccine-skeptic public would continue to expand well into the 19th century as anti-vaccination leagues grew in England, with journals, books, and tracts continually being released. Some of these journals included *Anti-Vaccinator* (founded 1869), the *National Anti-Compulsory Vaccination Reporter* (1874), and the *Vaccination Inquirer* (1879) [59]. Continuing to spread to other parts of Europe, Stockholm, the capitol of Sweden, had its own challenges with anti-vaccine sentiments [60]. Summed up by Wolfe and Sharpe [61]:

In Stockholm, the majority of the population began to refuse vaccination, so that by 1872 vaccination rates in Stockholm had fallen to just over 40%, whereas they approached 90% in the rest of Sweden. Fearing a serious epidemic, the chief city physician, Dr C A Grähs, demanded stricter measures. A major epidemic in 1874 shocked the city and led to widespread vaccination and an end to further epidemics.

Back in Britain, the anti-vaccination movement in its organized, focused form could no longer be ignored by

British government, following a massive anti-vaccination event in 1885 in Leicester with a turnout of more than 100,000 attendees [62]. A royal commission was established to hear out the grievances of those opposed to the vaccine as well as taking in evidence in favor of vaccinations. Taking more than seven years to release their report, the commission concluded that vaccination did indeed protect an individual from smallpox, however entertained the antivaccination movement by supporting the abolition of fines and penalties for those refusing to vaccinate their children [63]. The Vaccination Act of 1898 removed these penalties and added a conscientious objector clause that allowed parents who did not believe the safety and effectively of the vaccine to omit vaccination of their child via obtainment of an exception [64]. However, the execution of the Act was different to that of the text describing it. The challenge came from obtaining the exception via the required two magistrates, or one stipendiary within four months of the child being born. However, this was not entirely possible as the magistrates and stipendiaries responsible for the exception often times-imposed delays or refused to accommodate the conscientious objectors. This problem was mediated by the Vaccination Act of 1907 which aimed to alleviate the dependance on magistrates and stipendiaries to approve exceptions. The new law allowed parents who questioned the safety and effectiveness of the vaccine to send an official declaration to the local Vaccination Officer to be granted exception.

The slow and steady recognition of the anti-vaccination movement spurned on by the success of English Anti-Vaccination leagues led to a similar phenomenon to take place in the United States. In 1889, California passed a law requiring smallpox vaccination for students attending school, something on trend as the expansion of mandatory schooling laws and transmission of smallpox infections grew [65]. California's law was unique as most states with mandatory smallpox vaccinations did not include a medical exception. This was a large point of contention for the growing anti-vaccination leagues in the United States. Founded in 1897, following a visit from one of England's key anti-vaccination movement leaders, William Tebb, the Anti-Vaccination Society of America was founded. This group grew quickly in size, and offshoots soon developed, including the New England Anti-Compulsory Vaccination League (1882) and The AntiVaccination League of New York (1855) being founded. The groups aim was to repeal compulsory vaccination laws in many states across the country. The anti-vaccination groups found great success through their use of pamphlets, literature, court battles, and debates in front of state congress. Successful enough to repeal compulsory vaccination in Illinois, Indiana, Minnesota, Utah, West Virginia, and Wisconsin, and in places like Montreal and Milwaukee, where antivaccination supporters instigated violent riots to spur public reaction [66]. One of the most tedious and lengthy battles that took place was in California, when in 1905, lawmakers approved a bill preventing mandatory vaccinations in their school system following a Supreme Court decision that upheld compulsory vaccination [67]. This bill was vetoed by the governor of California [68] and started a year's long battle between lawmakers and lobbyists which waived vaccination requirements in 1911 for any individual conscientiously opposed to the vaccine [69]. In 1929 the conscientious objector clause was altogether scrapped, as mandatory vaccination was entirely repealed in the state of California. Despite the conceited efforts of anti-vaccination groups to put a stop to compulsory vaccination, a World Health Organization campaign to eradicate smallpox globally via widespread vaccination efforts proved successful in 1977.

Present

One of the most, if not the most, impactful anti-vaccination campaigns in modern history was against the trivalent measles, mumps, and rubella vaccine. Although efforts of anti-vaccination groups are targeting the vaccine for all three of these viral diseases, the resurgence of measles is proving to be the most impactful in the modern day, as epidemics are occurring rapidly in affected communities with trends of raised anti-vaccination attitudes.

