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Review

The Two Sides of the COVID-19 Pandemic

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Abstract: On 5 May 2023, the World Health Organization (WHO) officially declared the end of the coronavirus disease-19 (or COVID-19) pandemic. Even before the official announcement from the WHO, signs of recovery from the pandemic started appearing, especially after rapid worldwide vaccination. As society is getting back to its usual with each passing day, with the increasing socio-economic activities, discussion of the negative and positive outcomes of the COVID-19 pandemic remain the predominant topic of debate. Through this review, we discuss the bright side of the pandemic without undermining the pain and suffering everyone has gone through in this pandemic. The review also examined the painful side of the pandemic. Therefore, this review can be looked at as a comparison between this pandemic's positive and negative effects. The review discussed aspects ranging from technological development, including mRNA-based vaccines, artificial intelligence-based screening, and telemedicine, to social behavior, from individual to global and from health to the environment. The review also examined the areas needing more attention for managing future pandemics. The review also highlighted what should be followed or continued for our preparedness for any possible pandemic. Toward the end, we also discussed how this pandemic has better prepared the world for future pandemics, as predicted by experts.

Keywords: COVID-19; pandemic; vaccines; social impact; positive impacts; negative impact

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1. Introduction

The term "pandemic" first appeared in 1666 and was defined as the continuous spread of disease in a community or locality [1]. In the contemporary world, a pandemic is described as an epidemic present or prevalent in more than one continent [1]. Human history is filled with pandemics reported as early as 30-26 B.C. until today [2,3]. The most recent pandemic in human history is COVID-19, a viral infection caused by severe acute respiratory syndrome coronavirus 2 (or SARS-CoV-2) [4]. From the start of the pandemic to date, a total of 771 820 937 cases of infection have been reported, with 6,978,175 deaths worldwide (https://covid19.who.int/) (last accessed on 19 November 2023). The overall mortality of COVID-19 infection ranges from 0.05 to 2.5% [5–7]. Mortality or fatality rates differed from country to country or region to region, with age, gender, and prior health condition [8,9]. The death rate was higher in aged or senior citizens and individuals with chronic diseases or clinical conditions like diabetes, renal failure, and hypertension [10–12]. Rapid emergency approval and use of COVID-19 vaccines worldwide remain essential tools in the fight against this pandemic. So far, 13,534,474,309 vaccine doses have been administrated (https://covid19.who.int/) (last accessed on 19 November 2023).

Although the WHO officially declared the end of the pandemic, vaccination against COVID-19 is still ongoing. New COVID-19 infection or re-infection cases are still detected daily, albeit at a low rate. However, the virus still can pose a severe threat, as mentioned by Dr Tedros Adhanom Ghebreyesus, WHO Director-General [13]. Therefore, despite

vaccination and fewer cases of infection, one needs to take necessary precautions. As society is becoming atypical, experts and concerned authorities globally are trying to assess the impact of the pandemic. Through this review, we compare the positive and negative effects of the pandemic and how this pandemic will change the world. We briefly highlight the negative aspects of the pandemic with more focus on the impact of the pandemic on healthcare workers (HCWs), followed by a discussion of critical positives. Some topics of note, including virus multiplication, composition, structure, transmission, infection, and symptoms are skipped intentionally as the same are discussed by others [14–17].

We include as many points as possible from the pandemic's positive and negative sides; however, we may miss some issues. Therefore, this review may not be a comprehensive account of the pandemic's negative and positive impact. Still, it provides the overall effect of the pandemic we all faced and the way the world changed after it.

2. The Darkside of the COVID-19 Pandemic

Before discussing the positive impact of the pandemic, it is essential to briefly highlight the dark side of the pandemic. This discussion will help us better appreciate the impact of the pandemic on the life of an individual or society as a whole.

