Chapter

Myths Surrounding Covid-19 Vaccine Candidates: A Guide to Fight Back

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Abstract

The Covid-19 pandemic has propelled public health officials into the socio-political sphere due to the need for constantly updated information on behalf of the public. However, many individuals choose to acquire health information/guidance from indirect sources, including social media, news organizations, and general word of mouth. As a result, myths and false narratives about various essential health topics, including vaccine characteristics and protective measures, can circulate un-verified between millions of individuals with little recourse. These can further widen the "gap" between public knowledge and current research, resulting in lower vaccine uptake (vaccine hesitancy) and protective measure adherence. Such actions have profound implications as nations attempt to achieve herd immunity and end the pandemic once and for all. Thus, it is vital that public health officials, health providers, researchers, and the general public be able to differentiate common Covid-19 myths from facts and be prepared to approach such interactions via sound reasoning and research-based evidence. This chapter will serve as a guide to accomplish just that.

Keywords: Covid-19 vaccine, vaccine hesitancy, herd immunity, myths, mRNA technology, clinical trial

1. Introduction

Before the Covid-19 pandemic, vaccine hesitancy was a term reserved for individuals, primarily in developed countries, in which there is a significant refusal or delay in uptake despite vaccine availability/access. In this instance, the term minute might be misleading since vaccine hesitancy is in no way a monolith. Indeed, vaccine hesitancy can take many forms and stems from multiple etiologies. However, never in the past decade had individuals' choices and personal convictions regarding a vaccine had such a profound effect on the perceived ability of entire nations to effectively control a pandemic at large [1].

This "rise to fame" and increased recognition in the public health community was borne out of the realization that multiple vaccine candidates were nearing the later stages of clinical trials in the fall of 2020. After nearly nine months of social protective measures and economic turmoil, a clear disparity had been recognized between the rapid vaccine production process and public knowledge/acceptance toward eventual vaccine uptake. For instance, the first vaccine (Pfizer) against

Covid-19 was given emergency use authorization on December 11, 2020, in the U.S. A week later, a second vaccine (by Moderna) was also approved. However, unlike traditional vaccine rollouts, the U.S. government had pre-purchased hundreds of millions of doses from multiple manufacturers via Operation Warp Speed, hoping to speed up the initial delivery to essential frontline workers and high-risk individuals [2]. The program was considered an overnight success as over 6 million doses of each vaccine was shipped within a week of authorization, enough to vaccinate the entire U.S. healthcare worker population. Within a few weeks, reports began emerging that only 68% of healthcare workers, the supposed most informed subset of the population, had chosen to receive the vaccine when offered to them [3]. To put this in perspective, annual influenza vaccine uptake in the U.S. stands at around 81% [4]. One might ask, what separates the two numbers? The answer is, of course, much deeper than surface level; however, one question has been proposed and proven highly appropriate in post-roll out public opinion polling: where was the vaccine marketing campaign? After all, the U.S. spent over $12 billion on vaccine candidates undergoing clinical trials before a single jab was given [2]. The first official Covid-19 vaccination information campaign was not announced until January

