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MATHEMATICAL MODELS FOR COVID-19: A REVIEW ANALYSIS

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ABSTRACT

In the past century, the COVID-19 epidemic has caused a global health disaster never seen before. With its ever-expanding influence on the economy, society, and health, it is destined to rank among the worst worldwide calamities since the World Wars and the 1918 epidemic. This novel illness mostly spreads through human carriers, and it does so far more quickly than other flu viruses and coronaviruses that have previously been discovered. It will be difficult to eradicate this illness even with the development and distribution of vaccinations. It is critical to comprehend the virus's mode of transfer from one host to another as well as how future infection hotspots can be identified in order to save lives. A significant part in the ongoing dilemma has been played by mathematical models, which have influenced state policies and many of the global social distancing initiatives. In this paper, we summarize some of the key mathematical models that underpin the continuous preparation and reaction activities. These models vary in terms of their application, mathematical structure, and range.

1. INTRODUCTION

Starting with a common cold, a broad family of viruses known as coronaviruses can spread diseases and cause severe acute respiratory syndrome, or SARS. Middle East Respiratory Syndrome, or MERS-coronavirus, was first identified in the Kingdom of Saudi Arabia (KSA) in 2012. It usually started as camel flu and transmitted to people through a variety of routes as a severe respiratory illness[1,2,3]. Acute pneumonia is a result of respiratory infection symptoms. The Huanan Wholesale Seafood Market has been connected to the ongoing new coronavirus illness (COVID-19) outbreaks that started in Wuhan, in the Hubei Province, China, in December 2019 [4,5,6]. Even though vaccinations have lately been made available everywhere, decision-makers find it difficult to combat this infectious disease because there is now no cure. Thus, it is essential to gain more knowledge regarding the virus's quick dissemination mechanism and potential future controls for infection spread. Mathematical models, however, offer an additional means of providing critical instructions for disease mitigation strategies while also helping to comprehend the fundamentals of COVID-19 transmission dynamics.

When evaluating the sizes, peaks, and transmission patterns of an infectious disease like the new SARS-CoV-2, mathematical modeling is helpful and appropriate. To take additional action in the event of a pandemic of an infectious

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disease, it is important to include the affected parameters into a mathematical testing model. For infectious diseases, there are numerous mathematical models available, ranging from the traditional SIR to more complex compartmental models. These models are crucial in quantifying potential mitigation and control measures for infectious diseases [7].Monitoring, predicting large outbreaks, and identifying trends and disease characteristics that may indicate appropriate control measures for disease propagation are among the most important tasks performed by epidemic models. Quick situation assessments for suitable distribution of resources have been made possible by mathematical simulations. Mathematical simulations can be revolutionary in scenarios when the expense of testing limits the acquisition of new data. The importance of dynamic mathematical models for anticipating and controlling outbreaks, responding logistics, and formulating policy for non-pharmaceutical intervention (NPI) strategies has been highlighted by the Covid-19 pandemic [8]. When it comes to public health treatments and assessing the momentum of disease outbreaks, mathematical models that quantify illness progression might be useful [9]. The present paper is divided into following sections:

Section 2 gives the relevant views given in the existing literature, different scenarios used in Mathematical models for COVID-19 are discussed in section 3, section 4 gives the different models for COVID-19, discussion based on these models is done in section 5 and conclusion is discussed in the section 6.

2. CURRENT REVIEWS THAT ARE RELEVANT

Important epidemiological characteristics like series interval, harshness of the disease, death rate per case, and kinds of intermediation techniques are reviewed in the majority of the publications that are currently in publication [10,11,12,13]. The following outcomes are anticipated from analysis based on mathematical models:

(1) figuring out how many cases are anticipated in a specific amount of time; (2) assessing the effectiveness of potential interventions; (3) determining the conditions under which a disease-free equilibrium exists; (4) determining control inputs in situations where resources are scarce; and (5) determining the best time frame to attain a cost-effective outcome. There will frequently be insufficient data for model creation and validation in the event of an ongoing epidemic. There may be extremely complex models, depending on the crucial demographic characteristics influencing the epidemics. It might be challenging to fit such intricate models using the data at hand, though. However, accuracy will be lost if a simpler model is used. The availability of data and the precision and intricacy of the model will therefore need to be traded off. The most popular mathematical models for examining the mechanics of epidemics are deterministic compartmental models. Moreover, logistic models have also been applied [14,15,16].

Scenario:

The mathematical models covered in this part can be used for scenario-based analysis at the local or national level. Policy makers are searching for mathematical models that may be utilized to generate judgments related to real-time scenarios, despite the fact that SIR and SEIR models come in a number of versions. Specifically, the impact of

- geographical dynamics, bringing in and sending out cases, and the migration of infected cases between regions,
- recovery rates for instances that are found and admitted to hospitals, severity of distinct diseases,
- differential transmission of diseases amongst frontline workers, hospital staff, the general public, white- and blue-collar workers, etc.,
- the influence of viral concentration on different surfaces,
- hospital saturation, vaccination availability, cost of interventions,
- how other hotspots affect when schools close or open
- cases that were found and those that were not, and
- vaccinations, compliance from individuals, and the reversal of quarantine for the chronically ill and aged,

arethe situations covered in this paper, which are based on the general dynamics of disease spread.

