

# Modeling the Impact of Various Treatment and Prevention Tactics on COVID-19 Worldwide



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**Abstract** World Health Organization declared an epidemic on March 11, 2020 known as COVID-19. In the world, there are deceptive distinctions in prevalence and impermanence of COVID-19 cases in different areas. The COVID-19 first case in India was found on January 30, 2020. Presently, no remedy is available for COVID-19 treatment. The organs or the cells having ACE-2 expression are at higher risk of COVID-19, and in this manner, lymphocytes, which make a larger portion of the immune system, are the primary target of COVID-19 virus. Without authentic vaccines or treatment, there is a crucial need for the tactics of treatment and prevention for COVID-19 virus. Developing such tactics involves full understanding of how the virus is spreading in all over the world. Various treatment and prevention methods have been started worldwide such as BCG vaccination, plasma therapy, antiviral drugs, and immunoboosters to decrease the high death rate caused because of COVID-19 pandemic. Our motive is to compare various models (BHRP transmission model, SIR model, and SEIR model) and then put on different control factors to understand the results of recovery from COVID-19 virus.

**Keywords** COVID-19 · ACE-2 · Mathematical modeling · Immunoboosters

## 1 Introduction

COVID-19 is an acronym and it is an infection caused by the severe acute respiratory syndrome coronavirus 2 (SARS-COV2). China country office informed about death cases to WHO on December 31, 2019, which were susceptible of an unknown disease

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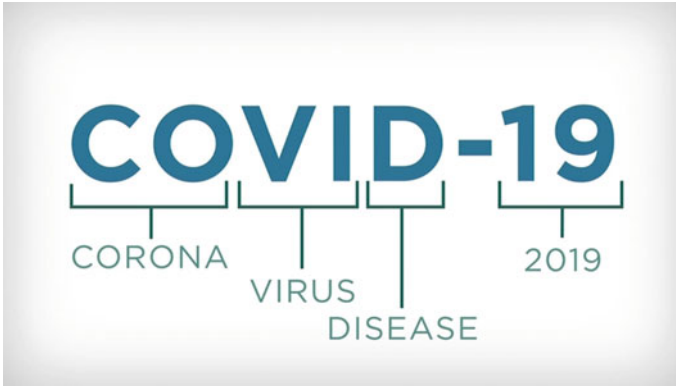
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in the Wuhan city, Hubei province China, then WHO announced that as novel coronavirus. SARS-COV-2 was named by International committee on taxonomy of viruses on February 11, 2020. First, it is found that virus transmitted from bats to humans. Therefore, the spreading of virus was linked to seafood market. After this epidemic, COVID-19 grabbed severe attention across the world. WHO declared the COVID-19 as a universal epidemic in March 2020. The main reason of radiate COVID-19 was the unavailability of data and awareness regarding causative agent during its foremost stage of infection. The virus spread in the crowning through respiring droplet during sneezing or coughing from the infected person. An earlier healthy inhabitance may become infected when they breathe in contaminated area or touch the infected surface. COVID-19 symptoms develop in 2–10 days. The prime symptoms involved dry cough, difficulty in breathing, and high fever. In beginning stage of infection, we isolate the infected person.

**Angiotensin-Converting Enzyme:** Angiotensin-converting Enzyme is a zinc-dependent carboxypeptidase which has two catalytic domains. ACE imparts an important role in regulation of blood pressure by conversion of angiotensin I to angiotensin II. This enzyme also has a role in immunity response focusing on innate and adaptive responses by modifying functions of macrophage and neutrophil cells. These effects are increased when expression of ACE is over-expressed in these types of cells. Over-expression of ACE in macrophages is more effective in managing tumors and infections. Discovery of ACE was coming into light in 1953 in the course of rennin-angiotensin system (RAS), on cell membrane present which is attached through a transmembrane domain having carboxy terminal. In various treatment strategies of different types of diseases, ACE or kininase II inhibitors are widely used as therapeutic agents. The pharmacological effects of ACE-2 have been reported as it increases constriction in blood vessels, alleviates oxidative stress, and results in fibrosis. It also stimulates to angiotensin II due to which concentration of water and salt is increased in blood plasma. ACE-2 has well-known vasoconstrictive, proinflammatory, and fibrotic effects. In various studies, it has been proved that activity of ACE is found in an alleviated amount and downregulation of ACE-2 also reported in patients suffering from various diseases as diabetes, hypertension, and other cardiovascular disorders.

