Mathematical Modeling ofSecond Wave on Indian COVID-19 Pandemic with Control Strategy Outbreak

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Abstract. Since the first peak on April 19, 2021, the second wave of COVID-19, which began around February 11, 2021, has wreaked havoc on India, with daily cases nearly tripling. The epidemic evolution in India is particularly difficult due to regional inhomogeneities and the transmission of multiple coronavirus strains. We looked at some fundamental concepts of Mathematical modelling of virus transmission in the ongoing second wave in India and its states until October 31, 2021, as well as Mathematical modelling of COVID-19 in the present epidemic situation from the start of the control strategy outbreak.According to an exponential fit of recent data, the infection rate is likewise significantly higher than the prior wave. The features of COVID-19 mathematical modelling are then investigated, and four COVID-19 model examples are offered in this work.

INTRODUCTION

Humans and animals both susceptible infectious diseases. Cholera, Anthrax, Malaria, and Blake are just a few of the diseases that are passed from animal to human. Many diseases can also be transmitted directly from person to person when respiratory droplets are used [1]. If our body's respiratory system is in good shape, we may be safe from the virus's source. Mosquitoes are the world's most common virus spreader are seasonal diseases for humans [2]. Vaccines, antiviral drugs, and antibiotics can all help to control various diseases.We look at several control options for a specific condition, such as Corona virus disease (COVID-19), because knowing the features is important. Mathematical modelling is particularly effective for determining the control approach of a potential disease in humans, as well as focusing on the relevant components of the condition [3]. The very crucial threshold quantity here is the basic reproduction number R_0. Infected and vulnerable are the two primary divisions [4]. Where the infected people have a disease, yet the vulnerable people are healthy and may develop a disease. So, since the severity of an illness is determined by a number of factors, we determine the value of R_0.

We mostly explored how to determine the fundamental reproduction number R_0 in several ways and how to determine that utilised a approach [5]. In January 2019, a new Corona virus was discovered in China, and it spread throughout Wuhan, Hubei Province [6]. The Corona viral illness (COVID19) was identified by Chinese scientists and medical professionals in January 2019. The biggest issue with this virus is that it is completely undetectable.Since SARS can cause kidney failure and even death in people, we are unable to determine the cause of Corona virus disease (COVID19) in humans because the same[7]. Corona virus illness easily;however, it takes a few days. As a result, more than 1.6 billion individuals are infected; otherwise, the entire globe will be devoid of humans as a result of this virus [9]. We strive to prevent one sick another by implementing measures such as a quarantine period.This virus has a high rate of propagation in densely populated areas [8].

The mortality of humans and animals will be determined by the basic reproduction number R_0.$R_0 < 1$, $R_0 > 1$, and $R_0 = 1$ [9]. We explore the three categories and attempt to reduce human death. We take a close look at the reproduction number R0. If the infection is severe, utilise medicines to control Malaria to the best of your ability. R(0) key in the entire epidemic model [10]. We used a approach, as well as a study the best control strategy for this model [11]. The abstentionistIf a person is infected with the Corona virus (COVID-19), infected with HIV/AIDS. As a result, viral transmission from one person to another is tricky.

CONTROL STRATEGY OUTBREAK

As of October 31, 2021, the overall number of people affected was 3,36,68,560, with 4,58,437 deaths, and 1,58,817 others. Many individuals died as a result of the oxygen crisis, which caused the supply to be disrupted. It takes longer for individuals who have perished here. If the 490 metric tonnes of oxygen required per day distribution were not delivered. It is the responsibility of the central government to ensure that the NCT has favourably given the statement. Following immunising patients aged 18 and up against COVID-19. Vaccinations are now available to anybody over the age of 18. In COVID-19 cases, the death ratio exceeded 450000.It is a universal inoculation; immunisation is required for those aged 18 and up. The vaccine is available to everyone, including those who have been affected by the epidemic. It is only recommended for those between the ages of 18 and 44. Different prices have been set. The immunisation could cost between 300 and 600 rupees in Indian currency, if I'm not mistaken. It will be better if the cost of vaccines is reduced. The vaccination supply chain, vaccine delivery, and vaccine cost are three critical elements in the immunisation process. It is impossible to vaccinate 700 million individuals in less than 24 hours. People have many questions about vaccination, such as who was chosen for vaccination, why it was pressed on them, vaccine testing findings, and whether it works or not.

