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Review article

Impact of Basic Science Research on Controlling the COVID-19 Pandemic

Running Title: Basic Science Research and Controlling the COVID-19

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Abstract

Background and objectives: The COVID-19 pandemic has significantly impacted the global community and created unprecedented challenges. Basic science has played a vital role in understanding the virus and developing diagnostic tools, vaccines, and treatments. Using the principles of virology and immunology, researchers have discovered the transmission routes and physical pathology of COVID-19. This mini-review covers the basic science accomplishments during the COVID-19 pandemic.

Materials and Methods: This review study conducted a content analysis of texts on basic science findings in the COVID-19 pandemic by reviewing PubMed, Google Scholar, and Scopus databases. By July 2024, 197 relevant articles were extracted, while the findings of only 78 studies were assessed.

Results and discussion: Identifying the virus as a new coronavirus and developing diagnostic tests have made it possible to track its spread. Preventive measures such as social distancing and wearing masks have been introduced as essential in controlling the virus while promising treatments to combat COVID-19 have saved many patients' lives. The development of vaccines such as the Noora, PastoCovac, and COVIran Barekat vaccines has been significant in the fight against COVID-19. The pandemic has caused widespread economic impacts and prompted international organizations and policymakers to propose mitigation strategies. Covid-19 has also had a profound impact on society and mental health, leading to increased anxiety and social isolation, which has been studied in psychology and sociology. Utilizing these experiences during future infectious epidemics will be incredibly beneficial.

Keywords: SARS-CoV-2, COVID-19, Basic Sciences

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Introduction

The COVID-19 pandemic has brought the world to a standstill, affecting millions of lives, economies, and societies (1). In the face of such an unprecedented crisis, basic science became an important tool in understanding the virus, developing treatments, and inventing strategies to fight against disseminated illness (2). Basic science, otherwise called fundamental or pure science, delves into the core of natural phenomena, thus giving rise to applied research and technological advances (3). In that respect, basic science about the COVID-19 pandemic has been instrumental in unveiling the mysteries of the unknown virus, discovering potential treatment agents, and supporting public health responses (2, 4).

Basic science has historically determined much of our current understanding of infectious diseases and has provided a lead toward public health interventions (4). For example, the earliest underpinning for the current field of virology resulted from basic science research laying a foundation for discovering viruses and their mechanisms of infection (5). It contributed to basic scientific research on the structure and function of viruses, providing deeper insights into the biology of SARS-CoV-2, the virus responsible for COVID-19. This, in turn, enabled researchers to develop diagnostic tests, vaccines, and therapeutic interventions (6).

The contribution of basic science to the COVID-19 pandemic could not be underrated. Basic science research has rapidly developed diagnostic tests that identify infected people; a vaccine to prevent virus spread has been realized, and severe cases of the disease have received treatments from such research (7). For example, the mRNA technology used in the Pfizer-BioNTech, Noora, and Moderna vaccines was based on decades of basic science research on the biology of viruses and the human immune system (8).

This review provides an overview of basic science accomplishments during the COVID-19 pandemic.

Methods

This review study searched for the keywords "SARS-CoV-2", "COVID-19", and "basic sciences" in the Google Scholar, PubMed, and Scopus databases, both together and individually. By July 2024, 197 relevant articles were extracted, and unrelated or weak articles were excluded. Ultimately, the findings of 78 studies were assessed.

Hereby, the impact of basic science on various features in the prevention, diagnosis, and treatment of COVID-19 are discussed as listed below:

1. Transmission Routes and physio-pathology
2. Epidemiology and Prevention
3. Diagnosis
4. Pharmacology and Pharmacotherapy
5. The development of a vaccine during the COVID-19 pandemic
6. Economic impacts
7. The impact of COVID-19 on society and mental health

1-1 Transmission Routes

SARS-CoV-2 can be a virus causal agent of COVID-19 and may be transmitted via respiratory droplets, contact, airborne particulate matter, and fecal-oral transmission routes (9). An association with a Wuhan seafood wholesale market was

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discovered with the SARS-CoV-2 breakout. The primary routes of human-to-human transmission are in community, healthcare, and household settings (10). This proves to be difficult to control infection due to the virus being detected in various organs and body fluids after infection (11). Close contact and respiratory droplets are identified as the main modes of transmission, emphasizing the need for social distancing and mask-wearing (12). The contaminated surfaces may also propagate the virus if one touches them and then, consequently, one's face again, showing the importance of hand hygiene in this case (13).