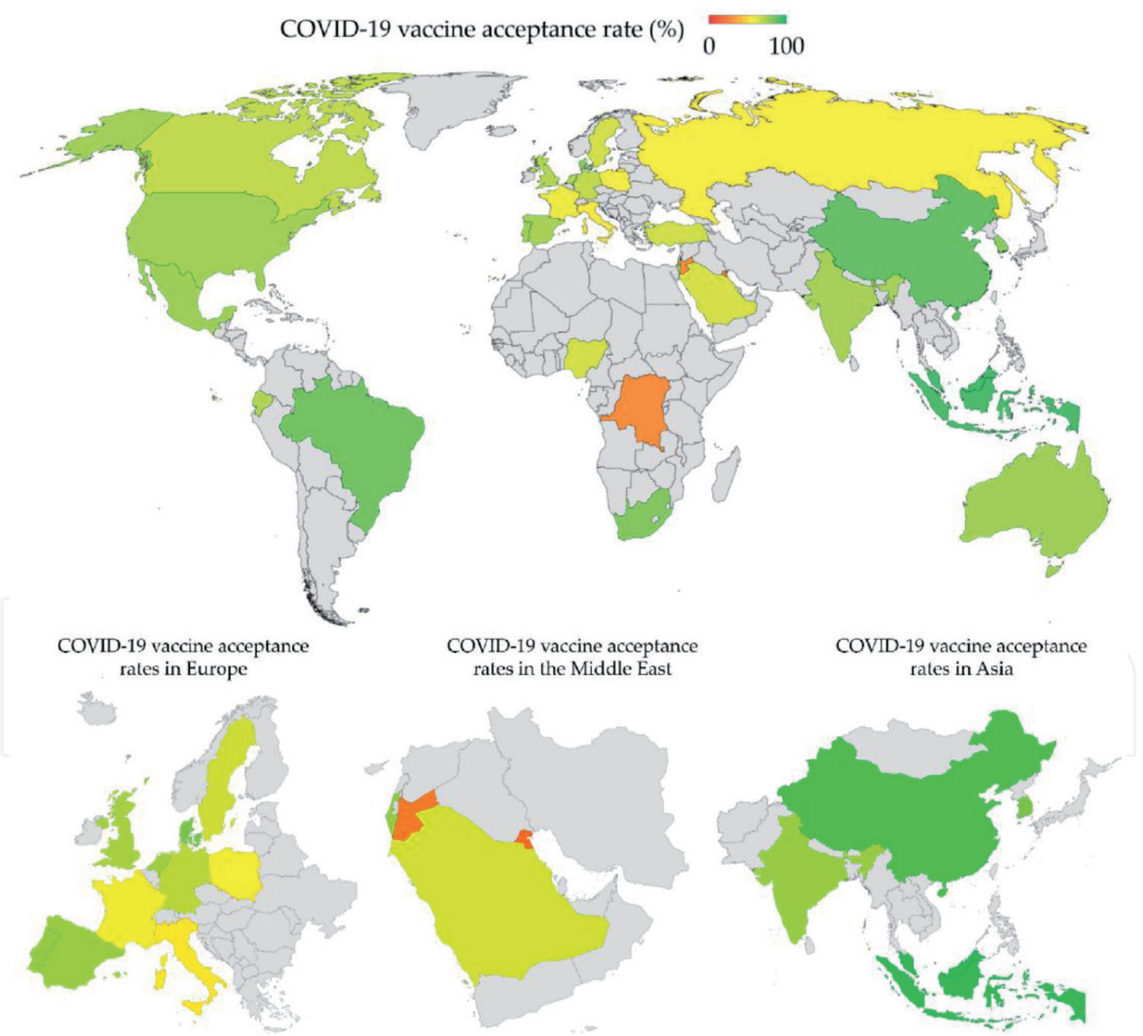

Figure 1.
*"COVID-19 vaccine acceptance rates worldwide. For countries with more than one survey study, the vaccine acceptance rate of the latest survey was used in this graph. The estimates were also based on studies from the general population, except in the following cases where no studies from the general public were found (Australia: parents/guardians; DRC: healthcare workers; Hong Kong: healthcare workers; Malta: healthcare workers)." Source: Reproduced from "**Figure 2:** COVID-19 vaccine hesitancy worldwide: A concise systematic review of vaccine acceptance rates" by Malik Sallam. Licensee MDPI, Basel, Switzerland. Made available under the CC by 4.0 license.*

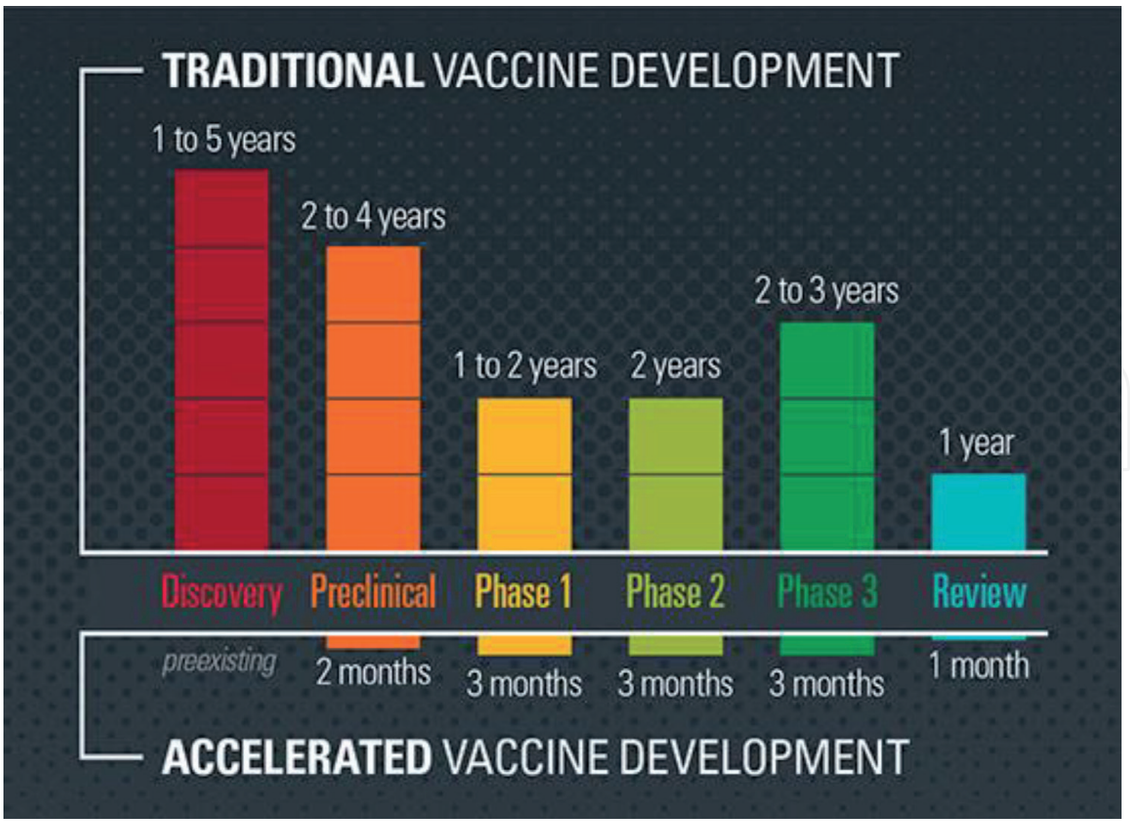

Figure 2.
Traditional vs. (accelerated) Covid-19 vaccine development timeline. Source: GAO analysis of Food and Drug Administration (FDA), pharmaceutical research and manufacturers of America, and Operation Warp speed information. | GAO-21-319.

27, 2021, over a month after the first vaccine approval. Multiple analyses of the U.S. vaccine timeline have dubbed this period, between the late summer of 2020 and early spring of 2021, the "lost time" in the fight against the Covid-19 pandemic [5].