Sherris and Ryan's Medical Microbiology 8e summarizes the measles morbillivirus as:

Measles virus, a member of paramyxoviridae family and Morbillivirus genus, is a negative-sense RNA, helical, enveloped virus with H and F spikes, which replicates in the cytoplasm by using viral RNA polymerase. Measles (also known as rubeola or 5-day measles) is transmitted through respiratory inhalation (incubation period 7–18 days) and replicates in respiratory mucosal epithelium infections followed by spread to regional lymph nodes and development of viremia and transportation of virus to all body organs. Measles often produces severe illness in children, associated with fever, cough, coryza, widespread rash, and transient immunosuppression. One to 2 days before the development of rash, Koplik spots (small bluish-yellow spots) appear on the buccal mucosa opposite the molar teeth. Severity of measles includes high fever, delirium, conjunctivitis and photophobia. The virus is one of the most contagious agents among humans. Serious complications include encephalitis, pneumonia, otitis media, mastoiditis, sinusitis and bleeding disorders. Pathogenesis involves infection of immune cells, down-regulation of lL-12 and depressed cell-mediated immunity. Skin lesions show vasculitis and presence of viral components in rash. Immune-mediated post-infectious encephalitis may occur in some patients through CD8 T cells infiltration in the CNS. Long-term sequelae, such as blindness, may occur, and, rarely, a few patients develop a slowly fatal condition called subacute sclerosing pan-encephalitis (SSPE) with onset years after the initial infection. Immunity to reinfection is lifelong associated with the presence of neutralizing antibodies. However, patients with defects in cell-mediated immunity and malnutrition have a

prolonged infection with severe complication. An effective live attenuated vaccine is recommended (as part of MMR or MMRV) in the first year of life and a booster between 4 and 6 years of age.

The first measles vaccine released to the public was in the year 1963, and with it, a plummeting of measles cases globally. From hundreds of thousands of cases per year in the US before the introduction of the vaccine, to tens of thousands of cases per year following the introduction of the vaccine, and down to thousands of cases a year in the 1980's [70]. Before the release of the vaccine, a measles infection was seen as a death sentence, as more than 2.6 million casualties were attributed to measles before the introduction of the vaccine [71]. Nowadays, global rates of measles cases continue to drop, the World Health Organization states that in the year 2000, there were estimated to be more than half a million measles cases worldwide, and in 2018, that number has dropped down to more than a hundred thousand individual cases per year. Today the attitude towards measles is seen as a disease that is generally controlled, however not completely eradicated. Outbreaks are generally viewed to occur in *less developed* areas such as Asia, Africa, the Pacific, and parts of Europe [72]. However, as measles cases continue to decline, a growing threat of outbreaks continue to threaten communities all over the world, spurred on by antivaccination movements' goal of indoctrinating anxious parents via a false equivalence between the connection of the measles, mumps and rubella vaccine, and Crohn's disease along with autism [73, 74].

Andrew Wakefield is a name in the medical community, synonymous with modern medical opportunism and academic dishonesty. Born into a family of doctors, Andrew Wakefield studied medicine in St Mary's Hospital Medical School, finishing his degree in 1981 [75]. Becoming a member of the United Kingdom's Royal College of Surgeons, Wakefield went on to work at the University of Toronto from 1986 to 1989, with a focus on transplant rejection in the small intestine [76]. Returning to his homeland in the United Kingdom in the 1990's, Wakefield published his first study while working with the liver transplant team for the Royal Free Hospital in London [77] in 1993 with the topic being a hypothesized connection between measles causing Crohn's disease [78]. In April 1995, Wakefield published an article in *The Lancet*, postulating a causality between the measles vaccine and autism, which attracted the attention of the medical community [79]. At the same time, a British solicitor, Richard Barr, was gaining momentum in his class action lawsuit campaign of the manufacturers of the MMR vaccine. Barr, gaining support for his class action lawsuit from a legal aid group sponsored by the United Kingdom's Ministry of Justice, was acting in the interests of JABS (Justice, Awareness and Basic Support) [80]. JABS, a support group for parents with children affected by the MMR vaccine, supported a connection between the vaccine and associated health issues, including but not limited to epilepsy, brain damage and autism [81]. Due to his association with JABS, and rising momentum for a successful class action lawsuit against Aventis Pasteur, SmithKline Beecham, and Merck, Barr contacted Wakefield seeing the two published articles the doctor had written on the relevant topic [82]. Wakefield was contacted earlier in 1995 by a concerned parent from Allergy Induced Autism, another vaccine skeptic group [83]. Following this meeting, and his first meeting with Barr in January 1996 [84], Wakefield was motivated to continue his work in the connection between the vaccine and autism.