The Centers for Disease Control and Prevention advises that precautions against droplet and contact transmission include personal protective equipment, surface disinfection, and restriction of patient movement (14). Other major routes include aerosol transmission, especially in poorly ventilated indoor environments; the CDC recommends isolating and employing appropriate PPE in these settings (15, 16). Moreover, the fecal-oral transmission route cannot be discounted because some patients excreted viruses in their stool samples, indicating that the pathogen could contaminate food and water (17).

The different routes of SARS-CoV-2 transmission are relevant for COVID-19 prevention (4). Good hygiene, social distancing, mask-wearing, and proper infection control measures, as prescribed by the CDC, are some factors that would reduce the prevalence of the disease (18). The various ways the virus can propagate its effect could be identified, and a subsequent effort can be made to change such an outbreak with little effect on public health.

1-2. Physio-pathology, immunology and virology

The physiopathology of COVID-19 was extensively understood due to basic scientific research, which further allowed the discovery of key mechanisms ruling the development of the disease. It was by studying fundamental processes that investigators described some interactions between the virus and the human body, resulting in finding possible methods for treatment and prevention (4). Those have been playing key roles in discovering pathways influencing the progress of COVID-19 and have offered targets for therapeutic intervention in areas of immunity, virology, and molecular biology (5).

Challenges, however, include possible conflicting results and the disease's complexity. Further basic research will enable scientists to adjust our understanding of COVID-19 and develop novelties in fighting it, better preparing them for future outbreaks (19). The basic sciences will retain a central role in shaping responses to infectious diseases in the future, from understanding the functions of molecular interactions to studying how immune systems can control, sometimes even facilitate, disease progression (20).

One interesting finding was that angiotensin-converting enzyme 2 (ACE2), acting as an important regulator in the Renin-Angiotensin System (RAS), serves as the entry receptor for SARS-CoV-2 invasion into host cells (21). ACE/ACE2 imbalance may lead to severe complications in people with cardiovascular diseases, particularly in those where virus-induced imbalance was present (6). ACE2 gene expression varies among individuals, being higher in men and Asians. The virus attacks by binding to the ACE2 receptor, causing damage to alveolar cells with systemic reactions that may end in death (21, 22). This finding has suggested many possible treatments by modulating ACE function.

In its mildest form, COVID-19 manifests as fever, cough, and asthenia; in more severe cases, it gives way to symptoms such as dyspnea and other organ dysfunction (21). Neurological complications like stroke and nerve damage can also occur (23). One of the key causes of mortality in patients infected with COVID-19 is acute respiratory distress syndrome, often precipitated by cytokine storm, which acts as an aggressive inflammatory response that alone can cause injury to the lungs and eventually organ failure (24).

Once it enters the body, SARS-CoV-2 infects the alveolar cells of the lungs through its spike proteins, causing an immune response that later could damage body cells (25). This can lead to the production of a cytokine storm that results in acute lung injury with impairment of gas exchange, which can be life-threatening (26). However, the progression of the cytokine storm includes inflammation, fibrin formation, fluid accumulation in the lungs, and eventual respiratory damage (27).

While most patients with mild symptoms of COVID-19 recover within one week, those suffering from severe cases have been recorded, showing progressive respiratory failure, finally leading to death from damage in the alveoli (28). In middle-aged and elderly patients, the mortality rate is pretty high, while the recovery ranges from two weeks in a mild case to several weeks in a severe one (29).

2. Epidemiology and Prevention

Since there is no specific treatment for COVID-19, preventive measures have been the cornerstones in limiting its spread. The preventive measures include quarantining the infected, identifying and monitoring contacts, disinfecting the environment, and using personal protective equipment (30). Moreover, nosocomial infections can be avoided by raising awareness, using protective equipment, and using disinfection tools by laying down protocols (30, 31). Psychological interventions are suggested for suspected and confirmed cases as well as medical staff (31). Epidemiologists are at the forefront of investigating emerging infectious diseases by determining the reasons for their spread and investigating disease outbreaks to implement measures that could slow the actual spread of the disease (32).