Thus, a question emerges. What could have been done to quell the impending rise of vaccine-hesitant individuals (**Figure 1**)? Here we find a great model in annual influenza immunization campaigns. The initiatives are backed by decades of research showing that a multi-disciplinary collaboration consisting of providers, public agencies, and private sector companies is needed to adequately address questions and instill confidence in individuals regarding upcoming vaccines. The word upcoming is critical in this context, as the marketing campaign is kicked off months BEFORE the first jab is expected to be given. Consequently, a logical time to begin educating individuals on the developing Covid-19 vaccines likely would have been months before the first approval. Unfortunately, the movement did not catch enough support, and we may never know the difference this may have made on vaccine hesitancy levels during the rollout.

During this "lost time," as mentioned, very little data exists surrounding vaccine hesitancy levels via traditional cross-sectional studies/surveys. Most statistics cited are taken from public opinion polling, which asked individuals their opinion on various aspects of the pandemic and, specifically, whether they intended to receive a Covid-19 vaccine if and when it is approved. To continue with the U.S. example, a poll taken in July 2020 showed that only 42% of Americans were considering getting vaccinated, with lower rates among minority groups, who are disproportionately affected by Covid-19 in both hospitalization and mortality rates [6]. Fast forward to November, and that number had not changed. However, the percentage of anticipated uptake among Black Americans had gone down [7]. Hence, we have our disparity: billions of dollars and public resources were given to vaccine

development, while virtually no attention was given to promoting the vaccine among its intended populations.

But what could have caused this? How did millions of individuals in one of the most developed nations in the world with access to social media, news outlets, and governmental information not warm to the greatest vaccine development feat in modern history? Well, aside from the missing vaccine marketing campaign, other factors must have been at play to erode public confidence and stall optimism in the wake of the surging pandemic. Of these factors, one was very preventable and remains a global barrier to vaccine administration: myths. That is, myths surrounding virtually every aspect of vaccine production, trials, administration, and long-lasting effects. Such myths, circulated at large with the rise of unverified outlets (e.g., social media), have the ability to reach a mass audience with little recourse. A potent example lies in the fact that one false statement from a well-known celebrity can potentially reach hundreds of millions of viewers before any official rebuttal or correction is offered. Therein lies the challenge in combatting myths, reliant on the public's level of trust in public health officials compared to those spouting such research-lacking claims [8]. To accomplish this on an individual level, like all delicate encounters, requires both first-hand knowledge and effective communication techniques. While the latter two are character traits that may or may not be improved (see Section 2), the first is an area that deserves a review.

2. Addressing vaccine myths

Before diving in, it is worth reiterating that countering vaccine hesitancy, similar to the definition itself, is not a one-size-fits-all approach. The knowledge laid out below will provide a foundation for providers and the general public alike to interact with and have fruitful conversations regarding common misconceptions. However, there are extraneous principles that are important and necessary to follow to maximize such opportunities. A 2018 study out of the Thomas J. Long School of Pharmacy and Health Sciences identified several successful strategies that can be used to improve confidence and decrease hesitancy levels in recipients. Even more impressive is that the study involved pharmacy students rather than licensed medical providers, decreasing the likely power differential and knowledge gap seen in clinical practice [9].

The first viable strategy found was that of rapport. For example, a commonplace argument for vaccine aversion is that "vaccine side effects are worse than the disease itself." Instead of trying to ramble off a dozen facts and figures, a better solution was found in asking patients to boil the fear down to a specific side effect (e.g., headaches, diarrhea, etc.). Once this was done, the student could dig even deeper to determine if the patient had personally suffered or had a family history of suffering from such symptoms. From here, rapport could be established, and a risk–benefit analysis consisting of actual data would be much more appropriate than trying to combat the entire notion that vaccines should be "side-effect free." Now, this may seem like a "no brainer." However, one may not know as much as they think about their friend's/family member's health if they only interact once a year. Thus, it may be wise to take a deeper dive, regardless of relationship, before countering their pre-existing vaccine perceptions.

Once rapport has been established, a winning strategy is to start with the positives rather than harping on rare side effects and complications. A popular starting point would be explaining vaccine-driven herd immunity and how community protection is the basis for eradication/control of nearly all major outbreaks. Next, a solid turning point would be to suggest that they resist looking to unqualified

personnel (on social media, television, etc.) and talk to an actual expert on the topic, such as their physician or pharmacist. Another important goal is to evaluate an individual's level of knowledge about the vaccine. Studies have shown that greater education simply about the vaccine itself and how it works can lower levels of hesitancy [10]. Thus, they do not need to walk away agreeing with you; simply informing them about how the vaccine works (mRNA technology, viral vector, etc.) is a step forward in our book. Then, it is important to assess their current risk–benefit stage. Two popular dimensions used are an individuals' perceived likelihood of harm and perceived consequence severity if that harm were to occur [11]. Narrowing this down, similar to establishing rapport, is key to addressing underlying fears/aversions. Consequently, it is also important to establish their "best-case scenario." They likely want the same endpoint for society (eradication/negligible transmission). Using this as common ground and talking about realistic paths toward getting there is an excellent segway into discussing current research projections.

Two factors that cannot be ignored are that of socio-cultural pressure and religious convictions. Unfortunately, these are very hard to change in the long-term, much less in the course of a single conversation. Leveraging the idea of social responsibility, where an individual has a sort of role to play in achieving herd immunity for the betterment of those around them, has proven effective. However, a fine line should not be crossed so as to force down a specific belief on individual behavior [12].