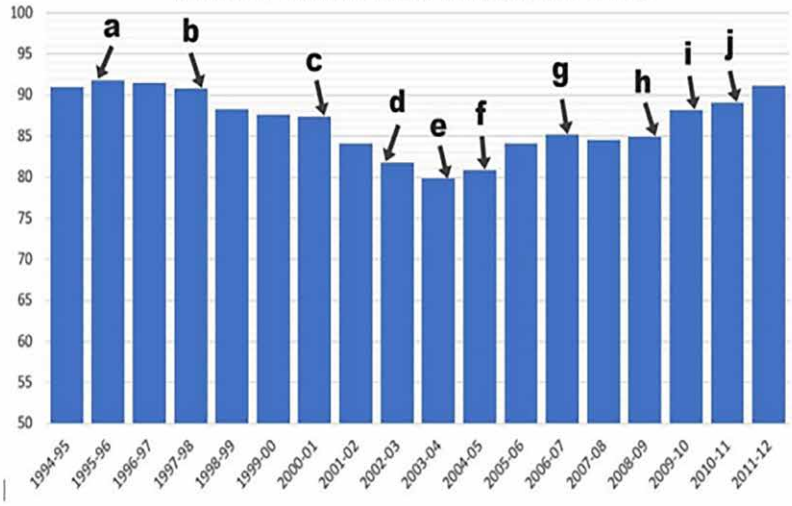
In February 1998, The Lancet published an article that can only be described as Wakefield's opus. The paper, supported by the Royal Free Hospital in London where Wakefield worked, included a 12-patient-study of children with developmental disorders and intestinal issues. The paper stipulated that this constellation of symptoms was a new diagnosis which Wakefield referred to as *autistic enterocolitis* [85]. In the article, using clinical results of colon tissue biopsies and endoscopies, Wakefield speculated that the occurrence of Crohn's disease is tied to a long-term infection of the measles virus. The paper went on to hypothesize that because eight of the 12 patients were vaccinated, there is a causal relationship between the vaccine and the development of autism, and this relationship needed further research [86]. In a news conference hosted by the Royal Free Hospital with the release of the newly published paper, Wakefield took to the crowd and shared his support for the monovalent measles vaccine, as he believed the trivalent MMR vaccine had startling implications for long term health [87]. Buffered by the words of his mentor, Roy Pounder, the Professor of Medicine at the Royal Free Hospital (who parroted the notion that a monovalent vaccine was safer than the trivalent), the news of this startling discovery spread like wildfire [88]. Within the following years, Wakefield published two more papers on the topic, neither one providing any new evidence, and being published in relatively unknown scientific journals. This led to mass media attention to the topic in the following years. News organizations focused their coverage on the horror stories involved with the vaccine scare, including tales of suffering parents and their children and attacks on healthcare providers and services [89]. There was a clear scent of blood in the water regarding that topic, as news publications across the country focused on the skeptical outlook of the MMR vaccine. With most writers being uninformed on the topic, the articles focused on the more contentious aspects of the story. Less than a third of the published articles from January to September 2002 included the information that there was no medical proof of the dangers of the MMR vaccine, focusing instead on the son of the United Kingdom's prime minister, Tony Blair, who may or may not have autism as a direct cause of the MMR vaccine [90].

What the media failed to mention, was the undeniable proof that Wakefield's hypothesis and papers were focused propaganda, with ulterior motives that were later

revealed under the dedicated efforts of Brian Deer, an investigative reporter for *The Sunday Times*. What Brian Deer uncovered, was a connection previously unknown to the public, that Wakefield and Richard Barr were accomplices in a mission for a fat payout from the MMR vaccine scare. In a newly obtained audio recording of a conversation had by the two, it was revealed that Barr was using the money granted to him by the Ministry of Justice to keep Wakefield on retainer as a medical expert. Over the working relationship, Wakefield was paid around $250 hourly for his time, totaling out to a little under a million dollars adjusted for current inflation [91]. Another detailed uncovered by Deer was that months before the release of the 1998 Lancet study, Wakefield filed a patent for a monovalent measles vaccine that he deemed was *safer* than the current available product. This connection was impossible to ignore, as Wakefield was setting himself up for financial success via denouncing the safety of the MMR vaccine and offering a solution that he gained to benefit from massively [92].