According to research, COVID-19 can affect all ages and, more recently, is transmissible from symptomatic as well as asymptomatic patients. There was no significant difference in viral load between asymptomatic and symptomatic patients (33). The virus can transmit a distance of up to two meters with respiratory droplets and can survive on the surface for several days but can be killed by common disinfectants. Older adults and people of any age who have severe underlying medical conditions may be at higher risk for severe illness from COVID-19 (34).

The WHO recommends that breastfeeding should not be stopped due to the risk of COVID-19 transmission, as the benefits of breastfeeding outweigh the potential risks (35). Generally, control of COVID-19 and reduction of disease burden among vulnerable groups rely on preventive measures taken, awareness created, and teamwork exercised by scientists (36).

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3. Diagnosis

Because COVID-19 has no definitive curative treatment, timely diagnosis and isolation of the disease have become more critical in its management (37). Various methods can be used for early diagnosis, including the RT-PCR method, CT-Scan, Serological antibody blood tests, and artificial intelligence (AI) (38).

The real-time PCR method is designed to discover the type of nucleic acid found in the nasal swab sampling or respiratory tract. It is the method of copying the RNA and DNA structure of the sample for detecting the SARS-CoV-2 virus in respiratory specimens (39). Samples are collected from the lower and upper respiratory tracts to identify the virus infection further. Information concerning the visualization of lung lesions associated with COVID-19 can be given by CT imaging, which is valuable for physicians in diagnosing and monitoring the progress of the disease (40).

Serological antibody blood tests can detect antibody-mediated immune responses against infectious agents. Although they are not appropriate for the early detection of infections, they are useful in epidemiological and monitoring applications (41). If molecular testing by PCR testing remains limited, an alternative is rapid serological testing. AI technology is promising for controlling and diagnosing epidemics, including COVID-19 (42). Artificial intelligence can easily recognize the symptoms of the disease and help reduce decision time in the traditional diagnosis process (43).

The role of nanotechnology in diagnostics, therapy, and prevention of COVID-19 is monumental. It harnesses properties of nanoparticles such as high solubility, small size, and surface adaptability to produce safe and quality drugs, targeting therapies and early diagnosis (44). Nanotechnology can also be used to design safe personal protective equipment, produce antiviral disinfectants, develop nano-based sensors for rapid infection detection, and enhance drug delivery and vaccination production (45).

4. Pharmacology and Pharmacotherapy

Pharmacotherapy, the science of using medications to treat diseases, is intricately linked to basic sciences. This connection became particularly evident in the treatment of COVID-19, where a comprehensive understanding of virology, pharmacology, and human physiology was essential for developing effective therapies. Basic research into the virus's structure, its replication mechanisms, and the biochemical responses of the human body to infection provided critical insights that enabled researchers to identify and formulate appropriate medications. Consequently, this interdisciplinary approach facilitated the rapid development of antiviral drugs and vaccines. It underscored the importance of integrating basic sciences with clinical practice to improve patient outcomes in the face of emerging infectious diseases (46-48).

Since its beginning, the COVID-19 pandemic has represented an important challenge in developing effective pharmacotherapy (46, 47). However, scientists have not stopped trying to discover new treatments and find new uses for licensed drugs (repositioning) in the fight against the disease. Although the development of efficient vaccines has made people hopeful, there is a pressing need to focus on drug candidates that could be used for treating patients with severe symptoms-these range from antiviral agents to therapies targeting the host (47, 48).

Antiviral agents such as remdesivir, favipiravir, and protease inhibitors like lopinavir have shown some effectiveness in treating Covid-19 (49). Results, however, have been mixed, with some clinical trials showing positive outcomes and some showing no significant difference compared to standard care (48). To date, several combination therapies using multiple antiviral agents have been taken up; this proved very well in alleviating symptoms and reducing recovery time (50).

Inhibitors of nucleoside and nucleotide reverse transcriptase, such as azvudine and molnupiravir, have also shown promise in treating COVID-19 (51). Molnupiravir, in particular, has been authorized for emergency use in adults with mild-to-moderate Covid-19 (52). Unfortunately, many drugs, like amantadine and oseltamivir, among others, entered clinical practice and even prescribed protocols without having an acceptable therapeutic effect, sometimes bringing high costs to the health system and patients (53).