These research-driven strategies may or may not be enough to build your communication arsenal the next time a patient, friend, or loved one mentions hesitancy toward vaccination. However, striving for rapport, providing judgment-free educational information, and being knowledgeable about all components of vaccine development and administration is a recipe for success in this fight toward ending the Covid-19 pandemic and future pandemics to follow. Speaking of knowledge, perhaps you are wondering what myths exactly are circulating about Covid-19 vaccines. If so, let us address your eagerness (not hesitancy).

3. High-yield vaccine myths to know

Recent studies have identified five common myths surrounding Covid-19 vaccines [13, 14]. Let us break them down one by one, separating fact from fiction.

3.1 Myth #1: getting the Covid-19 vaccine will give you Covid-19

To date, no vaccine authorized or in development in the U.S. contains the live SARS-CoV-2 virus. Thus, receiving a Covid-19 vaccine cannot and will not cause Covid-19 infection. However, symptoms seen in common viral infections can arise due to the body's immune response to the vaccine's mechanism of action. Symptom presentation and timelines can vary among different vaccine types and recipient demographics. Generally, the most common symptoms seen in Covid-19 vaccinated individuals are injection site pain, fever, muscle pain, fatigue, and/or headaches. These are a completely normal and benign response as the immune system detects the vaccine components and begins adapting to fight off an actual Covid-19 infection, should that individual get exposed. These side effects typically occur within 24–48 hours post-vaccination. Experts often refer to this as a "good sign" that your immune system is building a response to battle future infections. While this period generally contains a mild presentation, there are steps you can take to alleviate side effects that arise. The first is to use an ice pack or damp cloth to reduce injection

site pain/soreness. Next is to take an over the counter (OTC) pain reliever such as acetaminophen. Finally, finding ways to de-stress (e.g., taking off of work, self-care routine) is always a good idea to strengthen your immune system [15].

3.2 Myth #2: vaccine development was rushed and unreliable

In this instance, it is helpful to begin by confirming one of the assumptions of this myth: that the Covid-19 vaccine was developed in record time [16]. Yes, there is some merit to this assumption. However, the other two assumptions are where this myth fails to hold water: that corners were cut, and safety was inherently not ensured as in traditional vaccine development/supervision. There are two possibilities in this discussion that are important to recognize before diving in: (1) the individual holds this distrust regarding all vaccines (or at least the idea is not confined to the Covid-19 vaccine development) or (2) the individual solely holds this belief surrounding Covid-19 vaccine production. If the former, then the individual needs to be counseled about basic vaccine development facts as a whole. If the second is the case, then the argument becomes much more straightforward: how did/does Covid-19 vaccine development compare to previous vaccines? For this, we can look to historical data and the "usual" timeline, step by step (**Figure 2**). So how exactly are vaccines made?

3.2.1 Discovery (1-5 years)

The discovery phase generally consists of learning all aspects of the microbe we are trying to combat (e.g., structure, mechanism of action, etc.) Once SARS-CoV-2 was identified as a type of coronavirus, researchers were able to sequence its genome. From here, the spike protein was selected as a unique target based on its function allowing the virus to penetrate host cells and cause infection. Additionally, the spike protein had been targeted before against the Middle East respiratory syndrome (MERS) coronavirus. This precedent allowed the discovery phase to be accelerated to weeks or months rather than years.

3.2.2 Preclinical (2-4 years)

The preclinical stage generally consists of sifting through potential antigens (such as the spike protein) and deciding which will produce the best immune response and long-lasting protection. This is determined by assessing the safety of candidates for each antigen in cell and tissue cultures as well as in live animal testing. Traditionally, studies are performed on rats and mice; however, the rise of transgenic "humanized" mice, genetically modified with human genetic components, has aided in generalization toward human bodily responses. Researchers must also determine appropriate dosing and delivery form (e.g., injection, pill, etc.). Once this has been completed, the candidate vaccine moves on to the clinical stages. And how did this notoriously tedious process happen so quickly in the case of Covid-19? One example was found in March 2020, when Janssen reported that their novel technology platform, used in its Ebola and novel RSV and HIV viral vector vaccines, was effective against Covid-19. Thus, decades of research on the platform's delivery mechanism, ideal thresholds, and animal study proof-of-concept were utilized to jumpstart the development timeline.

3.2.3 Phase I clinical trial (1-2 years)

The main goal of a Phase I trial is to show that the vaccine is safe in humans and how the body receives it. A small group of volunteers is enrolled. Careful attention

is given to signs of adverse events, such as toxicity, organ damage, and death. After the trial is completed, data is analyzed and submitted to the FDA for approval to begin Phase II trials. The FDA has the ability at any point to intervene if one or more serious adverse events are found. If a treatment has already been shown to work for a different condition, the Phase I trial can be shortened or accelerated to Phase II since the vaccine has proven safe in human patients. As was the case with Covid-19, multiple manufacturers were able to combine Phase I and Phase II trials since the steps can be done in parallel without compromising oversight. The experience with the delivery system used for Ebola in Janssen's case is a key example.

3.2.4 Phase II clinical trial (2 years)

Phase II trials primarily focus on narrowing down the ideal dosage to maximize effectiveness and limit side effects. A larger patient population is used. Patients are assigned to multiple groups with varying doses, delivery methods, or controls to compare outcomes. All treatments given have been previously tested (including placebo or current vaccine standard), and this step is meant to pick a "best" scenario. When the trial concludes, the results of each group are compared to determine if the vaccine is better than current treatment/vaccine resources and, if so, ideal dosing/delivery. This is a major checkpoint whereby the FDA can either discontinue the study due to adverse events/ineffectiveness or push it through to Phase III trials.

