Interdisciplinary Approaches to COVID-19

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic has been a significant concern worldwide. The pandemic has demonstrated that public health issues are not merely a health concern but also affect society as a whole. In this chapter, we address the importance of bringing together the world's scientists to find appropriate solutions for controlling and managing the COVID-19 pandemic. Interdisciplinary cooperation, through modern scientific methods, could help to han-

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dle the consequences of the pandemic and to avoid the recurrence of future pandemics.

Keywords

Cooperation · COVID-19 · Interdisciplinary · Pandemic · Problem · Solution

52.1 Introduction

Coronavirus disease 2019 (COVID-19), an infection attributed to the severe acute respiratory syndrome of coronavirus 2 (SARS-CoV-2), attained pandemic proportions in early 2020 (Jabbari et al. 2020; Hanaei and Rezaei 2020). As of June 30, 2020, there are more than 10 million people confirmed to have COVID-19 worldwide. Even this disturbing amount is supposed to be just the tip of the iceberg. The COVID-19 fatality rate is probably around 0.02% to 0.4% (Ioannidis 2020); though, due to the high infectivity of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing COVID-19 (Huang et al. 2020b), the number of deaths has been high, with more than 500,000 people died from COVID-19 as of writing this. The pandemic has exposed the need for a holistic commitment to developing healthcare systems around the world; only, for example, during the pandemic, many scientists worldwide have been carrying out studies related to the pandemic (Remuzzi and Remuzzi 2020; Rzymski et al. 2020).

Public health is a practical and relevant area for the implementation of interdisciplinary research. Actions to enhance health services quality include innovative strategies like the

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inclusion of related disciplines, such as medicine and pharmacy, molecular and cellular biology, microbiology and biochemistry, genetics, immunology, pharmacology, nutrition, psychology, epidemiology, economics, societal needs, communication, and political sciences, health, and nursing care services, physics and chemistry, geography, and statistics or computational sciences for big data management. All of these diverse fields have study viewpoints that lead to the evaluation, review, perception, interpretation of the health consequences of COVID-19 as well as coping with them (Christakos et al. 2005).

Interdisciplinary study and evidence-based treatment of COVID-19 is essential for many reasons. One reason is the need by public health policy analysts for science-based information on the efficacy and usefulness of interventions. Such analysts may assist decision-makers when addressing the needs and desires of the population. Another reason is that this new human pathogen requires interventions at multiple levels, from the individual to societal. Collaboration

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with an interdisciplinary focus can help achieve these goals (Kivits et al. 2019; Yu et al. 2017).

52.2 COVID-19

The twenty-first century has seen the appearance and outbreak of three previously unknown coronaviruses: severe acute coronavirus respiratory syndrome (SARS-CoV) in 2003, Middle East Coronavirus Respiratory Syndrome (MERS-CoV) in 2012, and 2019 novel coronavirus (2019-nCoV, later officially named SARS-CoV-2) in December 2019 (Tu et al. 2020). The current pandemic of COVID-19, initially seen in China's Hubei Province, has spread to almost every nation in the world (Li et al. 2020b). On January 30, 2020, the World Health Organization (WHO) announced a public health alert based on increasing cases of COVID-19 observed in China and subsequently in other areas around the world (Velavan and Meyer 2020). This global health alert came just 1 month after the first officially recorded case in Hubei, another proof of the high infectivity of this virus (WHO 2020b).

Coronaviruses are enveloped RNA viruses that mostly infect birds and mammals. Before the three coronaviruses causing outbreaks appeared, four other coronaviruses, including 229E (alphacoronavirus), NL63 (alphacoronavirus), OC43 (betacoronavirus), and HKU1 (betacoronavirus), were identified in humans. They cause mild infection in the upper respiratory tract, like the common cold, and much less frequently do they cause severe lower respiratory tract infections (Weiss and Leibowitz 2011). However the three coronaviruses causing crises of SARS, MERS, and COVID-19, in essence, invade the lower respiratory tracts, though after the entry into upper respiratory tracts (Lotfi and Rezaei 2020).

