Nowcasting and Forecasting the Spread of COVID-19 and Healthcare Demand In Turkey, A Modelling Study

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Abstract

Background: A new type of coronavirus (later named Sars-Cov-2) drew attention in 31 December 2019 after the reporting of 27 unidentified pneumonia cases detected in Wuhan, China to the World Health Organization (WHO). Rapid progression of the COVID-19 pandemic has revealed the necessity of epidemic modeling studies to evaluate the course of the epidemic and its burden on the health system. This study aims to estimate the total number of infected people, evaluate the consequences of social interventions on the healthcare system and predict the expected number of cases, intensive care needs, hospitalizations and mortality rates in Turkey according to possible scenarios via the SEIR-based epidemic modeling method.

Methods: This study was carried out in three dimensions. In the first, the actual number of people infected in the community has been estimated using the number of deaths in Turkey. In the second, the expected total numbers of infected people, total deaths, total hospitalizations, and intensive care unit (ICU) bed needs have been predicted in case of no intervention. In third, distribution of the expected number of infected people and deaths, ICU and non-ICU bed needs over time has predicted based on SEIR modelling. A simulator (TURKSAS) has been developed and predictions made in 4 scenarios for Turkey.

Results: According to deaths, estimated number of infected people in Turkey on March 21 was 123,030. In the case of no intervention (1st scenario) the expected total number of infected people is 72,091,595, the total number of deaths is 445,956, the attack rate is 88.1%, the mortality ratio is 0.54%. The ICU bed capacity in Turkey is expected to exceed 4.4-fold and non-ICU bed capacity exceed 3.21-fold. In 2nd and 3rd scenario according to the calculations made by considering the social compliance rates of the NPIs, the value of R0 is estimated to decrease from 3 to 1.38 level. Compliance with NPIs makes a 94.303 difference in the expected number of deaths. In both scenarios, the predicted peak value of occupied ICU and non-ICU beds remains below the Turkey’s capacity. While this study conducted, curfew for ≥65 and <20 age groups was in force in Turkey. If the curfew is declared for the 21-64 age population (4th scenario), the R0 value drops below 1 (0.98), the expected deaths are 14,230 and the peak values of daily ICU and non-ICU bed demand are below the country’s capacity.

Discussion: Modeling epidemics with assumptions supported by scientific literature and establishing decision support systems based on objective criteria is an important requirement. According to scientific data for the population of Turkey, the situation is not expected to be of worse than predictions presented in the second dimension. Predictions show that 16 million people can be prevented from being infected and 100,000 deaths can be prevented by full compliance with the measures taken. Complete control of the pandemic is possible by keeping R0 below 1. For this, additional evidence-based measures are needed.

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Introduction

Infectious disease agents have existed throughout human history. The diseases they cause can persist in a certain population (endemic), spread at a sudden rate and affect wider populations (epidemic) or turn into a global threat (pandemic) as in the 1918 Spanish flu.(1). Coronaviruses, which were first detected in 1960, have been observed in humans until now and have 7 subtypes, also caused SARS outbreaks in 2003 and MERS in 2012.(2).

A new type of coronavirus (later named Sars-Cov-2) drew attention in 31 December 2019 after the reporting of 27 unidentified pneumonia cases detected in Wuhan, China to the World Health Organization (WHO). (3,4). The epidemic caused by the virus, called COVID-19, spread rapidly between countries and continents and was identified as a pandemic by the WHO on March 11, 2020.(5)

Rapid progression of the COVID-19 pandemic and its devastating effects in many countries (even in the developed countries like Italy and Spain); has revealed the necessity of epidemic modeling studies to evaluate the course of the epidemic and its burden on the health system properly. Stochastic, deterministic and agent-based models are used in scientific literature to model the COVID-19 spread.(6,7). Among these studies, the report published by Imperial College London on March 16, 2020, take an important place.(8). Following this report, the United Kingdom government has tighten its national policy for the COVID-19 pandemic and started the lockdown by the following week.(9).