As a response to the 1998 Lancet article, an effort was made to replicate the results of the original 12-case study performed by Wakefield, with no success [93]. This controversial publishing was heavily scrutinized and following a year's long effort by the international medical community to confirm a connection between the MMR vaccine and autism, The Lancet retracted the article completely in 2010 [94]. However, the damage done by the release of the article was already visible, as seen in the Appendix, Figure 1, a graph shows a clear drop of vaccination rates between the release of The Lancet article and the effort by the medical community to right the ship.

Figure 1. **MMR percentage uptake between 1994 and 2012 in England and Wales**



MMR percentage uptake, 1994–2012, England & Wales. Source data generating each bar above combine the last three quarters of each calendar year with the first quarter of the next.

a – Wakefield, Thompson, et al, *Lancet*, 29 Apr 1995 (false MMR & Crohn's disease claims).

b – Wakefield, Murch, Walker-Smith, et al, *Lancet*, 28 Feb 1998 (fraudulent MMR & autism claims — paper retracted Feb 2010).

c – Wakefield, Montgomery, et al, *Adverse Drug Reactions and Toxicological Reviews*, 22 Jan 2001 [release date] (sham, falsified, MMR safety review).

d – Wakefield, Uhlmann, Sheils, O'Leary, et al, *Molecular Pathology*, Apr 2002 (false measles PCR virology/autism claims).

e – Deer, "Revealed: MMR research scandal," *Sunday Times*, 22 Jan 2004.

f – Deer, "MMR scare doctor planned rival vaccine," *Sunday Times*, 14 Nov 2004.

g – Deer, "MMR doctor given legal aid thousands," *Sunday Times*, 31 Dec 2006.

h – Deer, "MMR doctor fixed data on autism," *Sunday Times*, 8 Feb 2009.

i – Deer, "Callous, unethical and dishonest," *Sunday Times*, 31 Jan 2010.

j – Deer, "How the case against the MMR vaccine was fixed," *BMJ* based on Deer's *Sunday Times* investigation, 5 Jan 2011.*

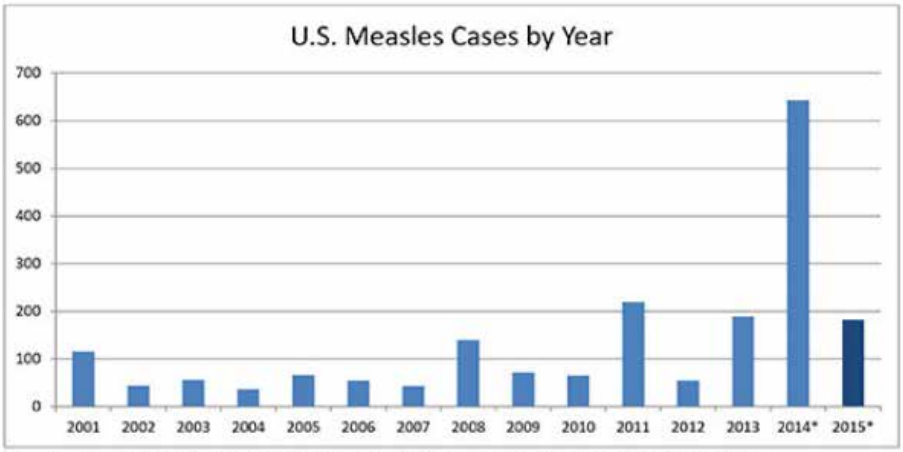
Unfortunately, the mass hysteria brought on by sensationalist reporting was seeping into public attitudes, leading to a rise in measles cases worldwide, especially in regions where measles was thought to be eradicated due to the high vaccination rates. A May 2000 BBC article reported on the rise of measles cases in Dublin, Ireland, with two babies dead from the virus, and dozens of children hospitalized. The article spoke of the Wakefield paper casting doubts on the safety of the MMR vaccine, and although medical experts denied the connection, the media's portrayal of the controversy frightened parents enough to reject the vaccine [95]. Dublin was heavily affected in the short span between 1999 and 2000, where there were three confirmed casualties, with hundreds hospital bound, thirteen children being sent to the ICU and seven of them requiring mechanical ventilation. A July 2003 Pediatric Infectious Disease Journal study attributed the issue to a low level of vaccination; with a national vaccine rate in Ireland being at 79% and North Dublin having a staggeringly low rate of vaccination below 70% [96]. Wakefield's goal of casting doubt on the MMR vaccine proved to be effective even despite the momentum to correct the mistake.