The SARS-CoV-2 virus affects not only the respiratory system but also the digestive, gastrointestinal, hepatic, and central nervous systems (Rodriguez-Morales et al. 2020; Arentz et al. 2020; Yazdanpanah et al. 2020b; Jahanshahlu and Rezaei 2020a; Saleki et al. 2020). Compared to SARS-CoV, which triggered an outbreak of SARS in 2003, SARS-CoV-2 has a higher transmission capacity (Lotfi et al. 2020). Despite SARS-CoV having a higher fatality (9.6%), the new coronavirus has caused many more deaths. The dramatic rise in reported cases makes it particularly challenging to prevent and control COVID-19.

Scientists and policymakers around the world have taken urgent steps to monitor the outbreak and carry out virologic, clinical, and epidemiological studies (Chen et al. 2020c).

52.3 The Importance of Interdisciplinary Research

The pandemic has made it clear that COVID-19 not only causes physical health damage but also poses a mental health threat and can stir major economic, social, and societal upheaval. Therefore, COVID-19 does not merely fall in the purview of medical sciences; also, it is a matter of urgency for economics, behavioral and social sciences (e.g., physical distancing rules, social isolation), and political decision-making (e.g., border control, unemployment) (Moradian et al. 2020; Dimant and Schulte 2019). The synergy of diverse fields of expertise promises to contribute to understanding, prevention, and management of the detrimental consequences of COVID-19 (Hartley and Perencevich 2020). We advocate such an interdisciplinary approach in this chapter, where researchers work jointly, but also from a disciplinary-specific base, to solve the common problem (Okumus et al. 2018; Mohamed et al. 2020a).

We provide examples below on the role of different sciences for controlling and managing the COVID-19 pandemic. Throughout, we emphasize the importance of experts' cooperation for achieving a proper solution to this pandemic and for decreasing the chances of similar natural disasters in the future.

52.3.1 Physics, Chemistry, and Engineering

COVID-19 transmission mainly happens through droplets containing the virus, which are formed in the respiratory tract of an infected person and come out of the mouth and nose when breathing, coughing, or sneezing (Huang et al. 2020c). In particular, droplet transmission or contact route of transmission occurs through physical contact with droplets on the surface or direct transmission into the mouth or eyes, while airborne transmission occurs through inhalation (Shereen et al. 2020).

The rules of physics modulate virus transmission. Virus-infected particles showing up through sneezing or coughing behave differently. After leaving the mouth or nose, the particles mainly join the other particles in the air and move with them (Bourouiba et al. 2014).

Physics can predict the particles' type of motion by examining their behavior, which depends on their size and speed. For example, small particles are suspended in the air and move upward, polluting the ventilation system in the ceiling (Bourouiba et al. 2014). Therefore, access to different models of particle motion can help to predict contamination at different levels. The chemical composition of the respirable aerosols containing the virus impacts on how much the aerosols can change in size upon inhalation owing to hygroscopic growth, which will ultimately determine if and where the aerosols will deposit in the respiratory system (Youn et al. 2016).

Either way, it is vital to disinfect all surfaces efficiently. Chemistry can change the properties of materials in nanoscale to increase the self-sanitization capacity of metal surfaces (Saccucci et al. 2018). It would be particularly useful in hospitals. Another beneficial surface decontamination solution has been recently obtained by physicists. They proposed that violet/blue (400–470 nm) light is antimicrobial against numerous bacteria and even viruses. Empirical research has demonstrated that this is a low-cost and safe opportunity to sanitize equipment, hospital facilities, emergency care vehicles, homes, and the general environment (Enwemeka et al. 2020; Kowalski et al. 2020).