COVID-19 infections and associated deaths have been reported from around 231 countries, thus covering the entire world (https://www.worldometers.info/coronavirus/) (accessed on 15 September 2023). By the end of the year 2021, about 270 million individuals were reported positive for COVID-19 infection, resulting in approximately 5.3 million deaths worldwide [18]. Despite effective vaccines, their distribution remains significantly unequal, and new waves of cases and variants persistently arise [19]. So far, the COVID-19 pandemic remains the most widespread viral infection compared to any previous pandemic in human history [2,20]. Because of its worldwide distribution, the pandemic has profound impacts ranging from personal to global and social to environmental [21]. Apart from the loss of life, COVID-19 infection also leads to long-term health issues due to damaging effects on different organs [22]. COVID-19 infection also leads to anxiety, depression, and other mental or neurological problems in infected and uninfected individuals [23,24]. COVID-19 also increases secondary microbial infection [25], including bacterial infection, fungal infection, or both [26–28]. The importance of fungal infections is discussed separately [29].

It is not just loss of life and other health issues; the COVID-19 pandemic also increased the problem of unemployment due to mass layoffs despite working from home [30]. Increased work from home and online education means all the household members are at home. It leads to mixing work and personal life and sometimes to a loss of mental peace, physical fights, and verbal spats [31,32]. Increased layoffs, unemployment, and the rising cost of living put an extra financial or economic burden on families [33]. COVID-19, due to lesser economic activity, leads to significant inflation worldwide [34]. Because of enormous pressure on the health sector, regular treatment and clinic visits have become challenging during the pandemic [35]. Restrictions on movement due to lockdown at both the local and national levels led the tourism industry to essentially collapse [36].

The COVID-19 pandemic also led to an increased generation of biomedical waste in the form of vaccine vials, needles, masks, sanitizer bottles, and gloves [37,38]. The increased biomedical waste and the lockdown also affected regular waste management [39]. Restricted movement, strict lockdown, and the shutdown of production units during the pandemic disrupted the global supply chain [40]. During the pandemic, lockdown increased illegal activities, including illegal mining, poaching, and wildlife trafficking [41]. The COVID-19 pandemic hampered vaccination programs [42].

Some other impacts of the COVID-19 pandemic include increased poverty and increased poverty rate. According to UN reports, around 71 million people have been pushed back into poverty in just a few years [43]. Apart from this, it is believed that the COVID-19 pandemic will keep pushing more people below the poverty line [44]. One of the reports from UNICEF predicted that this pandemic could cause more child labor, especially in developing and underdeveloped countries [45]. Apart from the mentioned adverse effects

of the COVID-19 pandemic, several more need to be discussed and have been discussed by others [46].

3. COVID-19 Impact in Developing Countries and Resources Disparities

The COVID-19 pandemic exposed inequalities(in terms of PPE or personal protective equipment, vaccines, and other infrastructure needed to tackle or handle the pandemic). It is vital to discuss these disparities so that they can be taken care of or for making policies for better management of possible future pandemics. We will briefly touch on this aspect to sensitize the reader towards this critical and often neglected topic. Detailed accounts of different inequalities or disparities, including social, economic, and health infrastructure, can be found elsewhere [47–51].

A study performed by Arsenault and co-workers (2022) [52] evaluated the effects of COVID-19 on thirty-one health services in ten countries that differ in terms of health expenditures, health system structures, the severity of COVID-19, and the national approaches taken to respond to the pandemic. Countries such as Ethiopia and Haiti (low-income countries); Ghana, Lao People's Democratic Republic, and Nepal (lower-middle-income countries); Mexico, South Africa, and Thailand (upper-middle-income countries); Chile and South Korea (high-income countries) were studied. The authors found that despite endeavors to uphold healthcare services, disruptions of varying extent and duration were identified in every country, with no discernible patterns based on country income group or the intensity of the pandemic. Such disruptions often preceded the onset of COVID-19 waves. Critical health screenings such as cancer, tuberculosis, and HIV testing experienced substantial declines ranging from 26% to 96%. Nationally, total outpatient visits saw a 9% to 40% decline, persisting below predicted levels by the conclusion of 2020. Approximately half of the countries encountered disruptions in maternal health services, with declines ranging from 5% to 33%. Although child vaccinations faced shorter disruptions, there are concerns that catch-up campaigns may have yet to reach all missed children. Notably, the provision of antiretrovirals for HIV remained unaffected. As of the end of 2020, significant disruptions persisted in half of the countries, and preliminary data for 2021 suggest that these disruptions likely endured. Therefore, nations should strategize and allocate resources to enhance their healthcare systems' resilience to handle future emergencies better.