Unfortunately, vaccine supplies were in short supply. It is insufficient for all persons. In Chennai, a triage centre opened. Methods in the Ebola virus epidemic disease model [12]. When controlled, human-to-human transmission is reduced. As a result, the social epidemic model [13] is properly regulated. Because novelty is vital in the overall epidemic model.The new Corona virus illness (COVID-19) is responsible for the majority of deaths in India. The Corona virus illness is also known as SARS-CoV and is caused by a novel Corona virus (2019–nCoV). Corona virus disease can be transmitted from person to person or from animal to human. As a result, we believe have as a result of the pneumonia outbreak caused by bats. As result, the Corona virus has infected the majority of people in Wuhan (COVID-19). The human recovery from Corona virus sickness is aided by a phase-based transmission paradigm (COVID-19).

We apply numerical methods to obtain the stability analysis of a mathematical model using an ordinary differential equation with fractional derivative operator. The Corona virus disease is rapidly distributed countries in its early stages, which means January 2019. We investigate a simulation of a pandemic mathematical model. Wuhan, China, has a high prevalence of the Corona virus. Fever is a common sign of Coronavirus infection (COVID-19).

MATHEMATICAL MODELING OF COVID-19

Mathematical modelling is greatest way making best related decisions. Furthermore, it has been designed as a time-sensitive necessity. Indeed, modelling has given scientists working on the COVID-19 project a better knowledge of how the disease spreads time [14]. Its effects are so intense during the course of illness that it has tremendous power. International mathematics experts have agreed to create a mathematical model for corona virus transmission dynamics and the present pandemic.

Utilising daily based real time data. To determine R(0), they simplified the RP model by omitting bats and hosts. The BHRP transmission network model assumes that the virus was first transmitted and later to unusual hosts, which are supposed to be wild animals.The hunters carried the presumed wild animals to the seafood market, which has been identified as the virus's reservoir. Who puts themselves at danger of infection by going to the market?

$$\frac{dS_u}{dt} = \varphi_u - d_u S_u - \beta_u S_u I_u$$

$$\frac{dE_u}{dt} = \beta_u S_u I_u - \mu_u E_u - d_u E_u$$

$$\frac{dI_u}{dt} = \mu_u E_u - (\alpha_u + d_u) I_u$$

$$\frac{dR_u}{dt} = \alpha_u I_u - d_u R_u$$

$$\frac{dS_v}{dt} = \varphi_v - d_v S_v - \beta_{uv} S_v I_u - \beta_v S_v I_v$$

$$\frac{dE_v}{dt} = \beta_{uv} S_v I_u + \beta_v S_v I_v - \mu_v E_v - d_v E_v$$

$$\frac{dI_v}{dt} = \mu_v E_v - (\alpha_v + d_v) I_v$$

$$\frac{dR_v}{dt} = \alpha_v I_v - d_v R_v$$

$$\frac{dS_q}{dt} = \varphi_q - d_q S_q - \beta_q S_q (I_q + rF_q) - \beta_c S_q C$$

$$\frac{dE_q}{dt} = \beta_q S_q (I_q + rF_q) + \beta_c S_q C - \left(1 - \gamma_q\right) \mu_q E_q - \delta_q \mu_q^{'} E_q - d_q E_q$$

$$\frac{dI_q}{dt} = \left(1 - \gamma_q\right) \mu_q E_q - (\alpha_q + d_q) I_q$$

$$\frac{dF_q}{dt} = \gamma_q \mu_q^{'} E_q - (\alpha_q^{'} + d_q) F_q$$

$$\frac{dR_q}{dt} = \alpha_q I_q + \alpha_q^{'} F_q - d_q R_q$$

$$\frac{dC}{dt} = eC \frac{I_v}{N_v} + \rho_q I_q + \rho_q^{'} F_q - \delta C$$

Effective reproduction number

All fundamental quantity is crucial in preventing disease spread. It's the average number of secondary infections over the course of the infection. Since $R_0 < 1$, the average number of secondary infections per infection period has been less than one, making the disease very straightforward to manage. However, the number of people infected with COVID-19 who develop secondary infections varies from time to time. As a result, the frequency of secondary infections and, as a result, the number of reproductions per day can be controlled.