3.2.5 Phase III clinical trial (2-3 years)

The main hallmark of a Phase III trial is its size, typically around 3,000 participants. Enrolling this many patients with a disease can be a drawn-out process depending on disease prevalence and geographical distribution, often lasting several years. Perhaps the most remarkable feat of the Covid-19 clinical trial race was the ability of vaccine studies to enroll record numbers of patients in record time. Take, for instance, the Pfizer Phase III trial, which recruited over 43,000 participants in just four months. This magnificent accomplishment was able to both shave off precious time and instill greater confidence in the public and scientific community due to the sheer sample size. After all, the number of participants was over ten times greater than that of a typical vaccine candidate. One might argue that this was an invaluable marketing strategy given the shortened development timeline. While this is likely true, it is important to realize that corners were not cut in enrolling patients either. On the contrary, pharmaceutical manufacturers worked with epidemiologists to ensure that the patient population recruited for the studies was representative of the target population for vaccine administration. In layman's terms, groups that are typically hard to reach in general studies (e.g., underserved groups, those at highest risk of transmission) were given priority in enrollment efforts. Once all trial data is compiled, a New Drug Application (NDA) is filed with the FDA, asking for consideration to bring the vaccine to market.

3.2.6 FDA approval/review (1 year)

One cannot understate the amount of administrative burden and patience that goes into reaching this point, much less achieving FDA authorization. A common question asked by patients after witnessing the Covid-19 spectacle is, "Why can't we approve everything this fast?" An excellent question, indeed, given the abundance of vaccines needed for incurable diseases. To answer this, let us talk about what goes into the FDA's decision once an NDA hits its desk. The first component a manufacturer must prove is that the vaccine is safe and effective throughout all clinical

trial data. From here, the decision moves toward logistics. Is there a manufacturing process in place? Can this process consistently meet the needs of the general public? Are the batches equivalent to clinical trial data in terms of effectiveness and safety? If all of these boxes are checked, then approval is a possibility. Several panels meet to consider the vaccine data submitted for approval and licensure/regulation grants. The reason for the year timeline is based on a variety of factors. First, a large percentage of applications are incomplete, with required studies missing. Next, a candidate is put on a priority ranking list in which drugs are reviewed based on global need. Then, the FDA must meet with sponsors to ensure no corners were cut and that transparency was insured. Finally, an in-depth manufacturing analysis must be conducted to ensure that the vaccine distribution can meet the global needs of world populations (especially underserved and at-risk groups).

As another wonder of Covid-19 vaccine development, two decisions were made that cut the necessary FDA review period down to less than three weeks: parallel review and anticipatory manufacturing. Since the Covid-19 pandemic was logically considered priority #1, all possible resources were given to evaluate and approve/reject clinical trial data upon submission. Additionally, trial transparency and adverse reaction monitoring was performed concurrently to ensure proper oversight. These cut the typical six-month to one-year delay off of the majority of pre-NDA phases. Anticipatory manufacturing, the production of unapproved vaccines in anticipation of approval, was a previously unproven idea that investing in potential candidates would be cost-effective in the long run and shave previous months or even years off the vaccine distribution timeline. Consequentially, this could save millions of lives by slowing the pandemic morbidity and mortality. This gamble has proven largely successful in the early months of vaccine rollout, and specific examples can be found under the "Introduction."

3.2.7 Manufacturing (6 months-3 years)

As mentioned, anticipatory manufacturing was the key to jumpstarting the vaccine production timeline. Currently, AstraZeneca/Oxford is producing an astounding 200 million doses of their Covid-19 vaccine per month. To give perspective, during the H1N1 outbreak, AstraZeneca was able to produce only 17 million doses of their H1N1 vaccine. That represents a roughly twelve-time increase in production compared to the previous pandemic [17]. While this is not a perfect comparison given differing circumstances, it is both probable and likely that the jumpstart in production and massive funding overhauls contributed to maximizing vaccine production.

3.2.8 Phase IV clinical trial (optional)

Phase IV trials are studies of adverse serious events and safety hazards that arise once a vaccine is approved and made available on the market. The FDA carefully monitors such instances through MedWatch, a service allowing providers, patients, and the trial sponsor to report a suspicious event. At any point, additional Phase IV trials may be commissioned by the FDA or sponsor to examine vaccine effects for varying benefits, risks, and patient populations [18].

3.3 Myth #3: the only way to reach herd immunity and end the pandemic is by letting the virus spread

Herd immunity has risen to prominence in both the scientific community and the general public due to its unique role in infectious disease outbreaks. To set the

record straight, herd immunity is the only proven method of definitively preventing the spread of infectious diseases to the point of being statistically irrelevant. This is achieved by a large percentage of the population, called the herd immunity threshold, being protected from infection (**Figure 3**). Consequently, the unprotected (e.g., uninfected individuals, individuals who cannot or choose not to get vaccinated) also become protected due to the interrupted transmission chain. This part, in most cases, is largely understood. Where the record gets bent is in HOW herd immunity is reached. It is important to understand that there are two routes by which herd immunity can be achieved: natural infection and vaccines [19].

3.3.1 Natural infection

When enough individuals in the population have recovered from a specific disease and developed lasting antibodies against future infection, herd immunity can theoretically be reached. However, the issue with this myth's underlying assumption is that relying on natural infection alone ignores two common deviants: reinfection and health toll.