Turkey has also taken precautions due to the COVID-19 pandemic and many additional measures were implemented after the identification of the first national case on 11 March 2020.(10). These measures include the Non-pharmaceutical Interventions (NPIs) such as school closures, cancellation of arts and sports events, mandatory quarantine for the people who travelled from abroad, closure of public places such as cafes /cinemas/ wedding halls, making mask usage in groceries obligatory, curfews for the citizens over 65, under 20 and those with chronic illnesses (11–13).

This study aims to estimate the total number of infected people, evaluate the consequences of social interventions on the healthcare system and predict the expected number of cases, intensive care needs, hospitalizations and mortality rates in Turkey according to possible scenarios via the SEIR-based outbreak modeling method. Thus, it aims to contribute pandemic response policies in Turkey by providing an epidemiological framework.
Materials and Methods

1. Study Design

This study was carried out in three different dimensions. In the first dimension, the actual number of people infected in the community has been estimated using the number of deaths in Turkey. In the second dimension, the expected total numbers of infected people, total deaths, total hospitalizations, and intensive care unit (ICU) bed needs have been predicted in case of no intervention.

The predictions in the second dimension includes cumulative numbers only. Thus, additional calculations are required to predict the distribution of healthcare needs, patients and deaths over time. Therefore, a third dimension was added to the study to model the distribution of the expected number of infected people and deaths over time, to determine the health resources required based on this model and to predict the impact of social interventions on the epidemic process.

In this third dimension, the SEIR model was used for estimations and predictions. This model divides the society into 4 main compartments during the epidemic: those who are not yet infected (Susceptible), those who have been exposed to the agent but show no signs of infection (Exposed), those who have had symptoms of the disease (Infectious), those who have resulted in recovery or death (Removed).(14).

2. First Dimension Assumptions and Forecasting Algorithm

The ratio of deaths in the total infected population is identified in the literature as Infection Fatality Ratio (IFR) (15). There may be a time shift bias in the estimations based on the number of deaths. For more accurate estimates, the number of deaths observed on a given day should not be compared to the number of infectious people occur on the same day, instead, it should be compared to the day the infection started(16). Thus, in this dimension of the study, the number of infected people was estimated by using death numbers based on IFR. According to the studies, the time elapsed from symptom to death is about 18 days. (15). The number of infected people was estimated with a delay of 18 days, and the remaining days were projected with a quadratic growth curve which has the highest R² value (0.9936). This study used the average IFR (0.66% [0.39-1.33]) and age-specific IFR values which is adjusted for the United Kingdom and the United States in ICL modeling based on calculations by Verity et al.(15).
3. Second Dimension Assumptions and Forecasting Algorithm

COVID-19 overall attack rate for Turkey was considered 81%. (8). 2018 TurkStat census data was used for age stratification. Using the expected age-specific hospitalization and intensive care ratios; total hospitalization numbers and ICU needs are estimated for each age group. First dimension values were used for IFR values. By applying age-specific IFR values to the expected number of infected people in the relevant age group, the highest number of expected deaths was determined. (8,15). In this dimension, it was assumed that no measures were taken, and the pandemic spread freely throughout the society.

4. Third Dimension Assumptions and Forecasting Algorithm

In this dimension of the study, a SEIR-based model was created, and a simulator called TURKSAS was developed by adding transmission dynamics as well as clinical dynamics and social intervention dynamics. TURKSAS model structure is as presented in Figure-1.