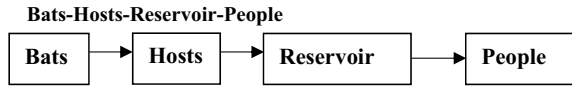
**Lymphocytes:** Innate immunity is the first line of defense against viral infection which is important in providing immunity to viruses. Al-Shura [1] discussed that in blood, white blood cells are one of the types of blood cells which have lymphocytes. Omman and Kini [2] discussed on lymphocytes that they are found in the immune system of vertebrates and are composed of different types of cells as natural killer cells, T and B lymphocytes cells, etc. Total lymphocyte counts decreased in the first two weeks of illness in COVID. It also has reported that patients who have immune dysregulation, due to infection of COVID-19, had decreased counts of different types of lymphocytes cells specially counts of CD3+, CD4+, CD45+, CD8+, CD45+, CD16+, and CD56+ cells than those individuals who has an intermediate immune state.



There is no established medicine and vaccine for the treatment of COVID-19. The drug chloroquine and antibiotic azithromycin which is used as antimalarial exposed some promise against COVID-19 but its effectiveness has been debated lately [3]. Only strong immunity of humans can decrease the spread of disease [4]. Some researches such as Chen et al. [5], Hung et al. [6], Ko et al. [7], and Zhou et al. [8] showed successfully the safety results of CP therapy during pandemic in their studies. The disease recognized as COVID-19 dated back its origin in December 2019 at Wuhan city, China. Jain et al. [9] explored an inventory model the learning impact on best policy with preservation technology for decline goods under in COVID-19 pandemic. Koutsakos et al. [10] and Althaus [11] also discussed on COVID-19 transmission in humans. Mittal et al. [12] discussed the measures of predictive and preventive for pandemic COVID-19. Mittal [13] explored a statistical modeling approach related to the factors affecting digital education during pandemic. Goyal et al. [14] discussed that COVID-19 is another way of natural disaster. Mittal et al. [15] explored the impact of air quality on the COVID-19 fatalities in Delhi, India, by using machine learning techniques.

The spread of the disease is similar to the spread of other airborne diseases such as influenza and tuberculosis via direct contact with the person infected by the virus through respiratory droplets. As there is no defined treatment or a vaccine which is effective for controlling the transmission of the disease, it is a crucial need to develop much more effective methods to deal with the increasing spread of the disease. Vaccines are responsible for providing protection against particular pathogens by making effective mechanisms that work directly toward the pathogens. The BGC vaccine is a live attenuated vaccine which improves the immunity against not only single bacteria but also to several other microorganisms which are present with acute respiratory tract infections.

**Fig. 1** Diagram of BHRP transmission model



### 1.1 *Bats-Hosts-Reservoir-People*

BHRP spreading network model was formulated on January 19, 2020. Here, we consider that the virus circulated among the bats and then transferred to an unspecified host. The host was the most purchased food in the market of seafood which was identified as the reservoir of the virus. People went to the market for food and became infected (Fig. 1).

Bats are divided into four parts susceptible, exposed, infected, and removed bats. After waste spreading of bats and hosts was disregarded, then reservoir-people spreading models come because we consider that COVID-19 might be carried from the market of seafood in a short time among many people.