While admittedly, the evidence for reinfection risk is limited given the novel nature of the pandemic, there have been clear instances of Covid-19 reinfection in the community. This phenomenon is dependent on an individual's antibody levels and appears to heighten in risk between six months to a year. Significant reinfection incidence can substantially harp a community's progression toward herd immunity due to waning antibody responses.

While a community could theoretically remove all protective measures and allow the disease to run rampant until herd immunity is achieved, this would allow the full brunt of the disease to affect the community. In layman's terms, this means that millions of individuals could suffer and potentially die unnecessarily. In July 2020, experts predicted that approximately 70% of the U.S. population would need to recover from Covid-19 infection to slow disease spread. Underlying this number was the reality that more than five million individuals could perish before this feat was achieved. As you can probably guess, such a situation is unacceptable, and hence social protective measures were mandated/strongly encouraged until vaccines could fill their role in ending the pandemic [20].

3.3.2 Vaccines

As mentioned, a strong antibody response against the target disease is key to achieving herd immunity. Vaccines remain the quickest and most efficient way of promoting antibody responses on a mass scale. Unlike natural infection, vaccine-driven immunity does not require illness to achieve protection. Herd immunity has been successfully reached against contagious diseases, including rubella, polio, smallpox, diphtheria, and many more. In the long run, vaccines offer a great way to protect newborns and immunocompromised individuals from disease without suffering from the disease itself. While vaccine-driven immunity is the gold standard in fighting back against pandemics such as the Covid-19 pandemic, it is not without faults. Several barriers remain in the fight against Covid-19 that need to be solved before the world can declare victory. First, vaccine hesitancy, as we hashed out in detail before, is a predominant risk to vaccine uptake. If individuals choose not to get vaccinated, herd immunity becomes much harder to reach. Please see "Introduction" for more details. Next is the issue of protection duration. While preliminary studies have shown adequate antibody levels for at least six months post-infection, the exact antibody level drop-off timeline is unknown. Thus, protection from vaccination may be insufficient and require a "booster" dose down