Table 1: Different subpopulations classified based on epidemiological status are represented by variable notations.

Variable	Description
$S(t)$	Susceptible population
$P(t)$	Protected population
$V(t)$	Vaccinated population
$E(t)$	Exposed population
$I(t)$	Infected population

C(t)	The amount of viruses present in the surroundings
Q(t)	Quarantined population
H(t)	Segregated population or hospitalized population
R(t)	Recovered population
D(t)	Dead population
W(t)	Workplace mobility

Table 2: Parameter notations.

Parameter	**Description**
β	Rate of exposure and transmission
β_v	The rate of viral infection of uninfected cell
γ	Rate or intensity of infection
δ , δ_a	The rate of quarantine, specifically the rate for cases without symptoms
α	Rate of susceptibility and protection
ϵ	Test rate
Ψ, Ψ_q	Rate of hospitalization, rate of hospitalization following quarantine
μ	Death rate associated with COVID-19
μ'	Rate of natural death
σ	Re-infection or reduction in immunity
ω	Rate of Mobility
d	Rate at which viruses degrade in the surroundings
τ	Recruitment rate
R_0	Basic reproduction number

3. DIFFERENT MODELS USED IN CASE OF COVID-19

The impact of the mobility of cases between regions on the general trend of disease transmission can be studied and analyzed at the national or local level using mathematical models. To make decisions about lockdowns, sealing of borders, and stopping foreign travel, these kinds of investigations are essential. In [17], the interregional migration between region A and region B is modeled using an expanded SIR model. Finding out the effects of imposing reverse quarantine—a measure to shield the elderly and sick individuals from infection—is another intriguing situation. In this case, an additional compartment P(t) can be included to describe the dynamics of the protected subpopulation. The model in [18] takes into account the effects of viral shedding on the environment, public compliance rates, and reinfection on the disease spread. In [19], the well-posedness and positivity of the COVID-19 mathematical model are examined. It is evident that the impact of isolation (in hospitalized ICUs) and quarantine (at home) measures on the overall spread of disease is modeled. The model-based research correctly estimated that, without the implementation of the required containment and prevention measures, the virus will reach its peak in Cameroon by June 2020. This model also looks at the possible effects of reinfection within the community. A mathematical model of COVID-19 that takes hospitalization, quarantine, and public health education into consideration is described in [20]. Based on the well-posed Pontryagins minimum principle, the model concludes that many interventions are necessary to restrict the spread of disease and that the NPI works best when adopted between 100 days of the epidemic. Even with the three therapies used in tandem, It was not possible to reach zero infection.Even though it was unclear at the start of the pandemic if a vaccine could be created, a number of mathematical model-based analyses released encouraging findings showing that even a vaccination with a moderate level of effectiveness might significantly lower the rate of transmission [21,22,23].

4. DISCUSSION

We have learned from this pandemic how crucial it is to stop an epidemic before it starts and deal with the consequences later on. There are numerous instances of epidemics that were successfully contained but did not receive widespread media coverage simply because they did not result in a pandemic. Since human behavior plays a major role in determining whether an outbreak is confined or becomes a pandemic, it is crucial to raise public understanding of the most effective containment techniques. Since pandemics are happening more frequently, holding a global day or week dedicated to raising awareness of the epidemic and to raise public understanding of the value of readiness and awareness could benefit future generations. By focusing on finding solutions to problems rather than the limitations that bind them, awareness typically enables a group to regain its independence. In order to emphasize the need of readiness and proactive, early containment initiatives, the accomplishment of containment of past epidemics should be examined in

more detail and used as case studies. All extant model-based analyses point to the importance of mathematical models as tools for controlling epidemics; as such, parameters of the model that particularly take into account factors such as human mobility, social contact, economic impact, and the disease's molecular and genetic components need to be updated and improved.It would be ideal, for example, to create a cross-scale model that takes into account social behavior, viral shedding, dynamics of the pathogen in the host, and population dynamics. Studies also show that population behavior, not population number, has animportant impact on disease transmission rates. It is also preferable to include the time lag in testing reporting and pathogen load data, which can be measured using qRT-PCR (quantified RT-PCR) to distinguish between other infections and extreme spreaders. Based on viral load and human behavior in public spaces, there are two types of spreaders that can exist. Establishing strategies for dealing with pandemics in the future requires carrying out analysis and re-validation of post-pandemic models.
Among the unanswered questions are the following: Why does the disease severity vary so much across the nation and across age groups? How long should I expect to be protected by a vaccine? Can a vaccination designed to prevent the SARS-COV virus also successfully protect against other virus variants? Does the effectiveness of vaccines vary depending on the age group?[24,25]

5. CONCLUSION

This paper reviews a number of mathematical models in an understandable and coherent way that can be used for scenario-specific analysis and decision making. The difficulties at hand and the potential for further research in the field of mathematical modeling are also covered. All the positive changes brought about by the COVID-19 pandemic should, in general, be strengthened in order to create a robust healthcare system and a population prepared for pandemics in the future. This includes analyzing the positive changes that occurred in the public health response and health care network.

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CONFLICT OF INTEREST

None.

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