The effective reproduction number (R(t)) impacted by a single primary infection on the "t"th day and is represented by R(t). The quantity R(t) will then provide information on the steps required to manage COVID-19 in India. The following renewal equation can be used to get out R(t).R(t)

$$R(t) = \frac{b(t)}{\int_{\tau=0}^{\infty} b(t-\tau) h(\tau) d\tau}$$

where b(t) is the number of new cases at tth day and h(τ) is the generation interval distribution for the COVID-19 disease. Distribution initial infection to the person's secondary infection case. Allow the infected class's rate of departure from the related compartments to be $m1 = \sigma a + \sigma i + \sigma q + \mu$, $m2 = \gamma a + \mu$, $m3 = \eta i + \gamma i + \mu +$

δ, $m4 = \eta q + \gamma q + \mu + \delta$ and $m5 = \gamma h + \mu + \delta$. Therefore, the function will be combination of the five exponential functions $m1e^{-m1t}, m2e^{-m2t}, m3ee^{-m3t}, m4e^{-m4t}$ and $m5e^{-m5t}$in the following form,

$$h(t) = \sum 5i = \frac{1m1m2m3m4m5e^{-mit}}{\prod 5j = 1j \neq i(mj - mi)}$$

with mean of the distribution is $T = \frac{1}{m1} + \frac{1}{m2} + \frac{1}{m3} + \frac{1}{m4} + \frac{1}{m5}$ and $\tau > 0$. The above relation is valid when the force of infection $\zeta > min\{-, m1,,, -, m2,,, -, m3,,, -, m4,,)(-, m5\}$. Using the model.

Mathematical Model 1

We receive the endemic points if none of the components are equal to zero. Examined using Lyapunov techniques. We also go through sensitivity analysis and the Ro reproduction number. MATLAB is used to create numerical solutions for calculating real-world data. When we examine real-life data to validate the theoretical outcome. Consider the following system of non-linear ordinary differential equations:

$$\frac{dA}{dt} = S - \gamma\frac{AE}{N} - \nu A$$

$$\frac{dE}{dt} = \gamma\frac{AE}{N} - (\nu + \beta + \theta)$$

$$\frac{dI}{dt} = \beta E - (\nu + \beta + \delta)E$$

$$\frac{dH}{dt} = \lambda I - (\nu + \alpha + \delta)E$$

$$\frac{dR}{dt} = \alpha H + \theta E - \mu R$$

Mathematical Model 2

Consider the current COVID-19 model, which is as follows:

$$\frac{dA}{dt} = S - mA - \gamma A(I + KS) - \gamma AW$$

$$\frac{dE}{dt} = \gamma A(I + KS) + \gamma AW - (1 - \delta)\omega E$$

$$\frac{dI}{dt} = (1 - \delta)\omega E - (\alpha + m)I$$

$$\frac{dA}{dt} = \delta\omega E - (\alpha + m)S$$

The aforementioned equation, as well as the equilibrium analysis and reproduction number R(0), were derived. Our concept is applicable to all countries (or) the entire world. The similar methodology can be applied to other countries, like as the Indian Pandemic. We projected that Delhi, Karnataka, Maharashtra, Tamil Nadu, and Andhra Pradesh would be severely hit. Finally, we determine whether the COVID-19 equation system is legitimate (or not) based on current real-world data from the World Health Organization. In the current pandemic situation 2020, all data is available.

Mathematical Model 3

The COVID-19 mathematical model is organised as follows:

$$A(t) = -A(t)[\beta I(t) + \gamma D(t)] + \alpha S(t) + \delta R(t)$$

$$I(t) = A(t)[\beta I(t) + \gamma D(t)] + \alpha A(t) + \delta R(t)$$

$$D(t) = \varepsilon I(t) - (\eta + \rho)D(t)$$

$$A(t) = \xi I(t) - (\theta + \nu + K)S(t)$$

$$H(t) = \lambda I(t) + \rho D(t) + KS(t) + \zeta R(t) + \sigma T(t)$$

$$E(t) = \tau(t)$$

Mathematical Model 4

The parameter values for the Indian epidemic are based on current COVID-19 data. Consider the COVID-19 equation, which is as follows:

$$\frac{dA}{dt} = -\lambda A - \frac{\beta A(I + \gamma S)}{N} - \alpha AQ$$

$$\frac{dE}{dt} = \frac{\beta A(I + \gamma S)}{N} + \alpha AQ - (1 - \phi)\delta E - \phi\nu E - \lambda E$$

$$\frac{dI}{dt} = (I - \phi)\delta E - (\sigma + \lambda)I$$

$$\frac{dS}{dt} = \phi\nu E - (\rho + \lambda)S$$

$$\frac{dR}{dt} = \sigma I + \rho S - \lambda R$$

$$\frac{dQ}{dt} = kI + \mu S - \eta Q$$

RESULTS

To estimate the viral transmissibility throughout India and different states.Variationn infection rate is roughly followed by the effective reproduction number trend. After a rather long period of silence, R(t) began to rise on February 19, 2021, which can be interpreted as a date for the second wave's arrival in India. Since then, R(t) has been steadily increasing with occasional oscillations; as of April 19, 2021, R(t) was around 1.37 (95 percent CI 1.28 1.47).