### 1.2 *SIR Model*

SIR model was first developed by Kermack and Mckendrick [16] in 1927. This was the first continual varying projection model considering epidemic population dynamics. In this model, constant populations are distinguished in three circumstances which include susceptible, infected, and removed. Three possible parts of transitions are susceptible  $S(t)$ , infected  $I(t)$ , and removed  $R(t)$ . The portion of inter-connection between  $S(t)$  and  $I(t)$  which taken as the rise to infection per unit time is  $\phi$ . The portion of infected people that recover with exemption or pass away from disease per unit time is  $\varphi$ .

The mathematical formulation of SIR model is as follows:

$$\begin{aligned} \frac{dS}{dt} &= -\phi S(t)I(t), \\ \frac{dI}{dt} &= \phi S(t)I(t) - \varphi I(t), \\ \frac{dR}{dt} &= \varphi I(t). \end{aligned}$$

### 1.3 *SEIR Model*

The SEIR model includes four parts: susceptible ( $S$ ), exposed ( $E$ ), infected ( $I$ ), and removed ( $R$ ). Let  $\alpha$  be the infection rate between susceptible ( $S$ ) and exposed ( $E$ )

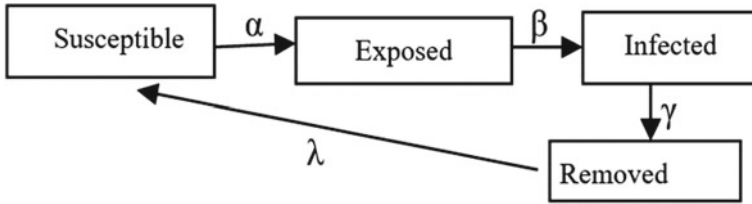


Fig. 2 Diagram of SEIR transmission model

which expresses the chance of disease transferring to susceptible people to exposed people;  $\beta$  is the growth rate which expresses the inactive rate at which one becomes infectious;  $\gamma$  is the recovery rate and  $\lambda$  is the rate at which recovered people become susceptible again because of health issues (Fig. 2).

The mathematical formulation of SEIR model is as follows:

$$\frac{dS}{dt} = -\alpha \frac{SI}{N} + \lambda R \tag{1}$$

$$\frac{dE}{dt} = -\alpha \frac{SI}{N} - \beta E \tag{2}$$

$$\frac{dI}{dt} = \beta E - \gamma I \tag{3}$$

$$\frac{dR}{dt} = \gamma I - \lambda R \tag{4}$$

Here  $N$  shows the sum of susceptible, exposed, infected, and removed.

The function of SEIR model is to find the value of  $R_0$  where  $R_0$  shows basic reproduction number.  $R_0$  denotes an average of people affected by an infected person in a limited time. Here, three cases arise:

- (1) If  $R_0 < 1$ , then the stage of disease is controllable.
- (2) If  $R_0 = 1$ , then the stage of disease is endemic.
- (3) If  $R_0 > 1$ , then the stage of disease is uncontrollable (or increasing).

$R_0 = \frac{\alpha_0 \beta}{(\mu + \beta)(\mu + \gamma)}$ , where  $\mu$  is the proportionately birth rate. The  $\alpha$ ,  $\beta$ ,  $\lambda$ , and  $\gamma$  value can be found from Eqs. (1–4).

Chen et al. [17] derived a model on novel coronavirus for reproducing the phase-based transmission from the source of infection to the people. Pal et al. [18] used a different model to study and forecast the increase of virus disease. Shah et al. [19] introduced the idea to control COVID-19. In model, they assumed all feasible cases of transmission of this virus. To examine the accurate transmission of the virus, a basic reproduction number is derived. They devised the plan to show control of disease numerically as well as graphically. Transmission model is divided into five compartments. Shah et al. [20] derived a model for the recovery of infected people

of COVID-19. They calculate the basic reproduction number and applied different parameters to see the impact of recovery from disease. Plasma therapy shows the better result for a long term. From the studies of COVID-19, Leung et al. [21] developed a method to evaluate the pandemic which is spreading globally. Shah et al. [22] derived the mathematical model by using the different parameters to control the COVID-19 and also agreed that better results can be seen by using plasma therapy.