Figure 1: TURKSAS model structure. In a time section; N: Total population; d: delta (expressing the change of the related cluster over time) S- E- I: The number of Susceptible-Exposed-Infected people, respectively, in the relevant time section. H: Infected who have mild symptoms. IH: Those who have recovered with mild symptoms. G: Infected and have not yet applied to the hospital. Y: Infected who apply to the hospital and occupied non-ICU beds. IY: Those who have recovered from the hospital as discharged. Iybu: Those who have recovered from ICU. YBÜ1: Those who will recover in ICU. YBÜ2: Those who will die in ICU. Ö: Those who died. For other parameters, see. Mathematical Equation of the Model
**Mathematical Equation of the Model**

1st Group: Asymptomatic cases

2nd Group: Symptomatic cases

\( p: \text{ proportion} \mid \text{ICU: Intensive Care Unit} \)

\( p_1: \text{Asymptomatic case proportion} \)

\( p_2: \text{Symptomatic case proportion} \)

\( p_y: \text{Symptomatic and will apply to the hospital} \)

\( p_h: \text{Symptomatic and will have mild disease} \)

\( p_t: \text{will recover from the hospital} \)

\( p_k: \text{will need ICU Bed} \)

\( p: \text{will recover from ICU} \)

\( p_0: \text{Fatality rate among ICUs according to IFR} \)

\( R_0: \text{Number of people contaminated by an infected} \)

\( T_{inc}: \text{Incubation period} \)

\( T_{inf}: \text{Infectious period} \)

\[
\begin{align*}
\frac{dS_1(t)}{dt} &= -\frac{S_1(t)}{N_1} I_1(t) \beta_1 \\
\frac{dS_2(t)}{dt} &= -\frac{S_2(t)}{N_2} I_2(t) \beta_2 \\
\frac{dE_1(t)}{dt} &= \frac{S_1(t)}{N_1} I_1(t) \beta_1 - \alpha_1 E_1 \\
\frac{dE_2(t)}{dt} &= \frac{S_2(t)}{N_2} I_2(t) \beta_2 - \alpha_2 E_2 \\
\frac{dI_1(t)}{dt} &= \alpha_1 E_1 - \gamma_1 I_1 \\
\frac{dI_2(t)}{dt} &= \alpha_2 E_2 - \gamma_2 I_2 \\
\frac{dH(t)}{dt} &= \gamma_1 I_1 + p_h \gamma_2 I_2 - \sigma_1 H \\
\frac{d\dot{H}(t)}{dt} &= \sigma_1 H \\
\frac{dG(t)}{dt} &= p_y \gamma_2 I_2 - \varepsilon \ vys \\
\frac{dY_1(t)}{dt} &= \delta_1 Y_1 \\
\frac{dY_2(t)}{dt} &= p_k \varepsilon \ G - \delta_1 Y_2 \\
\frac{dYBU_1(t)}{dt} &= p_t \mu Y_2 - \theta YBU_1 \\
\frac{dYBU_2(t)}{dt} &= p_0 \mu Y_2 - \omega YBU_2 \\
\frac{d\delta(t)}{dt} &= \omega YBU_2 \\
p_2 = 1 - p_1 \\
p_h = 1 - p_y \\
p_k = 1 - p_k \\
p_t = 1 - p_0 \\
p_0 = ((E\dot{O}/p2)/pY)/pK \\
N_1 = p_1 N \\
N_2 = N - N_1 \\
\alpha_1 = \frac{1}{T_{inc1}} \quad \alpha_2 = \frac{1}{T_{inc2}} \quad \beta_1 = \frac{R_0_1}{T_{inf1}} \quad \beta_2 = \frac{R_0_2}{T_{inf2}} \quad \gamma_1 = \frac{1}{T_{inf1}} \quad \gamma_2 = \frac{1}{T_{inf2}} \\
\delta = \frac{1}{\text{Mild to recovery duration}} \quad \varepsilon = \frac{1}{\text{Hospitalization lag}} \quad \sigma = \frac{1}{\text{Hospitalized to recovery without ICU}} \\
\mu = \frac{1}{\text{Hospitalization to ICU duration}} \quad \theta = \frac{1}{\text{ICU to recovery duration}} \quad \omega = \frac{1}{\text{ICU to death duration}} \\
\end{align*}
\]

S: Susceptible

E: Exposed

I: Infectious

H: Mild cases

\( \bar{H}: \text{Recovered with mild symptoms}. \)