Furthermore, the accessibility of vaccines and PPE differed broadly among various countries, and factors such as manufacturing size, distribution, international collaborations, and individual nations' vaccination strategies impacted the timing of their receipt. Most developed countries are privileged to secure early access to vaccines, PPE, and other life-saving equipment, such as ventilators, for front-line workers and the general population. On the other hand, underdeveloped and developing countries faced challenges procuring adequate vaccine dosages, PPE, and ventilators. To ensure sufficient supply of vaccines and PPE to low- and middle-income countries, initiatives like COVAX [https://www.who.int/initiatives/act-accelerator/covax] (accessed on 15 September 2023), efforts from NGOs, and international collaborative efforts played a crucial role in their distribution. PPE and vaccine receipt timing also varied between developed and underdeveloped/developing countries. Regulatory approvals, production capabilities, global supply chain constraints, and geopolitical considerations were responsible for the timing variation [53–56].

4. The Impact of the Pandemic on Healthcare Workers (HCW)

In the previous section, we highlighted the inequalities or disparities exposed by the pandemic. Through this section, we would like to discuss the negative impact of the COVID-19 pandemic on HCWs. Examining the effects of the COVID-19 pandemic on HCWs is essential for several reasons. For example, HCWs are the most vulnerable group in the community. Because of their continuous contact with infected individuals, they suffer from a high infection rate. It was observed that HCWs have a 10-fold higher infection rate [57], thus making them most susceptible to disease. This can be seen in a sudden increase in HCWs' death rate during the pandemic [58,59].

Unlike other professionals who can work from home or asked to stay at home, HCWs do not have this provision. Apart from a high incidence of infection, HCWs are overburdened during a pandemic. HCWs also reported physical abuse and manhandling on several occasions, thus further adding to their miseries [60].

HCWs from minority groups further suffer from disparities in the number of working hours or workload and access to PPE [53]. Recent data showed high rates of suicide, enhanced problems of burnout, anxiety, and insomnia, and more psychological stress [61,62]. HCWs also suffer from the fear of bringing the infection home and depression due to the loss of colleagues [63]. Further discussion and summary of the negative impact of the pandemic in general and COVID-19 in particular on healthcare workers can be found elsewhere [64].

5. The Impact on the Healthcare Sector

So far, we have highlighted the negative impact that the COVID-19 pandemic has had on the lives of everyone. However, as the world is returning to normal, at least some sections of society, if not everyone, are now talking about the aftereffects of COVID-19, i.e., how this pandemic changes the world around us in a positive way. Therefore, we compiled the positive changes that COVID-19 brought to this world. We will discuss the positive impacts of the pandemic briefly. The positive and negative outcomes of the pandemic are shown in Figure 1. Several of the positive consequences may be of short duration.