Moreover, personal protective equipment (PPE) restrictions have posed health risks for medical staff. Improving PPE, such as by reusing gloves, masks, air-purifying respirators, goggles, and gowns, as well as detecting the virus and monitoring the physiological condition of the person wearing the clothes, alleviates some of those health risks (Medicine 2006; Livingston et al. 2020).

It is also advantageous to use disposable equipment to reduce the production of plastic waste. The role of chemists and engineers working together to mass produce these products is becoming more and more crucial (Huang et al. 2020a).

52.3.2 Mathematics and Computer Science

Mathematical and epidemiological modeling is essential in forecasting, detecting, and monitoring epidemics. In order to better understand and model the complexities of an outbreak like COVID-19, researchers need to consider several factors, ranging from host-pathogen interactions to host-to-host encounters and the predominant political, social, economic, and local parameters worldwide (Soheilypour and Mofrad 2018). Mathematical modelers use evidence from recent and long-past outbreaks to determine who could be affected, where vaccine efforts may be more successful, and how to minimize the spread of the virus.

For example, a recent study implicated cell phones, along with online surveys, for data collection purposes. Such self-reported clinical data can be used for preliminary screening and early identification of COVID-19 cases. Thousands of data points can be analyzed by artificial intelligence (AI) system that can assess and stratify people in terms of risk status (i.e., no risk, low risk, moderate risk, high risk). Identified high-risk cases might then be quarantined early, thereby reducing the possibility of virus transmission (Srinivasa Rao and Vazquez 2020). Another newly investigated route for data collection, and a more objective one, is the analysis of wastewater as a way to estimate the total number of infected persons in a city. Virologists can locate traces of the virus in the water and then, with an adequate network model of the wastewater system developed by mathematicians, can track the virus back to its origin to identify hot spots. On this basis, scientists can plan for appropriate action depending, for instance, on postal code (EPFL Scientists 2020; Mallapaty 2020).

In order to make reliable predictions with a mathematical model, one would need to have accurate estimates of the parameters concerned. Data fitting is the method of modifying system templates and evaluating the accuracy of fit. The introduction of an effective and consistent protocol for calculating the number of sick, deceased, and recovered cases and for unifying various protocols at the international level is essential to the calculation of accurate estimates (roland Oliphant 2020; Rafa de Miguel et al. 2020). Dynamic simulation, game theory, and spatial modeling will be of growing importance in understanding the biology of complex systems. These approaches can also illuminate the complexities of interactions between pathogens and their host (Ewald et al. 2020).

Two statistical mechanisms specific to a pandemic such as COVID-19 are stochastic and susceptible-infected-recovered (SIR). The stochastic simulation includes all statistical equations of random variables in the function assignment. In other words, the stochastic simulation uses random assignment for predictive functions, which is useful in the early stages of virus dissemination (Ming et al. 2016). The SIR model has a robust predictive capacity extended to circumstances where people infect each other explicitly (Adamu et al. 2019). However, in recent years, spatial frameworks and, in particular, network theory (as a model for road networks or flight connections) and metapopulation have proven relevant in understanding the dynamics of virus transmission (Huppert and Katriel 2013; Rihan and Anwar 2012). Network theory proposes that simple mathematical models of epidemics presume a random combination between people, which is not the case in practice. Populations have a structure, and people appear to communicate with a tiny minority of the population. Contacts or connections between entities are a network, and infectious diseases that transmit by direct interaction may propagate only through the networks and pathways. In this module, specific models of communication and transmission networks are applied to investigate the impact of the network system on the dissemination of epidemics. It is one of the most challenging modules.

Tracing apps such as STOPCOVID (in France), Corona-Warn-App (Germany), and Ariana (Luxembourg) help build the network of contacts within a population, which can have a significant impact on the design of confinement and deconfinement strategies. From a given infected person, these apps, based on low-energy Bluetooth technologies, enable the safe and privacy-aware tracing of contacts, without any global positioning system. In turn, smartphone applications can also be used to track symptoms and hence help predict the spread of the pandemic and are invaluable in providing a rational and quantitative approach to estimating the main parameters appearing in epidemiological models, be they agent-based or equation-based (Arianatech 2020).