G: Infection but have not yet applied to the hospital

Y_1: Applied to the hospital and will recover

Y_2: Applied to the hospital and need ICU

YBU_1: Still in ICU and will be recovered

YBU_2: Recovered from ICU

YBU_3: Still in ICU and will die

0: Died
Because the incubation period, infectious period, and R0 variables differ between symptomatic and asymptomatic cases, these two groups are considered as separate community layers in this model. Also, it is assumed that asymptomatic cases will not apply to the hospital and die. The R compartment was also restructured to predict the need for health care. Some of the infected people will recover with mild symptoms without hospital admission (H) Some of them will be late to apply to the hospital even though they show symptoms. (G). After the delay, these people will apply to the hospital (Y). It is assumed that, all positive cases which admitted to the hospital are transferred to wards at first. Some of these patients will recover directly from the service (İY) and some will be recovered and discharged from ICU (YBU1). Others will go to ICU (YBU2) then die (Ö).

Due to the lack of studies that estimate the local clinical care dynamics and durations in Turkey, we used coefficients and assumptions from various scientific studies.

**Transmission Dynamics**

Transmission parameters used in the model were obtained from studies in the literature. Expert opinion was consulted for the parameters that could not be found in the literature. Average incubation period was accepted as 4.6 days for asymptomatic cases, 5.1 days for symptomatic cases and infectiousness period was accepted as 6.5 days for both groups.\(^{(8,17)}\). Symptomatic cases were considered to be two times more infectious than asymptomatic. \(^{(8)}\). It is assumed that R0 values are between 2-3 for Turkey. \(^{(18,19)}\). Considering that the study on the Diamond Princess ship was close to a prospective cohort design, the rate of asymptomatic cases was accepted as 17.8% in our study.\(^{(20)}\).

**Clinical Dynamics**

It is necessary to determine the duration of each stage in the clinical care and the ratio of mild patients for the prediction of those who will switch from the S-E-I to the R compartment. It has been assumed that people with mild symptoms will not apply to the hospital and their recovery will take 22 days.\(^{(21)}\). The delay time in hospital admissions is considered as 5 days and the period from hospitalization to recovery is considered as 10 days.\(^{(22)}\). The duration of recovery from ICU to discharge is considered as 15 days, and the duration from ICU to death is considered as 7 days.\(^{(23,24)}\). We find no literature record regarding duration to ICU after hospitalization and this period was assumed to be 5 days by expert opinion. The duration from the symptoms of the disease to the death is considered as 17.8 days.\(^{(15)}\). The total ICU beds and non-ICU beds capacity of Turkey is considered as 38,098 and 193,095 respectively, regarding the last official stats by the Health Ministry.\(^{(25)}\)
• **NPI Dynamics**

TURKSAS includes an additional panel to simulate social interventions. NPIs (over 65, under 20 and all society curfew, self-isolation, banning social activities, applying social distance to the entire society, closing schools) decrease the contacts, and this decreases the value of R0 directly. This decrease affects all outputs over the \( \beta \) value in the equation. The impact of social interventions on the R0 value in European countries is presented in detail in the ICL March 30 report.(26). In TURKSAS, these impact values from ICL report were used and simulations were made specific to the dates when each intervention is activated. It was also calculated that how much the social interventions applied in Turkey reduced the default R0 value in the model over time. Dates of NPIs applied by Turkey government since the beginning of the pandemic, relative % reduction on R0 and assumptions of social compliance to NPIs in Turkey presented in the Table 1.

**Table 1: Effect of NPIs on R0 value** (8) and assumptions of social compliance with policies. (NPIs: Non-pharmaceutical Interventions)

| NPIs                | Date     | Relative % Reduction R0 | Social Compliance (%) |
|---------------------|----------|-------------------------|-----------------------|
| School Closure      | 12 Mar 2020 | 20%                     | 100%                  |
| Self Isolation      | 13 Mar 2020 | 10%                     | 80%                   |
| Public Events Ban   | 16 Mar 2020 | 12%                     | 80%                   |
| Social Distancing   | 18 Mar 2020 | 11%                     | 80%                   |
| Curfew > 65 *       | 27 Mar 2020 | 14.3%                   | 90%                   |
| Curfew, <20 *       | 5 Apr 2020  | 14.3%                   | 90%                   |