Steroids like dexamethasone, budesonide, and ciclesonide have been used in treating inflammation related to COVID-19 (54). Dexamethasone, in particular, has improved survival rates in severe cases (55). Also, the JAK inhibitors, particularly baricitinib, seem to have an impact on reducing inflammation and hence improving clinical outcomes in hospitalized patients, as seen also by tofacitinib and ruxolitinib (56). Neutralizing antibody therapies include convalescent plasma and monoclonal antibodies; these have had controversial results in clinical trials. Some showed a reduction in hospitalization or death, while many others did not find significant improvement (57).

However, critical advancements in developing effective treatments for COVID-19 are essential in the fight against the virus. Promising results in improving clinical outcomes through combinatorial therapies such as JAK inhibitors and specific antiviral agents (58) should be noted. Further research will be fundamental in developing treatments that will be effective in future pandemics.

5. The development of a vaccine during the COVID-19 pandemic

The COVID-19 vaccine has marked a pivotal moment in the fight against the new coronavirus. The process of developing vaccines has always held significant importance in the historical context of combating infectious diseases. The rapid development of the COVID-19 vaccine is a testament to the commitment and collaboration of key individuals and organizations within the scientific community. This unprecedented effort brought together researchers, healthcare professionals, and regulatory agencies to share knowledge and resources, ultimately leading to the swift creation and distribution of effective vaccines. Such collaboration highlights the importance of teamwork in science and sets a new standard for responding to future public health crises (59).

At the very beginning of this pandemic, scientists and researchers worldwide worked on a vaccine to combat the virus and prevent further deaths. If there is something unique in the entire history of medicine, several vaccines have been developed and approved for emergency use quickly. Rapid

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development was possible only through alliances between technological advances, global collaboration, and a sense of urgency in combating this pandemic (60).

Key players in the development of vaccines thus played a vital role in the fight against COVID-19. Dr. Anthony Fauci, Director at the National Institute of Allergy and Infectious Diseases in the USA, served as a leading figure on public health advisement and acted throughout as a credible viral information source (61). His expertise and experience in infectious diseases have become essential in the development of vaccines and in shaping public health policy on how to fight the virus.

Other influential contributors to vaccine development include Dr. Katalin Karikó and Dr. Ugur Sahin, both inventors of mRNA vaccine technology. Groundbreaking research by these two individuals laid the foundation for the Pfizer-BioNTech and Moderna COVID-19 vaccines. Indeed, they have already proved highly effective in preventing severe diseases and reducing the transmission of viruses (62). They have changed vaccinology, opening up new paths for the development of vaccines in the future.

In a nutshell, the Noora vaccine, along with the PastoCovac vaccine and the COVIran Barekat vaccine, are some of the most succinct manifestations of science and innovation developed against all odds during the COVID-19 pandemic. With the fast-spreading SARS-CoV-2 virus, the world had almost come to a standstill until the global scientific community accepted the challenge to develop a vaccine to fight this deadly virus. At this point, researchers and scientists who had worked tirelessly on a safe and effective vaccine made the Noora vaccine one of the promising solutions in the fight against the pandemic (63).

The Noora vaccine is an mRNA-based vaccine; therefore, this immunization would trigger the immune system to identify and fight the spike protein of the coronavirus-one of the main tools for its ability to infect human cells. Therefore, it allows the immune system to grow robust and effective responses against the virus by stimulating antibody production against the spike protein, thereby defending from infection and reducing symptoms of COVID-19 (64).

The Noora vaccine is the brainchild of collaborative researchers, scientists, and health experts worldwide. It has undergone rigorous tests and clinical trials. Because of the emergency caused by the pandemic and the need to save as many lives as possible, it recorded the fastest approval for emergency use (63).

The rollout of the Noora vaccine has been among the critical milestones against this terrible COVID-19 pandemic at the core of reducing infection rates, hospitalizations, and deaths across many countries. By vaccinating an appropriate proportion of people, herd immunity was created, slowing the spread of the virus, which in turn led to a decline in new cases, allowing for a gradual normalization (63).

The success of the Noora vaccine is a testament to the power of science and collaboration in overcoming global health challenges. It serves as a shining example of what can be achieved when researchers and scientists come together to tackle a common enemy, and it has paved the way for future advancements in vaccine development and public health preparedness (64).

The development of a vaccine has been a game-changer in terms of controlling the COVID-19 pandemic. Vaccination slowed the spread of the virus, thus protecting vulnerable populations and saving lives. Running vaccination campaigns worldwide brought hope and optimism that normalcy would finally return after months of uncertainty and disruption (59).