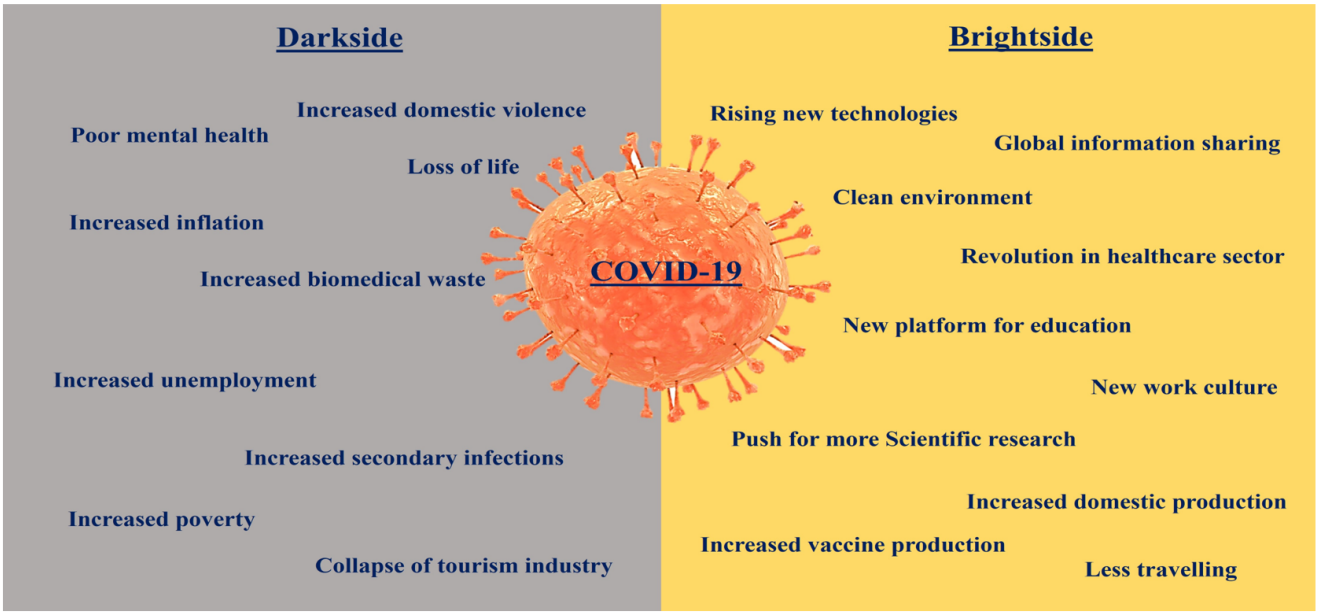

Figure 1. Schematic showing the positive and negative impact of the COVID-19 pandemic. Note: The figure may not include all the implications and should be seen as a mere comparative view.

5.1. The Arrival of mRNA-Based Vaccine Technology

The most apparent and positive aspects of the COVID-19 pandemic are the arrival, application, and acceptance of mRNA-based vaccines [65]. Under a typical scenario, the FDA (Food and Drug Administration) or regulatory authorities took a long time (from a decade or more in some cases) [66] before approving any drug or vaccine for public use. However, the approval for emergency use of mRNA-based vaccines worldwide showed that this vaccine development platform is safe, effective, and reliable. This is important as this opens the doors for the possible use of mRNA-based vaccines against other infectious diseases like malaria and leprosy, where developing a vaccine using conventional methods is not feasible. Also, the mRNA-based vaccine is an essential means of cancer therapy [67,68].

The acceptance of mRNA-based vaccines is significant as this boost companies' confidence, thereby increasing research and development related to mRNA-based vaccines. It is important to note that immunity provided by mRNA-based vaccines is for only a short duration (immunity lasts only for a few months) in general [69]. Besides short-term immunity, mRNA-based vaccines also need ultra-low temperatures during distribution and storage [70]. However, the fast manufacturing processes and safe and effective nature make mRNA-based vaccines a reliable platform for vaccine development. Different mRNA-based vaccines are shown in Table 1.

Table 1. Different mRNA-based vaccines along with their clinical status.

Disease (Nature)	mRNA	Protein	Company/Sponsor	Status	Reference
Coronavirus (viral)	mRNA	Spike protein	Pfizer, Moderna	In public use	
Zika virus (viral)	mRNA-1893	NCT03375047	Moderna	Phase-II clinical trials completed	NCT04917861
Respiratory syncytial virus (viral)	mRNA-1345	Prefusion F glycoprotein	Moderna	Phase-III clinical trials	NCT05330975
Rabies (viral)	CV7202	Rabies virus glycoprotein	CureVac	Phase-I clinical trials completed	NCT03713086
Chikungunya (viral)	mRNA-1944	Anti-CK virus mAb	Moderna	Phase-I clinical trials completed	NCT03829384
Melanoma (cancer)	BNT111	TAAs (NY-ESO-1, MAGE-A3, tyrosinase, and TPTE)	BioNTech SE	Phase-II clinical trials	NCT04526899
Cystic fibrosis (genetic disorder)	MRT5005	CFTR protein	Translate Bio, Inc.	Phase-II clinical trials completed	NCT03375047