*In the ICL 30 March report, the total effect of lockdown was measured as 50%. Turkey has applied curfew for >65 and <20 until now. We assumed this effect for three different age group consulting expert opinion as C65: %14,3 C20: %14,3 C21-64: %21,4.*
Results

1. First Dimension

The first deaths in Turkey were announced on 17 March. According to the IFR, it is estimated that there were 152 infected people 18 days before the first death occurs. 27 of 152 infected people were considered as asymptomatic and 125 as symptomatic cases and simulation has been applied starting from 28 February 2020. According to the estimates based on the number of deaths (announced daily), the number of real infected people in the Turkish population on March 17 was 75,909. The last death number announced at the time of this simulation is done was 812. According to this death number, estimated number of infected people on March 21 was 123,030. The number of infected people in society according to IFR and the future projection are presented in Figure-2.

![Figure 2](image)

*Figure 2: The estimated number of infected people over the number of deaths in Turkey. IFR: Infection Fatality Rate*

2. Second Dimension

In the case of free spreading of the pandemic without any interventions, the expected age-stratified distribution of the maximum total number of cases, total need for ICU and non-ICU beds and deaths are presented in Figure 3. Throughout the lifetime of the pandemic, if it is considered that there is no intervention, the maximum total number of hospitalizations estimated as 3.418.398, intensive care hospitalizations as 856.422 and deaths as 414.203.
Figure 3: In the case of no interventions, the expected age-stratified distribution of the maximum total case, hospitalization, ICU cases and deaths. k1: Attack rate. k2: age-specific proportions of hospitalization among symptomatic cases. k3: age-specific proportions of ICU need among hospitalized people. IFR: Infection Fatality Rate

3. Third Dimension

- **Scenario 1: No Intervention**

The estimations in the second dimension are also simulated in SEIR based TURKSAS simulator. (Table 2) The expected total number of infected people is 72,091,595, and the total number of deaths is 445,956. The attack rate is 88.1% for a pandemic period as the entire society is considered as the population at risk. The expected mortality ratio is 0.54%.

Table 2: Predictions of 1st scenario (in the case of no intervention)
It is predicted that all ICU beds and non-ICU beds reach 100% occupancy rate in May, while the need for ICU and non-ICU beds reaches its peak in June. At the peak point, the ICU bed capacity is exceeded by 4.4 fold and the non-ICU bed capacity is exceeded by 3.21 fold. (Figure 4)

![Chart showing ICU and non-ICU bed capacity and need](image)

**Figure 4:** In the worst-case scenario, the need for ICU and non-ICU beds and daily distribution of expected deaths

- **Scenarios 2 and 3: Social compliance to NPIs (<100% compliance and 100% compliance)**

The effect of applied NPIs in Turkey on R0 is presented in Figure 5. According to the calculations made by taking into account the compliance rates of the interventions, the value of R0 is estimated to decrease from 3 to 1.38 level.
Figure 5: The relative effect of social interventions applied in Turkey on R0 values

Predictions in first scenario (<100% compliance) and second scenario (100% compliance) are presented in Table 3 including differences. Compliance with social interventions makes a 94,303 difference in the expected number of deaths. In both scenarios, the predicted peak value of occupied ICU and non-ICU beds remains below the Turkey’s capacity.