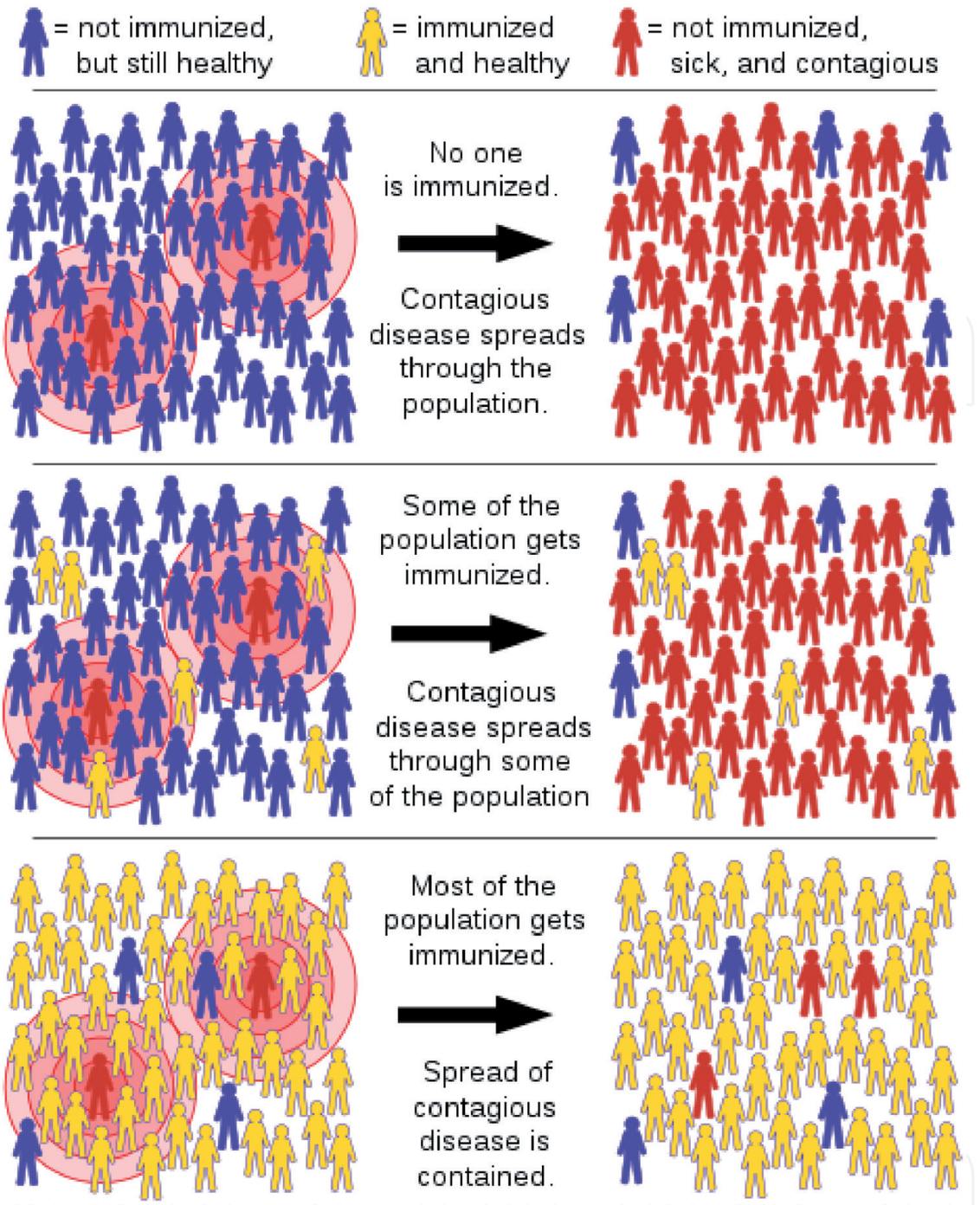

Figure 3.
"The top box shows an outbreak in a community in which a few people are infected (shown in red) and the rest are healthy but unimmunized (shown in blue); the illness spreads freely through the population. The middle box shows a population where a small number have been immunized (shown in yellow); those not immunized become infected while those immunized do not. In the bottom box, a large proportion of the population have been immunized; this prevents the illness from spreading significantly, including to unimmunized people. In the first two examples, most healthy unimmunized people become infected, whereas in the bottom example only one fourth of the healthy unimmunized people become infected." Source: Reproduced from Tkarcher under the creative commons attribution-share alike 4.0 international license.

the road. Additionally, new variants of the Covid-19 virus may be less efficiently targeted by the existing vaccines and require uptake of new vaccines specially made to counter such variants. Finally, outbreak control, while traditionally thought of on a community level, relies on limited transmission in surrounding regions as well. Thus, uneven vaccine distribution and resulting low transmission rates around an area can impact the ability of that area to contain the virus assuming individuals travel to and from [21].

3.4 Myth #4: mRNA technology is brand new

Perhaps the easiest myth to explain, let us state the historical fact: mRNA technology is not new, much less to fighting a pandemic. In fact, mRNA technology was pursued in vaccine research for quick response to a novel pathogen, such as Covid-19. The first studies using mRNA technology were in the 1990s. At the time, experts widely recognized that conventional vaccine types (e.g., live attenuated, subunit, etc.) were not always sufficient to combat pathogens capable of evading the adaptive immune response. Additionally, development and large-scale deployment were obstacles in the face of pandemic-speed response. Early reports showed that the introduction of mRNA could stimulate protein production and therefore antibody production via a disease-specific immune response. While early trials did hit roadblocks due to toxicity and delivery failures, recent advances such as RNA carriers and synthetic delivery have made mRNA engineering much more efficient. Before the Covid-19 pandemic, mRNA technology had been used in vaccine trials for cancer and other diseases for over a decade. However, the Covid-19 vaccines by Moderna and Pfizer/BioNTech are the first mRNA vaccines to receive FDA emergency use authorization. The crucial point here is that the technology is not experimental, has been excruciatingly vetted (see Myth #2), and will likely be a mainstay in vaccine development for future pandemics [22].