## 2 Formulation of Mathematical Model

Here, a model for COVID-19 transmission among the people is formed. Model is divided into eight parts:

1. Exposed people
2. Infected people
3. Symptomatically infected people
4. Non-symptomatically infected people
5. Quarantined people
6. Hospitalized people
7. Critical stage people
8. Recovered people.

First part is the category of exposed people to COVID-19 denoted as  $E$ . From these, some people are transferred into the stage of infection denoted as  $I$ , some infected people that have symptoms of COVID-19 denoted as  $S$ , and some people do not have any symptoms of COVID-19 denoted as  $N_S$ . From these class of people, some get quarantine denoted as  $Q$  and others get hospitalized denoted as  $H$ . From these hospitalized people, some shift to quarantine and others go to critical stage denoted as  $C$ , another some people recovered also denoted as  $R$ . From these critical stage people, some people also recovered (Fig. 3).

By using Fig. 4 and Table 1, the nonlinear differential equations are formulated as:

$$\frac{dE}{dt} = B - B_1EI \quad (5)$$

$$\frac{dI}{dt} = B_1EI - B_2IS - B_3IN_S \quad (6)$$

$$\frac{dS}{dt} = B_3IS + B_4N_S - B_5S - B_8S - B_9S \quad (7)$$

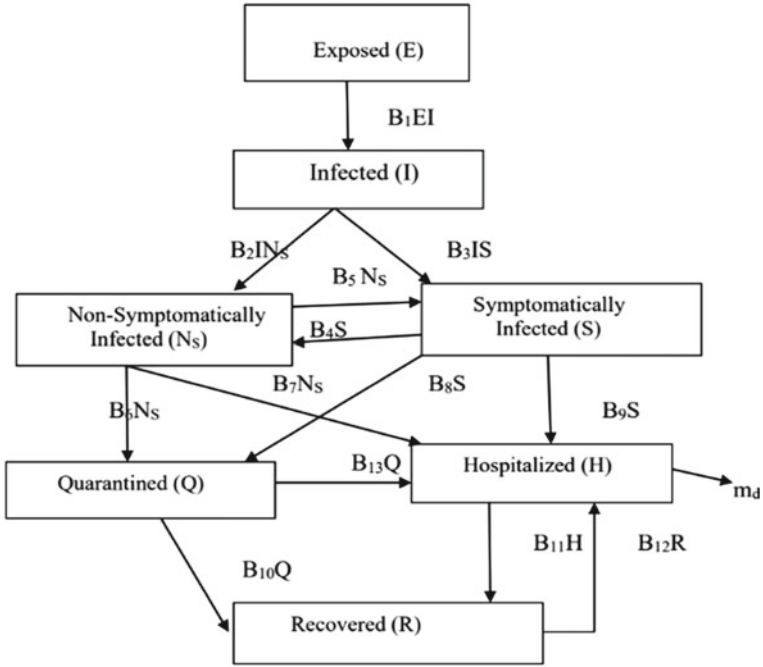


Fig. 3 Diagram of COVID-19 transmission model

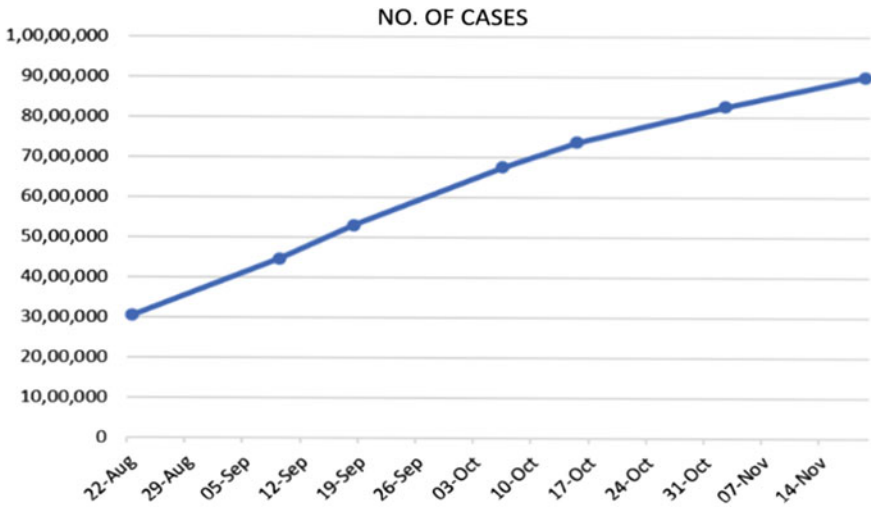


Fig. 4 Graph of India's total coronavirus cases

**Table 1** Notation and its description

$B$	Birth rate of exposed people
$B_1$	Rate of infected people
$B_2$	Rate of infected people who does not show symptoms
$B_3$	Rate of infected people who show symptoms
$B_4$	Rate of infected people lose symptoms
$B_5$	Rate of symptomatically infected people now show symptoms