Table 3: Predictions of 2nd scenario (<100% social compliance) and 3rd scenario (100% social compliance)

|                                | 2nd Scenario | 3rd Scenario | Difference | Unit |
|--------------------------------|--------------|--------------|------------|------|
| Expected total cases           | 32,528,665   | 16,502,277   | 16,026,388 | Case |
| Attack rate                    | 39.7         | 20.2         | 19.58      | %    |
| Expected total deaths          | 229,415      | 135,113      | 94,303     | Case |
| Mortality                      | 0.28%        | 0.17%        | 0.12%      | %    |
| Daily occupied ICU beds peak   | 28.821       | 14.220       | 14.601     | Bed  |
| ICU bed capacity exceeded      | 0.76         | 0.37         |            | Fold |
| Daily occupied non-ICU bed peak| 100.402      | 49.127       | 51.275     | Bed  |
| Non-ICU bed capacity exceeded  | 0.52         | 0.25         |            | Fold |
| Total recovered                | 30,174,033   | 12,678,861   | 17,495,172 | Case |
For second and third scenarios, the predicted numbers of daily total deaths, needed ICU and non-ICU beds are presented in Figure 6.

**Figure 6:** Daily distribution of total ICU and non-ICU beds and expected deaths for 2nd and 3rd scenarios

**Scenario 4: General curfew intervention**

While this study conducted, curfew for >65 and <20 age groups was in force in Turkey. We predicted that, if the curfew is declared for the 21-64 age population, the R0 value drops below 1 (0.98) and the pandemic tends to end. The predicted situation if the curfew for 21-64 age group is applied on April 15 is presented in the Table 4 and Figure 7. According to these
predictions, the expected deaths are 14,230 and the peak values of daily ICU and non-ICU bed demand are below the country's capacity.

**Table 4: Predictions of 4th scenario (general curfew intervention)**

|                                | Value | Unit  |
|--------------------------------|-------|-------|
| Expected total cases           | 594,924 | Case  |
| Attack rate                    | 0,7   | %     |
| Expected total deaths          | 14,230 | Deaths|
| Mortality                      | 0,02  | %     |
| Daily occupied ICU beds peak   | 1,355 | Beds  |
| Date of peak                   | May 2020 | Date |
| ICU bed capacity exceeded      | 0,04  | Fold  |
| Daily occupied non-ICU bed peak| 2,146 | Beds  |
| Date of peak                   | May 2020 | Date |

**Figure 7:** In the 4th scenario, expected daily hospital and ICU bed demand, distribution of deaths

**Discussion**

Estimating and predicting the burden of epidemic diseases to society and the health system in the most accurate way is important for the efficient use of the healthcare services to be provided
and the resources to be used. Although expert opinions are valuable for the predictions of the pandemic but it is difficult to find up-to-date evidence to support expert opinions in pandemics that are not frequently experienced. Due to the devastating social effects of epidemics, there is no possibility to experiment for most interventions, and there are also ethical limitations. For this reason, modeling outbreaks with assumptions supported by scientific literature and establishing decision support systems based on objective criteria is an important requirement.(27). Studies on epidemic modeling focus on mathematical epidemiology (28,29).

1. First dimension

The first dimension of the study is to nowcast the actual number of infected people using the IFR. In the estimation of the actual number of cases, the case fatality rate (CFR) and IFR concepts are often confused. The CFR refers to the ratio of the number of deaths in a given time segment to diagnosed cases. However, this rate includes only those who are admitted to the hospital and who have been identified, not the proportion of real infected people in the community. If perfect conditions were observed and all patients could be followed, how many infected people would die is expressed by IFR.(15). For this reason, it is more appropriate the use of IFR in the estimation of the final death numbers and the use of the CFR in the estimation of the death numbers in a time section.(16). In a study conducted in 1334 cases in China, age-specific IFR rates were calculated. (15). In the ICL report, these values were calibrated for the UK and US population. In this study, the rates in ICL report has also applied for the Turkey population.

According to the calculations in this study history in Turkey as of March 21, 2020 was estimated to be 120 thousand cases. According to the ICL report, this number was 7 million for Spain as of March 28, 2020; 5.9 million for Italy and 600 thousand for Germany.(8). However, due to the distribution of death numbers in our country by age is unknown, the projection was made on average IFR. The actual number of cases will change with the use of age-specific IFRs.