Such systems, together with information technology (e.g., bioinformatics, big data analytics, computer intelligence, artificial intelligence, sensors, image recognition), are used worldwide by public health authorities to analyze and establish strategies for ever-emerging infectious diseases and to respond to outbreaks (Ewald et al. 2020; Seno and Dansu 2019; Siettos and Russo 2013; Dansu and Seno 2019).

52.3.3 Biological Sciences

Biological science offers a greater understanding of pathogen-host interactions via molecular biology and computational biology advances developed during the first decade of the twenty-first century (Aderem et al. 2011; Li et al. 2020a). In particular, computational methods of drug discovery can help select among the best existing drugs for COVID-19 treatment during the pandemic (Mohamed et al. 2020c).

The control of COVID-19 depends to a considerable extent on two factors. The first factor is the discovery of testing methods and kits to estimate the extent of the pandemic accurately. The second factor is the development of new vaccines. Testing kits are the product of research on biomedical sciences and engineering. Ideally, they are designed to provide high precision and fast detection for mitigating the transmission of disease in the population (Speers 2006; Chen et al. 2020b; Konrad et al. 2020).

Regarding vaccine development, scientists need to identify viral epitopes that could be used as therapeutic targets and that not only activate the immune system but also recognize the virus as a target (Ahmed et al. 2020b; Sharifkashani et al. 2020; Saghazadeh and Rezaei 2020b). More than 100 vaccines are being produced against SARS-CoV-2 by research teams in universities and companies around the world. Scientists are exploring various techniques, some of which have not historically been used in an approved vaccine. At least eight projects have now started to administer substances into participants in health trials; many others have started testing in animals. There are now more than a half-dozen candidates, including live viruses, recombinant protein subunits, and nucleic acids, that could lead to an effective vaccine against COVID-19 (Chen et al. 2020a).

A look into the future is that current molecular biology methods have the potential to offer information beyond simply identifying causative agents for recently found infectious diseases, such as COVID-19, but could also inform us about the emergence of other novel pathogens, the longevity of infectious processes in nature, the study of the origins of this and other pandemics, and the resistance mechanisms of different host classes (Rezaei 2020b; Rabiee et al. 2020). This knowledge could culminate in the creation of DNA and RNA banking for the study of pathogenic gene encoding factors (Speers 2006; Qu et al. 2020; Yousefi and Moosavi-Movahedi 2020; Wong et al. 2007; Ahmed et al. 2020a).

Various theories have also arisen from this virus by scientists looking forward to demonstrating a novel disease mechanism. According to one of the theories suggested by Jean-Laurent Casanova of Rockefeller University, immunodeficiency leads, at least in part, to severe disease and high mortality among the elderly (jean laurent casanova 2020). However, it is equally important to explain the deadly disease that is sometimes found in the younger population. For example, there might be an inherent, inborn error in immunity associated with COVID-19 infection in younger individuals (Darbeheshti and Rezaei 2020).

52.3.4 Social and Economic Sciences

The occurrence of illness and the propagation of epidemics rely on individual behavior, the social systems, and the political and societal climate that could discriminate between different sectors of the society in terms of race and socioeconomic status (Arthur et al. 2017; Cauchemez et al. 2011). Once exclusion rules and social contact limitations (e.g., spatial distances) are placed into practice (Uchenna and Ossai 2016; Parmet and Sinha 2020), social scientists must be mindful of the psychological, behavioral, and economic implications of these decisions. Social and clinical psychology, as well as psychiatry, illustrates the psychological problems (e.g., loneliness, depression) associated with social isolation (Liu et al. 2012; Hawryluck et al. 2004; Hawkley and Cacioppo 2010).

