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Evaluating the effect of early policy responses on the COVID-19 pandemic: prediction model from data in Vietnam

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ABSTRACT:

- ***Objective:*** *Early responses to COVID-19 have been conducted by Vietnam's government in both the speed and the stringency of the interventions used. To evaluate the effect of these policies, we built the predictive model to compare the actual cases and estimated cases in Vietnam.*
- ***Subjects and Methods:*** *We applied the predictive model with two parameters at three points before the travel restriction policy, after one week, and after the policy's end (2 weeks). After each time of evaluation, two parameters in the model were adjusted to estimate new cases in the following time. Nonlinear Least Squares determined the nonlinear (weighted) least-squares estimates of the parameters of a nonlinear model.*
- ***Results:*** *Many measures were applied to prevent the spread of the pandemic, and two highlighted measures were quarantine and social distancing policy. Parameters were estimated before the policy (a = 20.686, b = 0.098), after the promulgation of policy (a = 23.179, b = 0.089), and after one week (a = 30.759, b = 0.072). The difference between expected and observed cases was statistically significant (p = 0.01), showing positive results of the policies. After one week (the incubation period), suspected and infected cases have been detected and managed, facilitating the reduction of new cases.*
- ***Conclusions:*** *The effects of early policy response on the COVID-19 pandemic were significant after each stage of serial measurements, according to the parameters of the predictive model. Our model can be considered in the next wave of the COVID-19 pandemic or another pandemic to predict progress and take measures effectively.*

- ***Keywords:*** *COVID-19 pandemic, Early policy response, Predictive models, Nonlinear Least Squares.*

INTRODUCTION

The SARS-CoV-2 virus has affected more than 2,000,984 people in 185 countries and territories, accounting for 128,001 deaths worldwide on April 14, 2020[1]. After over one year, on May 9, 2021, there were 157,756,810 global cases and 3,284,985 global deaths[2]. Extraordinary measures are needed to handle challenging situations. In Vietnam, the government has performed an early policy response to the COVID-19 pandemic. This may be because Vietnam performed well in dealing with the SARS pandemic in Northern Vietnam in 2003. The experiences with the previous SARS pandemic led to a significant change in government policy regarding the emerging pandemic. Moreover, Vietnam is a neighbor of China, with seven provinces having land borderline. Thus, early responses to COVID-19 have been conducted by Vietnam's government in both the speed and the stringency of the interventions used.

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To achieve these results, before the social distancing that was applied on April 1, many measures were used to prevent the spread of the pandemic, such as suspended flights, closed schools, and quarantine[3]. The purpose of these policies was early identification by strengthening surveillance and sharing updated information, promptly isolating the affected cases. When the situation got worse with the faster increase of new cases, other interventions necessary to reduce the transmission of COVID-19 involved restricting the population's activities to reduce transmission. The government decided to apply social distancing when the total confirmed cases in Vietnam got over 200 cases. The order applied strict nationwide social distancing rules for 15 days, starting on April 1 until mid-April, to control the transmission of COVID-19. Depending on how the pandemic developed in this period, the government issued further notices after April 15[4]. To confront COVID-19 effectively, stimulating the number of cases[5] and knowing the transmission dynamics[6] is essential.

In Vietnam, the SEIR model and multi-scale approach were used to depict the number of cases and transmission dynamics, and to quantify social distancing effects among the measures in policy responses in Vietnam[7]. A predictive model was needed to evaluate the total policy responses in each period by specific parameters. In our study, by using a predictive model to compare the actual cases and estimated cases in Vietnam after the serial measures of the government, we could evaluate the effect of early policy response on the COVID-19 pandemic in Vietnam for each period.

SUBJECTS AND METHODS

Vietnam confirmed the first case on January 23, 2020, while on February 13, 2020, 16 cases were confirmed. All patients were cured, and Vietnam had not announced any new cases until March 6, 2020. The mean incubation period could vary between studies, from 5.0 days (range: 2-14 days)[8] to 6.4 days (range: 2.1-11.1 days)[9]. Therefore, after 21 days (from February 13 to March 6) without detecting a new case, the sources of infection were considered as coming from outside of Vietnam. We began to build the predictive model from the day of detecting the 17th case (marked as day 1) and started to apply it after collecting full data on March 23, 2020 (the 18th day). To deal with the COVID-19 pandemic, the serial measures of government promulgated, such as a travel restriction policy on March 29, 2020 (the 24th day) and a social distancing policy on April 1, 2020 (the 27th day) with the two weeks of validity.

Follow-Up Method

We applied the predictive model with two parameters at three-time points: (i) before the travel restriction policy, (ii) after one week, and (iii) after the end (2 weeks) of the policy. After each time of evaluation, two parameters in the model were adjusted to estimate new cases in the following time.

Apply the Predictive Model

According to the Ministry of Health report, we listed the total cases per day from March 6, 2020, to March 23, 2020, in Table 1. Based on the predictive model of Koczcodaj et al[10] research from 1,000,000 cases outside of China, we applied this model in Vietnam by the following steps ***(Appendix 1)***:

- Step 1: Input data, including the date and total cases reported by the Ministry of Health day by day.
- Step 2: Use the nls function (nonlinear least squares)[11] in the stats package to estimate parameters a and b according to the formula:

$$y = f(x) = a * e^{b*x} \quad (*)$$

With x as day-model (from day 1 of the model), y as the total cases on that day.

- Step 3: Based on the predictive model, compute the predictions (Figure 1).

Nonlinear Least Squares determined the nonlinear (weighted) least-squares estimates of the parameters of a nonlinear model. A NLS object was a type of fitted model object that was used for the generic functions. To improve predictability, abductive reasoning was used in this model[12].