Attack rate refers to the ratio of cases occurring during the epidemic period to the whole society.(30). Theoretically, it is assumed that “herd immunity” will develop due to the spread of the epidemic to a certain extent in the society and the recovery of people gaining immunity. According to this assumption, when the rate of people who acquired immunity by recovering from the disease reaches $\frac{R_0-1}{R_0}$, herd immunity develops and susceptible proportion of population is protected by herd immunity. (31). When $R_0 = 3$ is accepted, this rate is 66.6%.
In the second dimension of this study, attack rate in the ICL report was considered to be 81%, due to lack of age-specific attack rates in the literature. (8).

2. Second dimension

In the second dimension of the study, the universe of death, number of patients, ICU and non-ICU bed demand that will develop due to epidemic has been calculated. According to scientific data for the population of Turkey it is not expected to be of worse than these numbers. In this dimension the maximum number of infected people is estimated to be 66 million, the number of deaths is 414 thousand and the mortality rate is 0.54%

3. Third dimension

There are various models developed to estimate and predict the course of epidemics in the literature. These models are generally classified under two groups as stochastic and deterministic. Depending on the developments in information technologies, simulations have been made recently with individual/agent-based models. (32). One of the most frequently used models among deterministic models is the SEIR model, which is a compartment-based mathematical modeling type. In this model, the time between compartments is the basis of all estimates. In SEIR-based studies, generally, asymptomatic and symptomatic cases were not differentiated according to the incubation time, infectivity time, and R0 variables. In this study, these two groups are included in the model separately. The proportion of asymptomatic cases can be up to 78% in the studies performed according to the symptoms of the day the PCR sample was taken. (33,34). However, WHO stated that 75% of cases that were asymptomatic developed symptoms later and asymptomatic proportion is very low and is not a major determinant of the pandemic.(35). In the study conducted on the Diamond Princess ship, 17.9% of all cases were stated to be asymptomatic.(20). In our study, it was accepted that the closest study to the cohort design was Diamond Princess and this value was used in calculations. Unlike previous studies, the R compartment was structured with the addition of clinical dynamics in order to evaluate the need for health care.

In the third dimension of the study, using the TURKSAS simulation, the number of cases and deaths that will occur within a year are predicted according to four different scenarios. In the first scenario, it was assumed that no intervention was done for the epidemic. According to this worst-case scenario, a total of 72 million people would be infected in Turkey, 446 thousand people are estimated to have died. According to the ICL report, if there is no intervention, 510 thousand deaths are expected in the UK and 2.2 million in the United States. Also, it is
calculated that the ICU bed capacity can be exceeded 30 fold for the UK. (8). In our study, the ICU bed capacity in Turkey is expected to exceed 4.4 fold.

In the second and third scenarios, the expected number of cases and deaths are also calculated according to whether the society is partially (2nd scenario) or fully (3rd scenario) compliant with the social interventions applied. Predictions show that 16 million people can be prevented from being infected and 100,000 deaths can be prevented by full compliance with the measures taken. With the measures that Turkey has taken so far, the highest expected need for ICU beds is taken under the existing capacity and ICU bed capacity is not exceeded in case of realization of both scenarios. In the fourth scenario, with the realization of the general curfew, it is predicted that the total number of cases will be 600 thousand and the number of deaths will be less than 15 thousand.

The basic principles in preventing the spread of the pandemic can be listed as 1) reducing the population that is not immune to the disease, 2) reducing the number of contacts or 3) acquire immunity. In cases where vaccination is not possible and the non-immune population cannot be reduced, the only effective means of combating the pandemic is to keep the number of contact contacts under control. In our study, we estimate that the R0 values decreased to 1.38 as a result of existing measures in Turkey. This decreases the rate of spread and attack rate of the pandemic. However, in the case of no intervention the attack rate will be 88.1%, while in the case of a general curfew, this value will decrease to 0.7% and mortality rates decline from 0.54% to 0.02%. Complete control of the pandemic is possible by keeping R0 below 1. For this, additional measures are needed. As the economic and social burden of the interventions to be made to reduce the R0 value below 1 are very high, the solution with the highest cost-benefit ratio is the development of a new vaccine molecule. These numbers will change if a new treatment or vaccine is developed throughout the year.