Communication of facts about COVID-19 is another critical issue. Many people doubt the veracity of information disseminated by politicians but are more receptive to information disseminated by scientists. Indeed, the presence of scientists on TV, the press, and, more generally, social media is becoming increasingly prevalent. Also, some people are susceptible to fake news (Sheera Frenkel and Zhong 2020) or conspiracy theories (Emma Grey Ellis 2020). These can be debunked with counter-persuasion techniques, such as inoculation (exposing people to a weak argument to build their defenses against a more robust argument) (Banas and Rains 2010) or nudge (prompting people to consider accuracy) (Bago et al. 2020). For more information on infodemic and misinformation, we recommend the following materials offered by the WHO (WHO 2020a, c; Organization, PAH 2020).

Moreover, COVID-19 has enormous socio-economic consequences. With the massive and systematic rise in international travel and commerce, pandemic outbreaks can cause economic shock waves that reach way beyond the conventional health system and extend beyond the initial geographic range of the pathogen (Smith et al. 2019). During the first months of the outbreak, the economic consequences were limited to China and affected China's economy by disruption and a drop in goods production. As a result, the entire supply chain has been disrupted, given that China provides essential equipment and materials to businesses and organizations worldwide (Warwick et al. 2020). The effect of COVID-19 on the global economy has been much higher than that of SARS. In 2002, China played a minor role in the global economy, but today it has become an economic powerhouse (Bobdey and Ray 2020). Also, the virus has spread far beyond China and is having a direct impact on economies worldwide. Analysts, for example, expect that the pandemic will result in a projected annual economic loss of 2–3% of global gross domestic product (GDP) in the coming year (Oxford Economics 2020).

Economists can encourage the need for companies to become pandemic resilient by building political, organizational, and financial resilience and declare that these measures are a duty of care for society and the environment. Intergovernmental coordination is a crucial component in controlling COVID-19. Coordinated measures are required to ensure that all external causes are taken into consideration to minimize the transmission of the virus across borders and to deter future pandemics, and this is important given the risk for re-infection with COVID-19 (Jabbari and Rezaei 2020).

52.3.5 Medical Sciences

Medical sciences are expected to spearhead the effort to address the pandemic, although, as we have argued, the frontline role of medical sciences would not diminish the importance of interdisciplinary research (Moradian et al. 2020). Here, we emphasize that the borderless approach should also be imposed within the branches of medical sciences itself. For years, medical sciences have been put into the solid box of the linear model (Godin 2006), which indicates a sequence of predisposing achievements to make innovation (and more specifically, intervention) possible. However, in extraordinary circumstances, an integrated approach could yield a faster and more appropriate response. For example, the usual perspective on diseases suggests that management protocols follow the identification of the disease pathophysiology. In the case of the new pandemic, though, the race to identify the pathogenesis was launched alongside (and not before) attempts to identify treatment approaches (Cao and Li 2020).

As the number of COVID-19 cases and deaths increases globally, the healthcare policymakers have re-oriented research on prevention, identifying risk factors, and estimating their future impact (Bedford et al. 2020; Kafieh et al. 2020). As preventive and treatment approaches advance, the role of health system design is becoming critical in achieving equity and efficiency in the distribution of screening and care services (Bollyky et al. 2020). This development and fairness would be drastically anticipated at the time of reaching effective treatment or vaccines. Moreover, the frequent updates on protocols for healthcare providers and critical caregivers remain vital in providing standard care. However, the mental and physical care provided specifically for the healthcare staff has not attracted the research attention it deserves (Li et al. 2020c). Such research is especially important, because a prolonged overdrive in healthcare is anticipated (Rezaei 2020a; Moazzami et al. 2020). On another level, fast decision-making and providing palliative care could benefit from the involvement of both medical ethics and healthcare management (The Lancet 2020).