Trouble with successful measles vaccination continued to spread worldwide. In places such as the Netherlands, an outbreak ravaged a reformed orthodox (Calvinist) provincial community that is generally vaccine skeptical, with almost 3000 children being affected by the measles virus. The vaccination rate of this patient population was around 5%, with the median age of the child affected being six years old [97]. An *Emerging Infectious Disease Journal study* reported on the extremely low vaccination rates in

this community, and further stipulated that despite the 95% successful vaccination rate sufficient to provide *herd immunity*, groupings of non-vaccinated people can lead to disease outbreaks [98] enough to significantly affect the population.

In the United States, starting from the early 2000s, there has been an ongoing battle with vaccination and the resulting outbreaks that it leads to. Ironically enough, in the year 2000, measles was declared eliminated from the country as the only new cases were imported from another country [99]. However, as we can see included in the Appendix, Figure 2 shows the occurrence of measles in the United States from 2001 to 2015, with outbreaks happening more and more frequently, with increased numbers of cases with each outbreak.

Figure 2. **United States measles cases by year as per the CDC National Center for Immunization and Respiratory Disease**



A 2005 outbreak in Indiana led to 34 new cases of measles being confirmed. This was attributed to a gathering that took place with an individual that returned from a trip abroad to Romania. This was confirmed with viral genotyping, which showed the measles strain was genotype D4, a strain endemic to Romania. Of the 34 cases, 94% were unvaccinated, 88% were younger than 20 years, and 9% were hospitalized. Of the 28 patients aged between five to 19, 77% of them were homeschooled. A 2006 *New England Journal of Medicine* article concluded that the high levels of vaccination (92-98%) in the surrounding community prevented an endemic [100]. It went on to emphasize that maintaining high levels of vaccination via effective communication methods with vaccine skeptic communities is necessary to prevent future outbreaks and to maintain measles elimination in the United States.

Despite the rather steady rate of vaccination happening between the years of 2008-2012 (>90% of 1 MMR vaccine dose) shared via the National Immunization Survey, Figure 3, outbreaks in the United States have occurred and continue to occur.

In 2013, three of the biggest measles outbreaks took place in the states of North Carolina, Texas, and New York. In all these situations, the outbreaks are attributed to an imported strain of measles entering a community with reduced vaccination rates and leading to an outbreak. This was seen in North Carolina, after a travel to India led to a measles outbreak of 23 individualsin an unvaccinated religious community with at least 78% of those infected having never received a measles vaccination [101]. The Vaccine Preventable Disease Reference Center at the Wisconsin State Laboratory of Hygiene identified genotype D8 being the causative virus of this outbreak, a genotype endemic to India. In response to the outbreak, thousands of dollars and more than 2000 hours were spent in trying to control and identify the spread of the disease.

In Texas, a similar outbreak occurred in 2013 following an individual's return to Texas after a trip to Indonesia. A few days after returning, the individual attended Mass at Eagle Mountain International Church in Newark. The congregation was led by daughter of Kenneth Copeland, a televangelist notorious for vaccine skepticism, even in the age of COVID (Copeland garnered national attention in 2021 when he pleaded with his congregation for more donations for him to escape the dangers of COVID with his private jet) [102]. Although the daughter, Terri Copeland Pearsons, was not openly against the measles vaccine in response to the 2013 outbreak, a statement released by the church confirmed vaccine skeptical attitudes shared amongst the church members. A total of 21 individuals were infected with measles, most of them being not vaccinated against the virus [103].

New York state, New York City has often struggled with outbreaks of measles, as recently as 2019. A significant outbreak that occurred the same year as in North

Figure 3. **Results of the National Immunization Survey from 2008–2012**

Vaccine and dosage	2008		2009		2010		2011		2012	
	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
DTaP										
≥3 doses	96.2	(±0.5)	95.0	(±0.6)	95.0	(±0.6)	95.5	(±0.5)	94.3	(±0.7)†
≥4 doses	84.6	(±1.0)	83.9	(±1.0)	84.4	(±1.0)	84.6	(±1.0)	82.5	(±1.2)†
Poliovirus (≥3 doses)	93.6	(±0.6)	92.8	(±0.7)	93.3	(±0.7)	93.9	(±0.6)	92.8	(±0.7)†
MMR (≥1 doses)	92.1	(±0.7)	90.0	(±0.8)	91.5	(±0.7)	91.6	(±0.8)	90.8	(±0.8)