$B_6$	Rate of non-symptomatically infected people getting quarantine
$B_7$	Rate of non-symptomatically infected people who get hospitalized
$B_8$	Rate of symptomatically infected people who get quarantined
$B_9$	Rate of symptomatically infected people getting hospitalized
$B_{10}$	Rate of recovered people who get quarantined
$B_{11}$	Recovery rate of hospitalized people
$B_{12}$	Rate of recovered people who get hospitalized
$B_{13}$	Rate of quarantined people who get hospitalized
$m_d$	Rate of death due to disease

$$\frac{dN_S}{dt} = B_2 I N_S - B_4 N_S + B_5 S - B_6 N_S - B_7 N_S \tag{8}$$

$$\frac{dH}{dt} = B_9 S + B_7 N_S - B_{11} H + B_{12} R + B_{13} Q - m_d H \tag{9}$$

$$\frac{dQ}{dt} = B_6 N_S - B_{13} Q - B_{10} Q + B_8 S \tag{10}$$

$$\frac{dR}{dt} = B_{11} H + B_{10} Q - B_{12} R \tag{11}$$

With  $E > 0$ ;  $I, S, N_S, H, Q, R \geq 0$ .

### 3 Basic Reproduction Number

The solution of Eqs. (5–11),

$E^* = (E^*, I^*, S^*, N_S^*, H^*, Q^*, R^*)$  is

$$E^* = \frac{B}{xB_1}, \quad I^* = x, \quad S^* = -\frac{BB_4}{y},$$



$$N_S^* = \frac{B(B_3x - B_5 - B_8 - B_9)}{y}, \quad H^* = \frac{B}{m_d},$$

$$Q^* = \frac{B((B_3x - B_5)B_6 - B_6(B_8 + B_9) - B_4B_8)}{y(B_{10} + B_{13})},$$

$$R^* = \frac{zB}{y(B_{10} + B_{13})m_d B_{12}}$$

where  $z = m_d B_{10} B_6 (B_3 x - B_5) - m_d B_{10} B_4 B_8 + B_{11} (B_6 + B_7) (B_3 x - B_5) (B_{10} + B_{13}) + (B_8 + B_9) (B_{11} (B_6 + B_7) (B_{10} + B_{13}) + B_{11} B_4 (B_{10} + B_{13}) + m_d B_{10} B_6)$  and  $y = (B_6 + B_7) (B_3 x - B_5) - (B_8 + B_9) (B_4 + B_6 + B_7)$ ,  $x$  is the highest root of the polynomial

$$m(P) = B_2 B_3 P^2 - B_2 (B_5 + B_8 + B_9) + B_3 (B_4 + B_6 + B_7) P + B_5 (B_6 + B_7) + (B_8 + B_9) (B_4 + B_6 + B_7)$$