5.2. Boost for Telemedicine

Restricted movement due to the lockdown, followed by the burden of COVID-19 patients, made regular doctor visits nearly impossible. During that time, the general population and patients started consulting doctors or healthcare providers through different platforms, including telephone, text messaging, and video conferencing. Thus, the pandemic gave a significant push for the use of telemedicine [71]. Before the pandemic, people rarely used telemedicine and preferred physical clinic visits. Although the pandemic gave a powerful impetus for telemedicine, many things need to be improved before the world can take full advantage of this technology. Uninterrupted internet or telephone service, followed by the availability of healthcare professionals, remains essential for successful telemedicine use. Telemedicine is crucial as it reduces or minimizes travel, reduces chances of infection (as a result of clinic visits), and is more economical. Other benefits and drawbacks of telemedicine are discussed separately [72].

5.3. Increased Production Capacity of Vaccines

Not only is the arrival of new technology in vaccine development (discussed above) seen as a positive takeaway from COVID-19, but a dramatic increase in vaccine production capacity can also be said to be a positive from the pandemic. The dramatic increase in production capacity is possible not only due to the adoption of new platforms for vaccine development but also an increase in production units worldwide. Apart from a few leading producers or suppliers of vaccines, including India, China, and the USA, several other countries have started their vaccine manufacturing [73]. Therefore, in case of any future pandemic, there will be less issues of vaccine availability. This is important as it was seen that developed countries had the first access to COVID-19 vaccines, and underdeveloped countries in Asia and Africa received their share of vaccines last, thereby creating a vaccine divide or inequality [74].

The increased number of vaccine manufacturing players means that major vaccine-producing companies' monopolies can no longer prevail [75,76]. It will also reduce the burden or pressure from existing manufacturing units, reduce vaccine availability delays, and boost global vaccination campaigns. Since more countries will produce vaccines, the competition may also lower the vaccine cost.

5.4. Increased Production of PPE

The rapid spread of COVID-19 infection, followed by the mandatory use of gloves and masks by everyone, led to a shortage of PPE for HCWs and common masses [77,78]. Setting up more production units to meet the sudden increase in demand for PPE was done on a vast scale. Apart from setting up new units, there was a significant enhancement in the production capacity of previously available units.

5.5. Development of an International Program for Vaccine Development and Production

The WHO runs global vaccination programs year-round. But to meet the need for a COVID-19 vaccine, the WHO adopted an international collaborative program (known as COVAX or COVID-19 Vaccines Global Access). COVAX allowed equitable access to COVID-19 vaccines. COVAX is a joint effort led by the Coalition for Epidemic Preparedness Innovations (CEPI), Gavi, the WHO, and UNICEF (https://www.who.int/initiatives/act-accelerator/covax) (accessed on 15 September 2023). COVAX ensures that vaccines are available to every country regardless of financial status. Such programs are essential for proper vaccine distribution and availability during future pandemics.

5.6. Increased Testing Capacity

During the early days of the pandemic, in the absence of vaccines and treatment, preventing viral spread by identifying infected individuals followed by isolation or quarantine was the only way to tackle the virus [79]. However, limited testing capacity and delayed results led to virus spread. The government or associated authorities set up more testing centers to meet the demand. The testing capacity of existing facilities was also increased by running twenty-four hours a day, seven days a week [80]. The increased number of testing facilities ensures the timely outcome of tests and minimizes the possibility of samples going bad. If these facilities are maintained properly, these facilities can prove highly important for any future pandemic. Apart from this, those facilities can be used during testing under normal conditions or during epidemics.

5.7. More Focus on Improving and Developing Healthcare Infrastructure

Within just a few months after the beginning of the pandemic, the healthcare infrastructure started feeling pressure, and during the pandemic's peak, the infrastructure essentially collapsed. The collapse of health infrastructure was common in developed and underdeveloped countries [81,82]. During the pandemic's peak, hospital beds, ventilators, and oxygen cylinders were unavailable [81,83]. This pandemic showed the healthcare system's weakness or fragility and provided an opportunity to improve and develop the healthcare system for any possible future pandemic [84].