In our study, deaths due to exceeding the number of ICU and non-ICU beds were not considered. Also, in case of exceeding intensive care and healthcare capacity, deaths that may result from disruption of healthcare services are not included in the equation.

Considering that many global and local parameters affect the result, it is quite difficult to draw definitive conclusions or to make clear statements about the natural course of the disease. Mathematical models are important tools in this period where rapid and evidence-based political decisions should be made under the devastating effects of the epidemic. The estimates in this study show that the progressive stages of the pandemic should be carefully projected...
and intervention strategies should be based on evidence. The ultimate goal of all NPIs is to keep the number of cases within the limits that the health system can intervene until any vaccine or medical treatment method is available, thereby minimizing deaths and disabilities by providing healthcare to as many patients as possible.

Ethical, legal and economic dimensions were ignored in the suggestions presented in this study. The applicability of widespread interventions, which concern not only health but also the economy and social life, should be evaluated with many more studies to be done in these areas.

Conflict of Interest:

We declare no competing interests

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Estimated Total Infected People
Projected Total Infected People

**IFR:** %0.66 (0.39-1.33)

%95 CI
| Age   | Turkey Population | k1 | Max. Expected Case | k2 | Max. Expected Hospitalization | k3 | Max. Expected ICU Case | IFR | Max. Expected Death |
|-------|-------------------|----|--------------------|----|-------------------------------|----|------------------------|-----|----------------------|
| 0-9   | 12.881.568        | 81%| 10.434.070         | 0.1%| 10.434                       | 5.0%| 522                    | 0.002%| 209                 |
| 10-19 | 12.725.029        | 81%| 10.307.273         | 0.3%| 30.922                       | 5.0%| 1.546                  | 0.006%| 618                 |
| 20-29 | 12.780.455        | 81%| 10.352.169         | 1.2%| 124.226                      | 5.0%| 6.211                  | 0.030%| 3.106               |
| 30-39 | 12.882.447        | 81%| 10.434.782         | 3.2%| 333.913                      | 5.0%| 16.696                 | 0.080%| 8.348               |
| 40-49 | 11.139.044        | 81%| 9.022.626          | 4.9%| 442.109                      | 6.3%| 27.853                 | 0.150%| 13.534              |
| 50-59 | 8.857.551         | 81%| 7.174.616          | 10.2%| 731.811                      | 12.2%| 89.281                 | 0.600%| 43.048              |
| 60-69 | 6.042.751         | 81%| 4.894.628          | 16.6%| 812.508                      | 27.4%| 222.627                | 2.200%| 107.682             |
| 70-79 | 3.107.727         | 81%| 2.517.259          | 24.3%| 611.694                      | 43.2%| 264.252                | 5.100%| 128.380             |
| 80-89 | 1.275.636         | 81%| 1.033.265          | 27.3%| 282.081                      | 70.9%| 199.996                | 9.300%| 96.094              |
| 90-99 | 170.023           | 81%| 137.719            | 27.3%| 37.597                       | 70.9%| 26.656                 | 9.300%| 12.808              |
| 100+  | 4.990             | 81%| 4.042              | 27.3%| 1.103                        | 70.90%| 782                    | 9.300%| 376                 |
| Total | 81.867.221        | 81%| 66.312.449         |     | 3.418.398                    |     | 856.422                |     | 414.203              |
2nd Scenario (<100% compliance with NPIs)

Turkey non-ICU Bed Capacity

- Blue line: Daily Total non-ICU Beds
- Red line: Daily Total ICU Beds
- Gray line: Daily Total Deaths

Turkey ICU Bed Capacity

- Yellow dotted line:

*Note: The graph shows the projected daily total need for ICU and non-ICU beds in Turkey under a 2nd scenario of less than 100% compliance with NPIs.*
4th Scenario (General curfew intervention)

Turkey non-ICU Bed Capacity

- Daily Total non-ICU Beds
- Daily Total ICU Beds
- Daily Total Deaths

Turkey ICU Bed Capacity