By using next generation matrix method, we calculate endemic equilibrium point. Now

$$f = \begin{pmatrix} B_1 EI \\ B_2 I N_S \\ B_3 IS \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix},$$

$$v = \begin{pmatrix} B_2 I N_S + B_3 IS \\ B_4 N_S - B_5 S + B_6 N_S + B_7 N_S \\ -B_4 N_S + B_3 S + B_8 S + B_9 S \\ -B + B_1 EI \\ -B_6 N_S - B_8 S + B_{10} Q + B_{13} Q \\ -B_7 N_S - B_9 S + B_{11} H - B_{12} R - B_{13} Q + m_d H \\ -B_{10} Q - B_{11} H + B_{12} R \end{pmatrix}$$

$$\text{Again, } F = \begin{pmatrix} B_1 E^* & 0 & 0 & B_1 I^* & 0 & 0 & 0 \\ B_2 N_S^* & B_3 I^* & 0 & 0 & 0 & 0 & 0 \\ B_3 S^* & 0 & B_3 I^* & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix},$$

$$V = \begin{pmatrix} B_2 N_S^* + B_3 S^* & B_2 I^* & B_3 I^* & 0 & 0 & 0 & 0 \\ 0 & B_4 + B_6 + B_7 & -B_5 & 0 & 0 & 0 & 0 \\ 0 & -B_4 & B_5 + B_8 + B_9 & 0 & 0 & 0 & 0 \\ B_1 E^* & 0 & 0 & B_1 I^* & 0 & 0 & 0 \\ 0 & -B_6 & -B_8 & 0 & B_{10} + B_{13} & 0 & 0 \\ 0 & -B_7 & -B_9 & 0 & -B_{13} & B_{11} + m_d & -B_{12} \\ 0 & 0 & 0 & 0 & -B_{10} & -B_{11} & B_{12} \end{pmatrix}$$

Hence  $R_0 = \rho(FV^{-1})$

$$= \frac{B_2 B_3 x ((B_6 + B_7)(B_3 x - B_5) - (B_8 + B_9)(B_4 + B_6 + B_7))}{\begin{pmatrix} (B_6 + B_7)(B_2 B_5 (B_3 x - B_5) - B_3 B_4 B_5) + (B_8 + B_9) \\ (B_3 B_4 (B_2 x - B_4) - B_2 B_4 B_5 - B_2 (B_8 + B_9)(B_4 + B_6 + B_7)) \\ +(B_6 + B_7)(B_2 B_3 x - 2B_2 B_5 - B_3 B_4) \end{pmatrix}} \tag{12}$$

where  $\rho$  is the eigenvalue of the matrix  $FV^{-1}$  (Figs. 5, 6, 7 and Tables 2, 3, 4, 5).