6. AI-Based Health Screen, Tracking, and Monitoring

Since the COVID-19 viral infection is highly contagious and can infect individuals of all age groups, there has been a sudden burst in the number of viral infections. On several occasions, countries like the USA and India reported nearly 500 thousand cases daily during the pandemic's peak. This puts extra pressure or burden on testing facilities. Even after increasing the number of testing facilities and increasing the testing capacity of existing facilities, there was a long delay in testing. This delayed testing also helps in virus spread and negatively affects the suitability or applicability of contact tracing [85]. To sort this out, AI-based daily health screening and self-reporting proved highly valuable [86]. This significantly reduces the burden on testing facilities and lowers the work pressure of

physicians [87,88]. Screening based on symptoms, travel history, and community accurately predicts infection. This allowed the infected or potentially infected individual to undergo self-quarantine, thus further helping to prevent the spread of disease. Since AI-based health screening is internet-based and can be done even using an app on a mobile phone, this allows the screening of millions of individuals daily.

The availability or use of AI-based screening in any future pandemic may prove highly valuable. Indeed, the push towards using AI applications in the health sector, especially during and after the COVID-19 pandemic, is a significant outcome of the COVID-19 pandemic.

7. New Dimension in Education

Since the WHO declared COVID-19 a pandemic, strict lockdowns by governments, colleges, and academic institutes have followed online learning. All teaching and exams were performed online [89]. Online courses offer several advantages, like no commute to school and back home, and can make education possible even in remote areas. However, online education also poses several challenges. For example, online education requires computers, families with several children need to buy more computers, increased internet usage (again making it costly), and continuous sitting and facing computer monitors, which may cause health issues. Therefore, to best use online education, more work needs to be done regarding affordable computers, cheap and uninterrupted internet, and proper policy.

8. Cleaner Environment

Continuous human activities have led to serious environmental degradation in the form of severe water and air pollution. The worldwide lockdown with limited economic activities led to a sharp decline in pollution. Within just a few months of the lockdown, the water bodies (rivers, lakes, and beaches) looked much cleaner [90]. In many instances, improved water quality improved aquatic life [91,92]. Besides dramatically reducing water pollution, the lockdown during the COVID-19 pandemic also improved air quality. A significant reduction in gases like CO_2 and SO_2 and a slight increase in ozone was observed due to lockdown [91,93]. A reduction in smoke and particulate matter during the pandemic lockdown improved visibility with clear skies. Significant noise level reductions were also observed, especially in big cities [92,94]. A clean environment with fewer human activities also allowed wildlife to flourish [95].

9. Work-from-Home, a New Work Culture Normal

The onset of the COVID-19 pandemic has given us a new way of working; several organizations embraced employee-friendly policies and allowed employees to work from home (WFH), playing a critical role in containing viral transmission. However, post-pandemic, remote work has emerged as a guiding principle for the younger generation, thanks to its enhanced flexibility. The evolving WFH culture has also impacted various other aspects, such as traffic congestion, commuting patterns, motorized trips, and pollution, especially in heavily populated regions worldwide. According to statistics, in the past few years, there has been a significant rise in the number of employees in the United States of America who are regularly engaging in WFH [96]. During and post-COVID-19, organizations have adjusted to the new work culture and operated in ways to generate secure, prosperous, and rewarding careers for their employees [97]. However, experts have raised critical questions regarding work efficiency, employer profitability, and work-life balance [98,99]. The everyday WFH concept was readily accepted by the employees with some prior WFH experience compared to those without any previous exposure. While working from home, many workers struggled to interact with colleagues online, had problems adapting to web meeting software, and faced self-discipline challenges; therefore, post-pandemic, a big group of individuals firmly refused to continue to WFH. However, it is worth noting that an enforced shift to WFH during the pandemic has positively impacted the post-pandemic choice of WFH [100]. Since COVID-19 has ended, many companies are looking forward to returning to the usual office environment; this immense shift in

work culture is now becoming an important issue, and a meticulous analysis is essential to comprehend public sentiments regarding the choice of WFH.