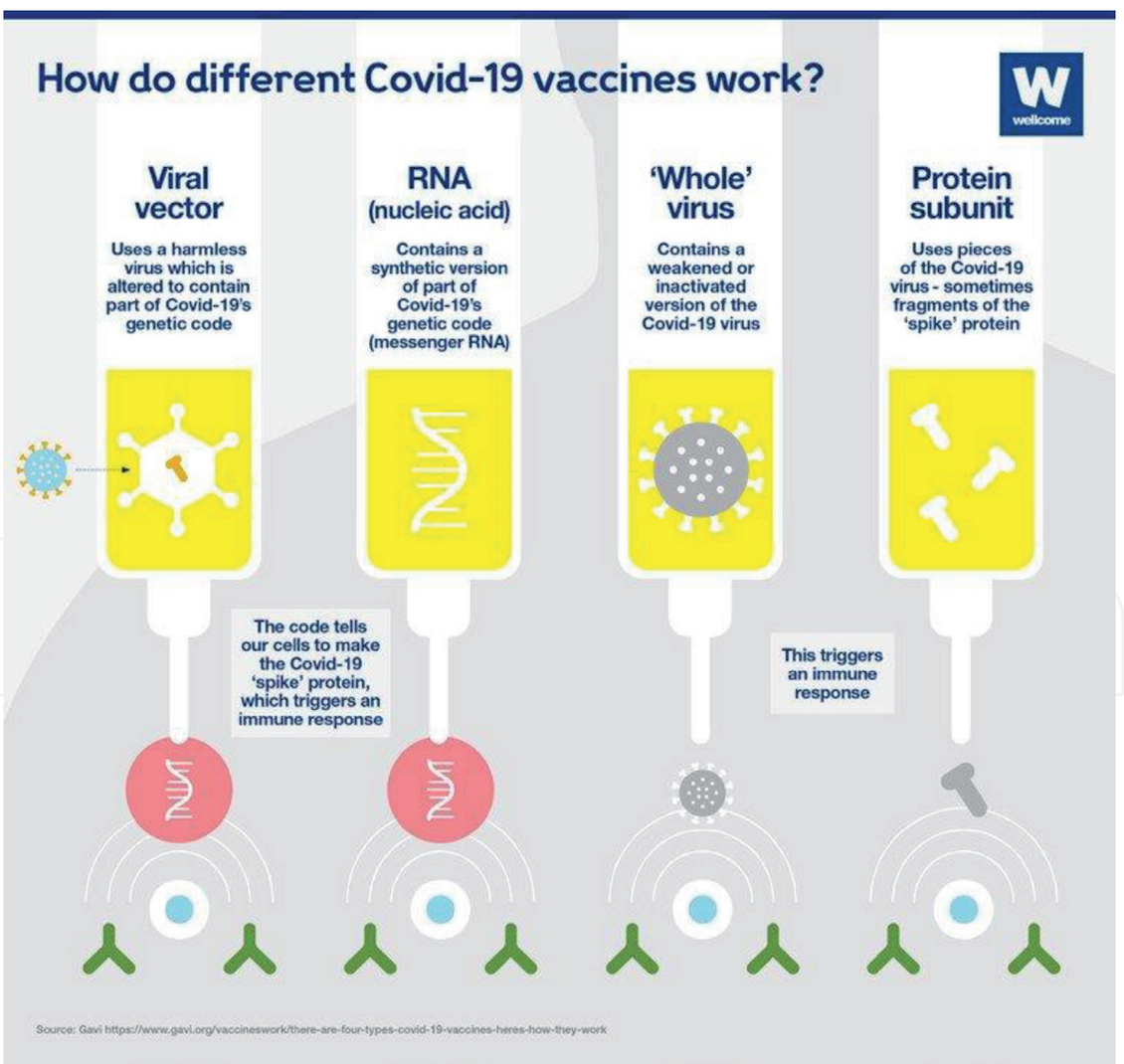

Figure 4.
A diagram showing the mechanism by which various Covid-19 vaccines/vaccine candidates induce an immune response. Source: Reproduced from Gavi https://www.gavi.org/vaccineswork/there-are-four-types-covid-19-vaccines-heres-how-they-work under creative commons attribution 2.0. Licensee the Wellcome Trust: https://wellcome.org/.

3.5 Myth #5: Covid-19 vaccines can alter your DNA

This is a common misconception, likely stemming from the fact that certain vaccines utilize parts of viruses/bacterium as a vector or stimulus to jumpstart the immune system [23]. To give context, we first need to explain the different types of vaccines in use/development against Covid-19 (**Figure 4**).

3.5.1 mRNA

The Pfizer/BioNTech and Moderna Covid-19 vaccines utilize mRNA technology. mRNA is a messenger bridge between DNA and protein synthesis. This process is of high relevance since Covid-19 virus surface proteins, particularly the spike protein, were identified early on. Thus, genetically engineered mRNA can be produced capable of instructing one's cells to make a partial piece of the spike protein that is completely harmless. By introducing raised levels of the spike protein fragments, the immune system will respond by making antibodies to the foreign particles. Upon infection with Covid-19, the body will have a large supply of antibodies ready to crush the virus. While the mRNA does influence body cells to produce protein fragments, it is rapidly degraded and does not enter the cells or influence DNA components [22].

3.5.2 Protein subunit

The Novavax vaccine is classified as a protein subunit vaccine. In this method, segments of a virus known to trigger the immune system are carefully selected. In the case of Covid-19, the vaccine consists of harmless spike proteins (cf. mRNA to stimulate spike protein production in mRNA vaccines). Once introduced, the immune system will recognize the spike proteins and mount an immune response. This will result in antibody formation, creating a reserve if that individual becomes infected. There is no effect on an individual's DNA [24].

3.5.3 Vector

The Janssen/Johnson & Johnson and AstraZeneca/University of Oxford Covid-19 vaccines utilize a vector-driven approach. This means that genetic material from SARS-CoV-2, the virus that causes Covid-19, is inserted into a live, weakened virus such as an adenovirus. The adenovirus serves as a delivery mechanism, allowing the genetic material to instruct your body's cells to make copies of certain proteins. These proteins are pre-selected based on their ability to stimulate the immune system to make antibodies and white blood cells. Consequently, if an individual is then infected with that specific virus (Covid-19), the immune system will be in an excellent position to fight back via rapid antibody production. Individuals who receive a Covid-19 vector vaccine cannot become infected with Covid-19 or the vector virus used as a direct result of vaccination. Additionally, the genetic material inserted does not integrate or become part of an individual's DNA in any way [25].

3.5.4 All vaccine types

In summary, none of the vaccines currently used against Covid-19 have the ability to alter an individual's DNA. Therefore, any such claim is a gross misrepresentation of both molecular processes and modern vaccine technology.

4. Conclusion

The Covid-19 pandemic has brought vaccine hesitancy to the forefront of both public conversation and health marketing research. While global vaccine development succeeded in launching several candidates against Covid-19, the missing link in such race was arguably a collaborative, targeted immunization campaign to inform and raise optimism toward the coming vaccines [2]. As a result, precious months were lost during a pandemic in which over three million lives have been lost [26]. Now, a few months after the initial vaccine rollout, nations are facing a declining yet formidable cohort of individuals who remain skeptical and/or averse to vaccine uptake due to a variety of factors [7]. This poses a serious challenge to communities attempting to reach herd immunity and crush the pandemic once and for all. Healthcare providers enjoy a unique position in society, capable of swaying public opinion through both direct and indirect interactions. Additionally, businesses, religious organizations, and loved ones represent promising avenues of outreach that should be empowered to combat vaccine hesitancy in their respective spheres [2]. While communication setting, skills, and personal relationship all play a role in one's ability to "fight back" against hesitancy, knowledge has a direct correlation with success in this endeavor. Thus, recognizing common myths surrounding Covid-19 vaccine candidate development, production, and administration is key to having fruitful discussions capable of persuading individuals to reconsider vaccination [9]. Herd immunity is closer than ever; it is up to us to band together and defeat misconceptions with research-backed knowledge, humility, and understanding. Together, we can and will crush the Covid-19 pandemic and any that dare to follow.

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Conflict of interest

The author declares no conflict of interest.

Notes/Thanks/Other declarations

Research surrounding the Covid-19 vaccine candidates, vaccine hesitancy response, and public optimism is fast-changing. All data used and studies cited were current at the time of this writing. For up-to-date information, please visit the World Health Organization and/or Centers for Disease Control and Prevention.

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