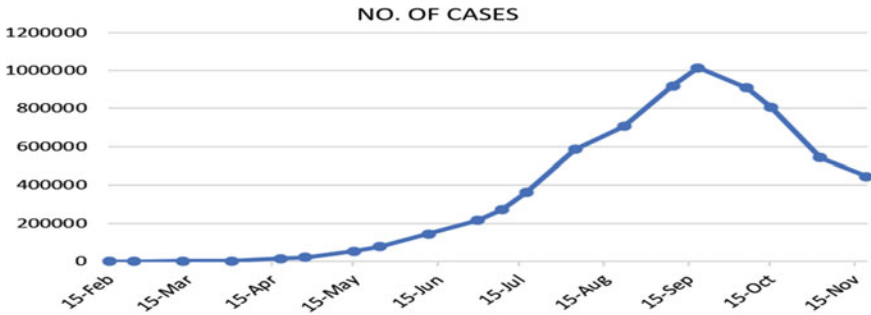


Fig. 5 Graph of coronavirus active cases in India

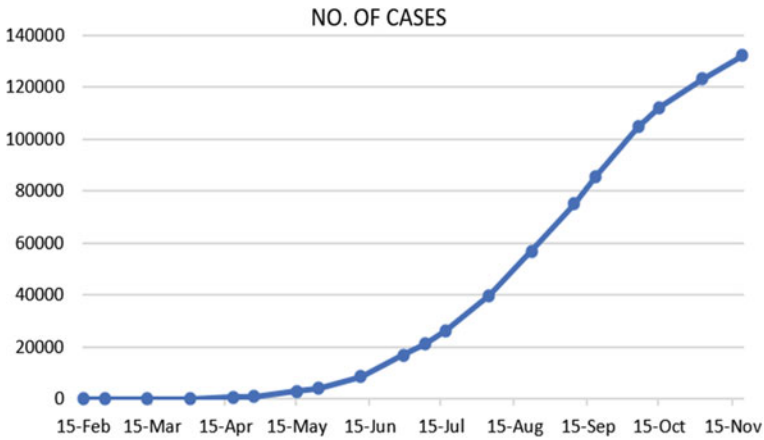


Fig. 6 Graph of total deaths due to coronavirus in India

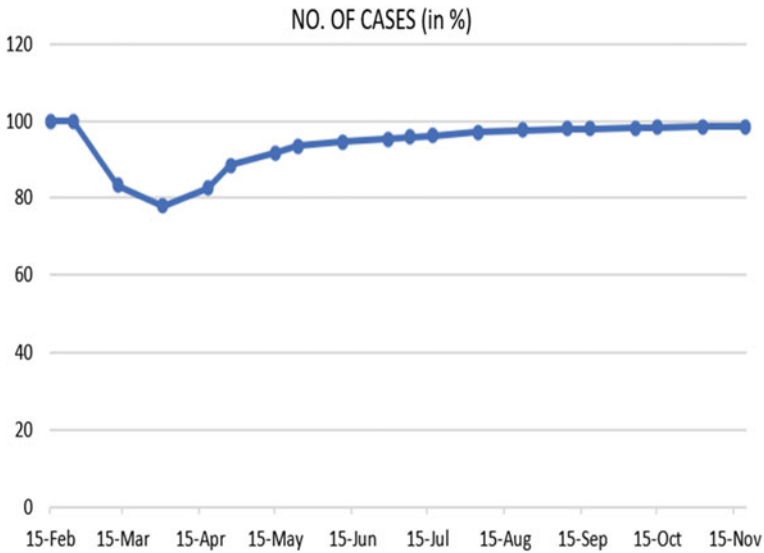


Fig. 7 Graph of total recovery rate of coronavirus in India

### 4 Summary and Conclusion

Coronavirus cases include a large family of viruses which causes illnesses like mild cold to severe respiratory disorders. The novel COVID-19 is one such strain that had not been identified in the past. In this chapter, SIR, SEIR, BHRP, and RP models were utilized to survey and forecast the extent of disease, and a compartmentalized model is proposed to find the transmission of COVID-19 in the human population class.

**Table 2** Total coronavirus cases in India

Date	No. of cases
15 February	3
24 February	3
13 March	82
31 March	1397
18 April	16,385
27 April	29,451
15 May	85,784
24 May	138,536
11 June	298,283
29 June	567,536
8 July	769,052
17 July	1,040,457
4 August	1,906,613
22 August	3,043,436
9 September	4,462,965
18 September	5,305,475
6 October	6,754,179
15 October	7,365,509
2 November	8,266,914
19 November	9,004,325

**Table 3** Coronavirus active cases in India

Date	No. of cases
15 February	0
24 February	0
13 March	70
31 March	1239
18 April	13,381
27 April	21,375
15 May	52,773
24 May	76,820
11 June	142,810
29 June	215,361
8 July	271,354
17 July	360,094
4 August	585,133
22 August	706,690

(continued)