Carolina and Texas involved an unvaccinated adolescent returning to New York City following a trip to London, leading to the largest outbreak of measles in the city since 1992. An investigation took place following the resulting outbreak and identified that of the 58 patients, 78% of them were unvaccinated due to the parents' refusal or conscious delays, 12% were younger than 12 months, so vaccination was not mandatory for them. The median age of a patient was three years old and 100% of the patient populations was Orthodox Jewish [104]. The investigation of cost and resource analysis showed that the toll on the public healthcare system totaled to more than 10,000-man hours and almost $400,000 spent in response to the outbreak. This is a trend that continued in the measles outbreak of 2018-2019, where under similar circumstances, an outbreak was attributed to an unvaccinated tourist from Israel returning to the city. What that led to be a massive outbreak totaling to 649 new cases, with the median age of the patient being, as mentioned before, three years old. The outbreak was localized to the Brooklyn neighborhood of Williamsburg, with more than 93% of the patients being Orthodox Jewish. 85% of the patients were unvaccinated, 5% experienced pneumonia, and 7% were hospitalized (with 40% of hospitalized patients being admitted to the intensive care unit at the perspective hospital). By September 2019, 559 members of staff of Department of Health and Hygiene were involved with controlling the measles outbreak, and total costs equaling $8.4 million [105].

These outbreaks of new cases are a common occurrence in communities with reduced vaccination rates and will continue to exist if anti-vaccine attitudes continue to prevail. From the Swansea measles outbreak of 2013, which is caused by a reduced measles vaccination rate in the youth population below 70% [106]; Romania, where a widespread campaign via propagation of antivaccination literature led to the government announcing a measles epidemic in 2016 [107]; to Samoa, where a 2019 measles outbreak led to the death of 70 individuals in a population of 200,000 [108]. All these outbreaks are a direct result of anti-vaccination attitudes gaining enough support and momentum to lead to serious casualties in the affected communities.

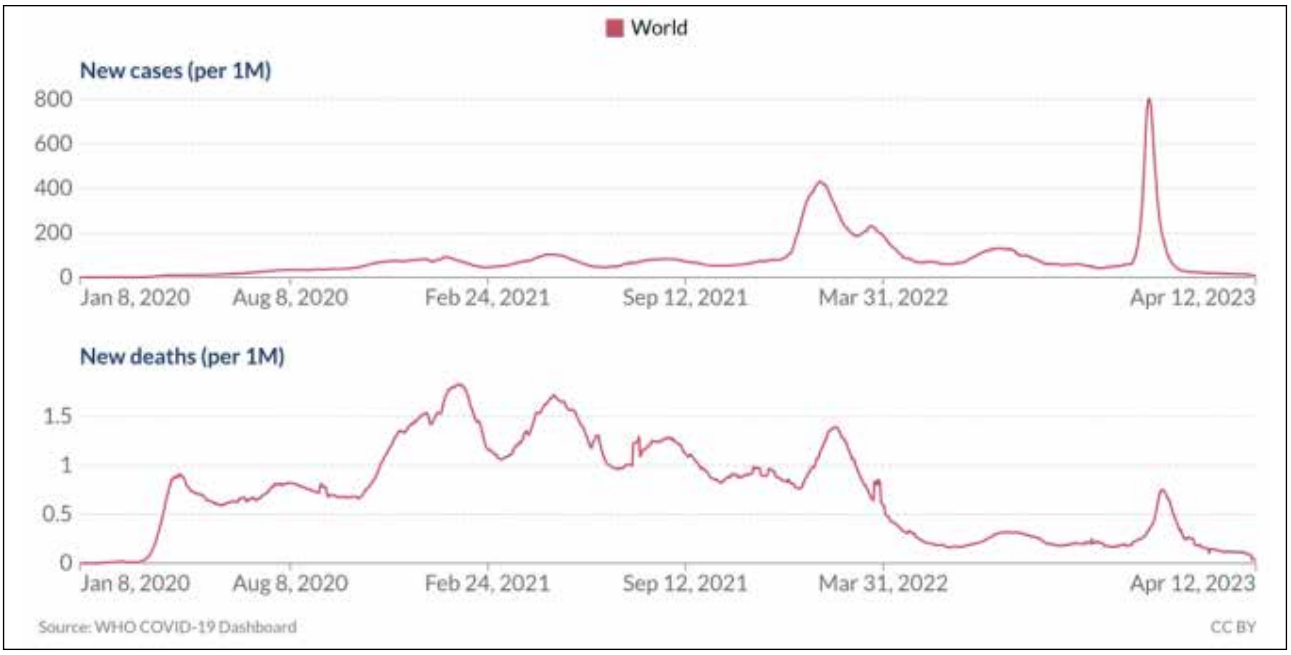
Future

With the announcement of the global SARS-CoV-2 COVID-19 pandemic, the world was launched into a years-long case study of modern pandemics, worldwide reaction to them, and responses from health organizations, governments, and individuals alike. As a quick summary of the microbiology of coronaviruses (including SARS-CoV-2), *Sherris and Ryan's Medical Microbiology 8e* writes:

Coronaviruses are the largest RNA viruses comprised of a positive-sense RNA genome, a helical nucleocapsid and a lipid bilayer envelope containing viral Spike (S) glycoprotein, membrane glycoprotein, and small envelope glycoprotein. The virus replicates in the cytoplasm by using its newly synthesized viral RNA-dependent RNA polymerase and assembles in the cytoplasm acquiring an envelope from ER-Golgi membranes. Four common human coronaviruses (Hu-CoV) -229E, - NL63, -OC43, and -HKU1 have been contributing to 5% to -10% common cold every year for decades. In addition, three novel human coronaviruses have been identified causing severe acute respiratory syndrome, SARS-CoV-1, MERS-CoV, and SARS-CoV-2 in 2019 (COVID-19). While SARS and MERS were highly fatal, they were limited in spread and number of cases. COVID-19 has become a pandemic infection involving most countries and causing 178 million cases and 3.86 million deaths globally. The United States has the greatest number of cases, and deaths of any country. SARS-CoV-2 is transmitted through respiratory droplets and its Spike glycoprotein interacts with ACE2 receptor in the upper and lower respiratory tract, and also utilizes TMPRSS2 host transmembrane protein for virus entry followed by viral replication, increasing viral copies number, up-regulation of pro-inflammatory cytokines and chemokines and recruitment of T lymphocytes, monocytes, and neutrophils. In the late stage, pulmonary edema can fill the alveolar spaces with hyaline membrane formation, consistent with early-phase acute respiratory distress syndrome. About 80% of infected people develop mild to moderate flu-like symptoms, ~15% develop severe disease such as viral pneumonia, and ~5% have critical illness such as acute hypoxemic respiratory failure, shock, or multi-organ dysfunction. Older people above 65 years of age develop more severe COVID-19 than younger people and the majority of deaths have occurred in this group, especially above 85 years. Molecular (RT-PCR) and antigen tests are available to detect SARS-CoV-2. Treatment includes antiviral remdesivir and dexamethasone. Combination monoclonal antibodies against SASR-CoV- 2 Spike glycoprotein are available to prevent severe disease progression. Two mRNA vaccines (Pfizer and Moderna) given in two doses and a one-dose adenovirus-virus vector encoding Spike glycoprotein have been authorized for emergency use in the United States, and are highly effective in preventing moderate to severe COVID-19.

What happened as a response to the pandemic was something previously unseen before in modern society, a global pandemic resulting in a yearlong scramble for solutions and answers. Due to the highly interconnected global lifestyle that 21st century humans experience, a mass shutdown of infrastructure and mandated social isolation resulted in unsavory attitudes towards healthcare, government, and information sources. As with smallpox, and with measles, these viral diseases and their outbreaks were able to be controlled through thorough vaccination of the public. There seems to usually be a demographic of individuals that will refuse vaccines on many specific individual bases. However, a goal of high vaccination rates must be met to curtail transmission or suppress symptom severity

Figure 4. **Daily new confirmed COVID-19 cases & deaths per million people**



in infected populations. The Mayo Clinic estimates that a vaccination rate of 94% must be reached to achieve herd immunity regarding highly contagious diseases [109]. As of April 2023, the percentage of the world population vaccinated against COVID-19 is under 65% [110]. Figure 4 represents the comparison of new COVID-19 cases along with deaths resulting from the disease. A significant piece of information that it portrays is that the higher the global vaccination rate is, the mortality of because of COVID-19 is reduced. By December 2022, more than five billion individuals completed the COVID-19 vaccination protocol. That same month, we experienced the largest number of new cases of COVID-19; however, the mortality rate from the disease was significantly reduced, especially when compared to the death rate in the early months of 2021 regarding new case discovery. A part of this reduction in mortality can be attributed to improved acute clinical care techniques in hospitals along with clinicians armed with the knowledge on how to manage the novel diseases. The significant reduction in mortality that the COVID-19 vaccine provided cannot be ignored. However, due to the limited information regarding anti-vaccination's specific toll on the healthcare space regarding a post COVID-19 world, a hard conclusion cannot be validated via peer reviewed sources. The topic should be followed closely as the novelty of the COVID-19 virus leaves room for speculation regarding the future of disease outbreaks. It is uncertain what trend of viral mutation is specific to COVID-19, and how that mutation will impact future outbreaks regarding vaccination refusal.