10. World Sharing of Information Is the Key

A fundamental pillar of responding to pandemics is the prompt and transparent sharing of information. Successful outbreak response relies on quick and accurate information sharing such as pathogen identity, rate of incidence, pattern of transmission, and mortality rate by pandemic-stricken countries with the rest of the world through the WHO, enabling others to implement targeted and comprehensive control measures against the pandemic swiftly. Most importantly, an efficient flow of information can avoid spreading "fake news" and misinformation globally [101,102]. The International Health Regulations (IHR) is a leading international legal framework that mandates governments to report to the WHO any incidences within their jurisdiction that could potentially contribute to a public health emergency of global concern (PHEIC) (https://apps.who.int/iris/handle/10665/20353) (last accessed on 15 September 2023). Based on the shared information, the WHO can announce a PHEIC and release guidelines to manage health emergencies. Regrettably, the governing bodies often hold on to information when confronted with a pandemic or outbreak, which is considered non-compliant with the IHR.

Similarly, China was criticized globally for delayed information sharing and manipulating the number of individuals impacted by COVID-19 infection (https://time.com/5813628/china-coronavirus-statistics-wuhan/) (last accessed on 15 September 2023). Enhancing the pandemic response will require the WHO and member states to take essential measures to build trust, including improving transparency and establishing formal mechanisms to address any adverse information-sharing impacts [103]. Building trust is demanding but deserves careful consideration if we intend to enhance the system for responding to outbreaks.

11. The World Working Together

This COVID-19 pandemic affects everyone. Despite much misery and suffering during the pandemic, the world has seen unprecedented care and love toward others. Helping gestures were seen even beyond borders. For example, during the second wave of the pandemic, countries helped India in all possible ways [104]. India also supplied free vaccines to several countries under the "*Vaccine Maitri*" program [105]. Industrialists and business houses donated money to respective government agencies especially for the COVID-19 pandemic [106]. This was seen not only with big business firms, but even ordinary people were donating money as per their capacity. International organizations [107] and governments like the Prime Minister's COVID-19 Pandemic Relief Fund [108] were set up where people donated. We gave a few examples, but such contributions were common worldwide.

12. Learning and Preparedness for Future Pandemics

The spread of COVID-19 taught us several things [109]. These include that together we can face any problem, early and accurate diagnosis is essential for infection control, and optimum use of technologies can make a big difference; in a situation like a pandemic, everyone is affected, and everyone has to understand and take responsibility. Timely and quick action to manage/control the unseen pandemic threat is necessary to minimize the loss. Governing bodies should give more importance to the improvement of healthcare infrastructure. Authorities should take care of inefficiencies and weaknesses in healthcare on a priority basis. Societies should invest more in science, education, and technology and develop rational and scientific attitudes. More investment should be made in science, knowledge sharing, information, resources, and expertise. Disparities or inequalities should be adequately addressed. During calamities like the COVID-19 pandemic, follow a scientific and human-centric governance. Changes in human behavior or ordinary people across the globe towards calamity and a sense of responsibility are the most significant gains and learning from this pandemic [110,111].

13. Major Concerns

This pandemic brought the world together; there was unprecedented cooperation among nations in the fight against infection. Sharing information about viruses beyond borders can be seen as a sign of care for all. Further, free access to COVID-19 papers by publishers was again a splendid gesture. This helped in fast access to information for everyone and greatly affected our ability to fight against viruses [112]. Still, several issues remain that need to be reconsidered in more depth if the world wants to be prepared for future pandemics. The hoarding or stockpiling of vaccines in amounts more than required by several developed countries emerges as a significant concern [113,114]. The stockpiling makes the vaccine unavailable to needy people and leads to massive wastage. This also makes it difficult to contain the virus and increases infection [115]. Since only a few companies were manufacturing COVID-19 vaccines, especially during the early days of vaccination, these companies enjoyed a monopoly. This significantly impacts vaccine cost and vaccination [116,117]. The world should keep vaccine production, supply, and distribution beyond geopolitics and material gain [118]. Manufacturers of vaccines should also focus on developing thermostable vaccines owing to the enormous cost and resources needed to store and distribute available vaccines. Natural uncertainties like storms and snowfall, which can disturb vaccine storage facilities, further warrant the need for thermostable vaccines [70,119].