As of April 19, 2021, these variations for the nine most-affected states, whereas the most recent R(t) values for all states are shown in **TABLE 1**. Except for Andhra Pradesh, these states reveal that current daily cases are already greater than the previous peak. **FIGURE 1**exhibits as of May 2021, regional characteristics of the epidemic spread in some Indian states. The Rt curve initially crossed the threshold in Maharashtra, followed by other states approximately a week afterwards. The Rt value in Maharashtra, on the other hand, has recently dropped slightly.Uttar Pradesh, populous state and one of the least impacted by the first wave, is now in the high growth phase, with a R t value of 1.74. West Bengal and Bihar, too, have high R t values, as indicated in **TABLE 1**. This is alarming since these states have a huge rural population and a healthcare system that is unfit for a pandemic of this magnitude.

We use the following well-known ratios to further characterise the second wave:

$$Test\ Positivity\ Rate\ (TPR)\ =\frac{Total\ infections}{Total\ tests}$$

$$Case\ Fatality\ Rate\ (CFR)\ =\frac{Total\ deaths}{Total\ infections}$$

TABLE 1. Regional Characteristics Of The Epidemic Spread In Some Indian States As On May 2021

Region	$\frac{CRF(\%)}{cummulati}$	$\frac{TRF(\%)}{cummulative}$	$\frac{CRF(\%)}{daily}$	$\frac{TRF(\%)}{daily}$	R(t)	Vac control %	Population
Andhra Pradesh	0.55	5.65	0.43	13.23	0.76	10	5.2
Maharashtra	2.00	17.33	0.49	28.21	0.88	12.54	12.2
Chhattisgarh	0.76	9.01	0.86	30.01	0.62	19.65	2.9
Punjab	3.03	5.23	2.22	16.30	0.9	9.0	3
Uttar Pradesh	0.88	1.98	0.87	13.77	2.01	5.0	22.5
West Bengal	1.65	7.44	1.12	21.57	1.23	10.0	9.7
Bihar	0.86	1.55	1.00	9.23	2.10	5.0	0.118
Tamil Nadu	1.45	5.01	0.20	10.00	1.76	5.79	7.6

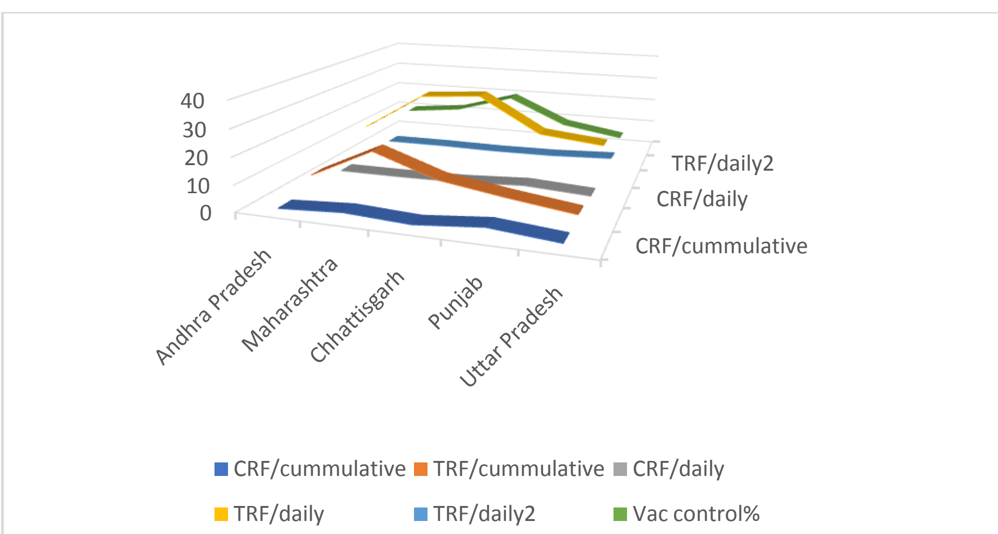

FIGURE 1. Two Characterizing Parameters- Test Positivity Rate (Tpr) And Case Fatality Rate (Cfr)- Are Shown In Temporal Variations

CONCLUSION

In this study, we will exclusively describe COVID-19 mathematical modelling, with some instances of additional COVID-19 mathematical models. It is extremely beneficial in the field of mathematical modelling and other medical research. These nonlinear ODE analyses were useful for determining the cure rate and illness transmission in current status reports. Additionally, we discussed the present control technique.

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