Three factors are found to influence an individual's hesitance or acceptance of the COVID-19 vaccine, being demographic (education, income, ethnicity), environmental (government policy, media), and vaccine specific factors (safety, efficacy) [111]. An international analysis showed that the latter point proved to be the most concerning for individuals, with public concerns of vaccine safety and effectiveness being the issues of most concern [112]. The approach to manage these issues of vaccine hesitancy is multi focal and must consider in large part, all three of the above stated factors. This is by no means an easy feat, as a major issue with the COVID-19 pandemic was the effect had via the influence of social media [113]. Misinformation was widely spread through these networks and the ability to share this misinformation cannot be understated. With the widespread sharing of personal experiences and information on platforms such as Facebook and YouTube, individuals highly scrutinized the safety of the COVID-19 vaccine. Studies regarding the quality of vaccination-related content on the internet shows that it is widely variable in quality and in large part, negative [114, 115].

However, an analysis of positive MMR vaccine information sharing on social media showed to be highly successful in England, New Zealand, and Australia [116]. This is a vital tool against the spread of vaccine misinformation and should be considered as a key mechanism for public education. The role of public education cannot be understated, as it directly leads to an increase in vaccine acceptance [117], especially when compared to the forceful approach of vaccine mandates, which in and of themselves are an ethical issue [118]. With the growth of the consumerism and shared decision making in medicine, it is hard to return to the classically patriarchal attitude in healthcare of prior generations [119].

A 2013 article published in Human Vaccines & Immunotherapeutics analyzing trends of vaccine hesitancy concludes that *vaccine hesitancy can be heightened by the current changing scientific, cultural, medico-legal and media environments*. Adding:

Many experts have proposed ways to counter vaccine hesitancy at the population level, including transparency

in policy-making decisions regarding vaccination programs, providing education and information to the public and health providers about the rigorous process that leads to approval of new vaccines and diversified post-marketing surveillance of vaccine-related events. In addition, as stressed by Larson and collaborators, "additional emphasis should be placed on listening to the concerns and understanding the perceptions of the public to inform risk communication and to incorporate public perspectives in planning vaccine policies and programmes." Finally, as their role is crucial in sustaining the success of vaccination programs, more research is needed to understand why some health professionals, trained in medical sciences, still have doubts regarding the safety and effectiveness of vaccination.

Conclusion and discussion

Despite what is known about the safety and effectiveness of modern vaccines, there will always exist a sect of society that is unreasonably skeptical towards vaccination. Due to the complex relationship that has been developed over the course of medical history, some patients will doubt the motivations of health care workers, often relying on misinformation and conspiracy theories to base their decisions off. As this spread of misinformation continues in the civilian population, it is the duty of healthcare providers to provide the necessary levity via scientifically proven information, empathetic communication, and strong partnerships with community and religious leaders. A mother who is concerned about the MMR vaccine for her newborn should be approached by public health professionals to discuss the safety benefits of the vaccine while being honest about the drawbacks. Much like a member of a religious community skeptical about vaccination should be regarded with an open model of communication- going as far as bringing their faith as part of the discussion should be adopted. These focused and individual-specific approaches should be implemented by the healthcare providers to guarantee proper understanding of vaccination among their local population. If the medical community continues to ostracize and dismiss the concerns of the vaccine skeptical people and denying communities beliefs, outbreaks of previously controlled diseases will continue to occur, bringing disruption in the health care system along with unnecessary casualties and growing distrust in the medical system. Healthcare professionals can be arbiters of public health and must extend their scope beyond diagnosing and treating diseases; to use communication strategies effectively and become trusted members in their community. This will be especially significant going forward into the future as the impact of social networking has shown to be especially significant in the outbreak of COVID-19. The potential of future outbreaks on the global scale cannot be understated. The role of healthcare workers in these instances will continue to be significant as channels of misinformation will continue to grow and impact acceptance of newly developed vaccines. Support for vaccination should be a common goal for all medical care providers and should be prioritized in response to mass misinformation campaigns taking place in the online space, media, and public discussion. If this goal is unable to be met, healthcare systems should be preparing themselves for more frequent and severe outbreaks of diseases that have vaccines available against them. A 2021 article in *The Annual Reviews of Public Health by Dubé, Ward, Verger and MacDonald* concluded that *it is more important than ever to pursue research to better understand community dynamics, sociocultural factors, and local knowledge, as well as how the influence of vaccine criticism may impact the acceptance of vaccines*. A sentiment that rings especially going forward into the future.

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