Aside from tackling strategies at a population level, an interdisciplinary response to individual care is also relevant. The virus attacks multiple systems. Patients may evince respiratory failure as well as cardiovascular complications, including myocardial injury, clot formation, vascular injury, and inflammation in different vascular beds, stroke, rhythm abnormalities, renal injury, liver failure, coagulation abnormalities, cytokine storm, vascular collapse, and shock (Rismanbaf 2020). The strain of multiple systems has challenged pharmacology (Zaim et al. 2020) and different medical disciplines, particularly cardiology (Shamshirian and Rezaei 2020), immunology (Ahanchian et al. 2020; Babaha and Rezaei 2020), oncology (Ahmadi et al. 2020), and hematology (Sahu et al. 2020). However, searching for other frequent manifestations of the disease might open new avenues for early diagnosis and treatment of the disease (Basiri et al. 2020a). Furthermore, the state of immunological hyperinflammation may play a fundamental role in the morbidity and mortality of patients, particularly younger ones (Merad and Martin 2020; Rokni et al. 2020; Bahrami et al. 2020; Yazdanpanah et al. 2020a; Mansourabadi et al. 2020; Saghazadeh and Rezaei 2020a; Pashaei and Rezaei 2020; Nasab et al. 2020). This prospect has called for the mobilization of multiple branches of medicine – including immunology (Mansourabadi et al. 2020; Pashaei and Rezaei 2020; Jahanshahlu and Rezaei 2020b; Pourahmad et al. 2020; Fathi and Rezaei 2020), personalized medicine (Basiri et al. 2020b), and genetics (Yousefzadegan and Rezaei 2020; Darbeheshti and Rezaei 2020) – in reaching a consensus over the potentially most effective therapeutic techniques. Ultimately, properly designed (and interpreted) randomized controlled trials are necessary to test the many therapies proposed for COVID-19 formally. These trials will benefit from clinical trialists, biostatisticians, and other members of effective clinical trial research teams.

As the COVID-19 infection continues to spread globally, the many branches of medical sciences are active and will keenly engage in the foreseeable future, often needing to take preemptive action. For example, as mentioned above, the pandemic will inflict mental health scars, such as anxiety and depression (Vieta et al. 2020). The anticipation of such consequences will inform a comprehensive approach concerning lockdowns, isolation strategies, treatment approaches, and follow-up care. On the other hand, the long-term somatic impact of the virus is still unknown (Morlacco et al. 2020). Medical scientists are in search of an effective plan for COVID-19 prevention, treatment, and rehabilitation. This plan rests on an interdisciplinary approach involving infection, re-infection, and immunity, epidemiology, physical distancing, recognition of the acute and asymptomatic disease, acute and chronic long-term multisystem complications, and clinical outcomes like morbidity and mortality, treatment, and vaccination.

52.4 Conclusion

Interdisciplinary research must be central to the international response to the COVID-19 pandemic, given its potential deleterious impact on individuals and society. The first half of 2020 has witnessed one of the greatest scientific collaborations, with experts crossing physical and intellectual boundaries (Mohamed et al. 2020a) and producing evidence-based guidance for responding to the pandemic (Holmes et al. 2020). COVID-19 has become a turning point for establishing the importance of interdisciplinary research. In this context, the contribution of health-related international bodies in integrating knowledge about the virus and improving the management of infections worldwide has been invaluable. These bodies include the World Health Organization (WHO), International Union of Nutritional Science (IUNS), International Union of Biochemistry and Molecular Biology (IUBMB), Food and Agriculture Organization (FAO), and Non-governmental Organizations (NGOs) as well as international consortia such as Universal Scientific Education and Research Network (USERN) (Momtazmanesh et al. 2020; Mohamed et al. 2020b). In particular, USERN has allowed the Integrated Science Association (ISA) to integrate different disciplines. ISA is built on top scientists and provides its members with a platform for moving beyond their own discipline. The Integrated Science book series is entitled to use such a platform.

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