**Table 3** (continued)

Date	No. of cases
9 September	918,790
18 September	1,014,649
6 October	908,335
15 October	804,705
2 November	542,346
19 November	445,107

**Table 4** Total deaths due to coronavirus in India

Date	No. of cases
15 February	0
24 February	0
13 March	2
31 March	35
18 April	521
27 April	939
15 May	2753
24 May	4024
11 June	8501
29 June	16,904
8 July	21,144
17 July	26,285
4 August	39,820
22 August	56,846
9 September	75,091
18 September	85,625
6 October	104,591
15 October	112,146
2 November	123,139
19 November	132,202

**Table 5** Total recovery rate of coronavirus in India

Date	No. of cases (in %)
15 February	100
24 February	100
13 March	83.33
31 March	77.85

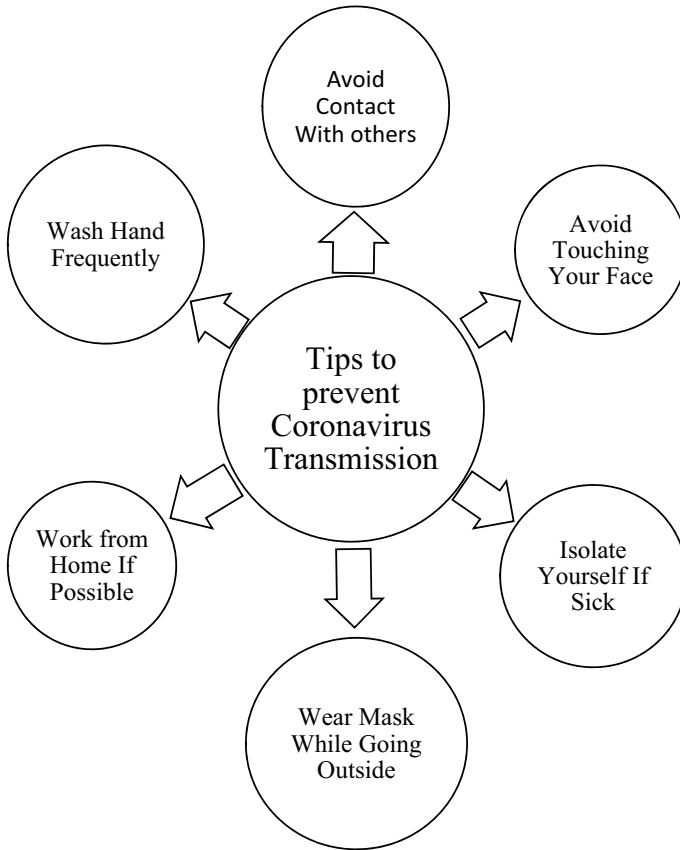
(continued)

**Table 5** (continued)

Date	No. of cases (in %)
18 April	82.54
27 April	88.37
15 May	91.66
24 May	93.48
11 June	94.53
29 June	95.20
8 July	95.75
17 July	96.14
4 August	96.99
22 August	97.57
9 September	97.88
18 September	98.00
6 October	98.20
15 October	98.29
2 November	98.41
19 November	98.46

Furthermore, basic reproduction number is found to find the origin value of spread of COVID-19. In this model, seven control variables are established to control tactics the spread of COVID-19. These tactics involve symptomatic and non-symptomatic of infected peoples, quarantine and hospitalization of infected people to reduce the case of COVID-19. It has not only possessed harm to the health of people but has also hampered the economy, trade, and relations between various countries at a noticeable stage. But, the long-term effects of this epidemic are still to be felt which cannot be predicted at such an early stage. The increasing cases of COVID-19 and deaths due to COVID-19 across the world also add to its seriousness. We all have heard that prevention is better than cure. Thus, we must take the desired steps to distance ourselves from the ever-growing COVID-19. These steps include:

- Use of masks
- Avoid to be in congested places
- Wash or sanitize your hands frequently
- Maintain considerable distance from people
- Do not touch your face often.



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