However, the vaccine development road has been met by several challenges and criticisms. Hesitancy in vaccination and misinformation have made wide vaccination coverage elusive, leaving the world concerned about the continuously emerging variants and a possible future outbreak. There have also been significant disparities in vaccine sharing and access, hence calling for fairness in the global rollout of vaccines so that populations from all walks of life can get vaccinated (59).

Looking forward to this COVID-19 pandemic, there is great room for continued improvement and innovation in the future of vaccine development. Citing examples of new technologies and approaches, researchers are searching for ways to improve vaccine effectiveness and availability to everybody, mainly emerging variants, and enhancing the durability of immunity. Global collaboration and cooperation will be required to rise to upcoming challenges so that vaccines remain a cornerstone of public health efforts in controlling infectious diseases (65).

Vaccine development against COVID-19 has significantly affected changing public health and medicine. Key figures in vaccine development have been one of the mainsprings of progress in curving the response to the pandemic. However, challenges and hurdles remain ahead, even as vaccines positively affect this journey (66).

6. Economic impacts

The COVID-19 pandemic has so far widely disrupted the global economy, infecting millions of people and killing thousands. Many countries worldwide have closed their borders, imposed lockdowns, and restricted the number of people attending public places/gatherings to limit the spread of disease (67). The "Great Lockdown" almost brought activities around the globe to a close, entailing lost livelihoods and failed businesses. Several economies have seen a spike in their unemployment rate, and industries like manufacturing, commerce, and tourism have been badly affected (68). The Fund sees a world economy shrinking by 4.4 percent this year, worse than in the Great Depression. Recovery will be slow, led by countries like China and India, while countries like the U.K. and Italy linger at the end of the line (69). The pandemic has affected sustainability, quality of life, education, agriculture, travel, and entertainment industries. Mitigation strategies so far have been suggested to deal with policy challenges, fiscal issues, macroeconomics, and development (70). International organizations are thus indispensable in mediating and providing financial aid to the neediest. Foreign Direct Investment is, therefore, bound to play a vital role in realizing the set goals of sustainable development by 2030 (71). Sector-specific policy implications are also discussed, highlighting the need for support for businesses and healthcare, the potential growth in online shopping,

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and the decline of traditional industries like tourism (72).

7. The impact of COVID-19 on society and mental health

The pandemic has immensely affected societies globally, making the impact on mental health and social behavior observable. Such consequences are explored as an important focus in psychology and sociology (73).

During the pandemic, unprecedented challenges have emerged, revealing fault lines in our lives and causing individuals to experience unease, anxiety, loneliness, and depression. Governments and medical authorities have taken action to deter virus transmission, such as issuing stay-home requests and social distancing (74).

Previous pandemics, the Spanish flu and HIV/AIDS, have also caused substantial psychological effects. Still, the COVID-19 pandemic represents a scale and speed not previously experienced anywhere in the world. Key figures, including Martin Seligman and Emile Durkheim, have underlined resilience, positive psychology, and the role of social structures in crisis (75).

While it has increased cases of mental illnesses such as anxiety and depression due to social isolation and economic uncertainty, it is also raising awareness about mental health and provoking self-practices in the form of care for oneself or community support (76).

The pandemic clarified how individual and collective resilience can drive responses to challenges and adjustment to change. To that end, mental health professionals are working tirelessly to provide access to mental health services that can help individuals cope with stress and uncertainty (77). Sociologists underline cooperation, solidarity, and mutual aid in global crises driven by social norms, values, and political structures. The pandemic has engendered a severe concern about mental health and social behaviors; these academic disciplines should be vigorously pursued to address the challenges raised by the crisis. To this end, further research and analysis of the emerging psychological and social dynamics would help to foster well-being during the pandemic (78).

Conclusion

During the COVID-19 pandemic, basic science has had enormously positive and negative impacts, presenting challenges and opportunities for future progress. Basic science has justifiably been responsible for the swift development of reasonably effective vaccines, diagnostic tests, and therapeutics in this pandemic episode. New solutions, products, and procedures save lives, improve health, and reduce loads at healthcare systems worldwide. It has also emphasized the continuous investment in basic research and public health infrastructure toward future preparedness against pandemics and infectious diseases. Serious efforts in basic research and evidence-based strategies are required to fully understand the risks of future pandemics and infectious diseases.

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