Although most countries followed strict lockdowns and canceled international travel to stop the virus spread, several countries (for example Sweden) [120] still do not follow these important and helpful guidelines. As a result, the virus keeps spreading in such countries, leading to more deaths and a prolonged pandemic.

14. Measures to Prevent or Prepare for Future Pandemics

The best way for society to appreciate both the negative and positive effects of a pandemic is by taking measures to prevent future pandemics or by minimizing the overall impact of a pandemic. To better prepare the world for any possible pandemic, the expert suggests the following measures that should be taken to manage the pandemic better. In this section, we compile the things that, if carried forward, can play a vital role in adequately managing any possible viral pandemic. The compiled suggestions are based on experts' comments or organizations' recommendations for managing future pandemics [121–127]:

1. Set up more testing facilities throughout the country.
2. Set up more local PPE production units.
3. Associated authorities should keep stocks of PPE and common medicines.
4. Year-round surveillance, monitoring, and prediction (using AI technology) of microbial infections locally and globally.
5. Concerned authorities should be made more accountable and transparent.
6. States or governments should be forced to share data on microbial infection more accurately, rapidly and in real-time.
7. More investment in research related to microbial infection.
8. Set up more oxygen-generation plants and increase the number of beds and ventilators.
9. Include topics like microbial diseases or infections and ways to prevent infection in primary education to equip the population with the correct information.
10. Lifesaving medicines or vaccines should be made accessible to everyone.
11. Develop facilities for better distribution and storage of medicine and vaccines.
12. Establish more vaccine production facilities spread throughout the world.
13. Strict guidelines and procedures to contain the spread of disease; all states and nations should abide by them without exception.
14. Use of daily health screening and contact tracing in day-to-day life.
15. Facilities for quarantine or self-isolation should be developed and maintained.
16. With more strict guidelines for international travel, airlines should ask travelers to provide medical history (infectious diseases) up to the last three months from the journey date.

17. International travelers should complete a health screening before leaving the airport.
18. More facilities for self-isolation.
19. More focus on telemedicine.
20. More online education activities.
21. More focus on mental health management.
22. Better distribution system for food and other life essentials.
23. More awareness about zoonotic diseases.
24. Teaching healthy habits of hygiene and cleanliness.

15. Conclusions

In the form of COVID-19, the world witnessed the most widespread pandemic in human history. Although the WHO officially declared the end of the COVID-19 pandemic, we still see rare COVID-19 infections now and then. Fortunately, due to mass immunization, naturally acquired immunity, and herd immunity, the number of COVID-19 infections is decreasing, and infection is seldom a severe health concern. COVID-19 infection also showed the relation between the host genome and immune response [128–130]. A more detailed understanding of the host genome and immune response is essential as this will help devise better treatment with fewer side effects. Therefore, information gleaned from understanding the impact of the genome on immunity can also be helpful in the case of other viral infections.

The loss of loved ones will remain in the present generation's memories, and the world will keep discussing the pandemic for years. As the world returns to normalcy with increased socio-economic activities, societies are now evaluating the two sides of this pandemic. Like every problem, this pandemic comes with new challenges and opportunities. On one side, the COVID-19 pandemic essentially collapsed health infrastructure even in most developed societies. It provided a push towards new technologies in the form of mRNA-based vaccines and AI in the healthcare sector. This pandemic also informs us that if the world unites together, no problem is big enough that it cannot be solved.

In the end, with the right government policies, proper and optimum use of technologies, the right mindset, and a sense of responsibility and duty, we can face any problem. Therefore, this pandemic, despite its adverse impact, should be taken as a test of our preparedness for future pandemics as predicted by experts in the field.

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