Table 1. The parameters of the predictive model.

	Parameters	Estimated	SE	*p*-value
Parameters estimated before the policy.	a	20.686	0.792	< 0.001
	b	0.098	0.003	< 0.001
Parameters estimated after the promulgation of policy.	a	23.179	0.9	< 0.001
	b	0.089	0.002	< 0.001
Parameters adjusted after one week.	a	30.759	1.97	< 0.001
	b	0.072	0.002	< 0.001

```
library(readxl)
library(stats)

#load COVID data

COVID <- read_excel("COVID.xlsx")

#determind the value of parameters

fit <- nls(case ~ a*exp(b* day), data = COVID, start = list(a = 1, b = 0))
t <- summary(fit)

print(t)

```

Figure 1. Predictive model.

Explanation of the model (Figure 2):

- Variables: x, y (defined as above).
- Parameters: a, b – they showed the situation in each period. With a definite policy response, with a and b, we could predict the number of cases (y) at day x in each period.

The parameters a and b reflected the situation of transmission dynamics and the effect of policies. Especially in Vietnam, it was a signal for preparedness and response in international collaboration[13] and strict measures[14].

Statistical Analysis

Building model and data were analyzed using R language (The R Foundation for Statistical Computing, Vienna, Austria). Differences were evaluated using the Mann-Whitney U test. Categorical variables were compared using the Chi-square test or Fisher's exact test. The *p*-values lower than 0.05 were considered significant.

RESULTS

The Pandemic Situation in Vietnam Before the Policy

Total confirmed cases from the 1st to 18th day were shown in ***Appendix 2***, according to the Ministry of Health report. The number of new cases varied from day to day ranging from 1 to 19 cases (the mean was 5.9 per day). The alarming increase in the number of new cases on 22-23 March led the government to raise concerns about a national outbreak.

To evaluate the accuracy of the predictive model for the epidemic situation in Vietnam, the parameters were estimated (Table 1) using a well-known NLS function in R programming to predict the number of new cases on the following day. As shown in Table 2, the model accurately predicted the number of new cases the next day. The discrepancy between the expected and observed cases increased from day to day, but it was not statistically significant (*p*

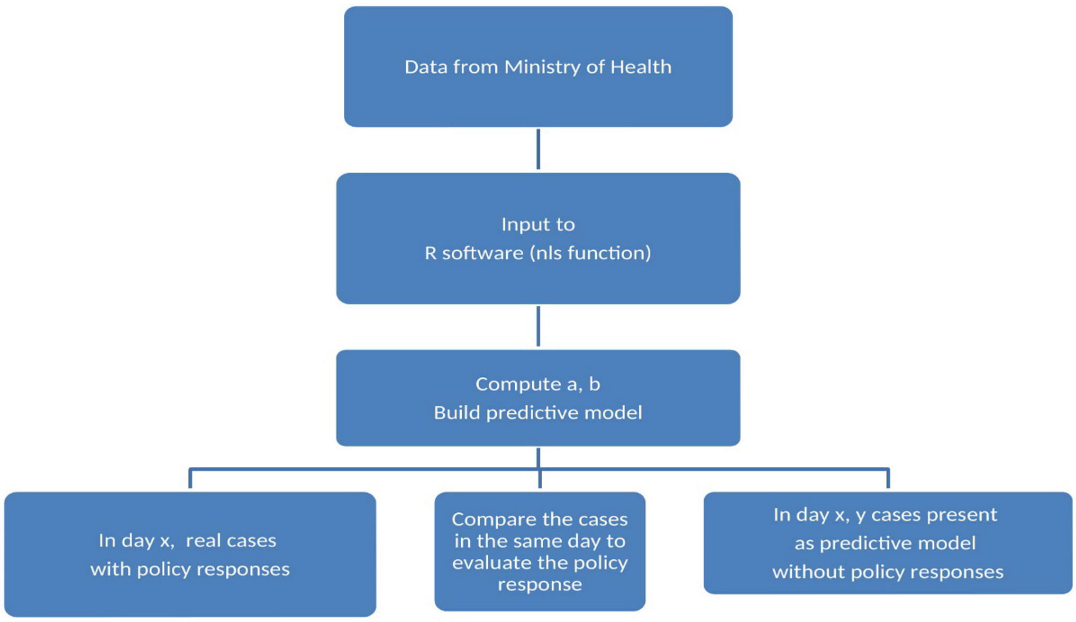

Figure 2. Flowchart of the study.

Table 2. Expected and observed cases before the policy.

Day Number	Date	Expected Cases	Observed Cases	Deviation	*p*-value
Day 19	2020-03-24	134	134	0	0.06
Day 20	2020-03-25	146	141	+5	
Day 21	2020-03-26	162	153	+9	
Day 22	2020-03-27	178	163	+15	
Day 23	2020-03-28	197	174	+23	

= 0.06). The number of new cases ranged from 7 to 12 (the mean was 8 cases per day), and the government and MOH determined the promulgation of the travel restriction (both domestic and international) policy.

Initial Results when Implementing Policies

Combining the data from the 1st to the 23rd day, parameters a and b were adjusted to estimate the number of cases in the next week if the policy was not implemented. As shown in Table 3, the difference between expected and observed cases was statistically significant ($p = 0.01$) and showed positive results. However, the number of new cases per day did not decrease (from 4 to 15 cases, the mean was 11 cases), so the social distancing policy was implemented on April 1, 2020.

Impact of Policies on Pandemic

After the first week of applying the social isolation, the parameters were revised to predict the new cases until the end of the policy. As shown in ***Appendix 2***, total confirmed cases from 1st day to 18th day, health and social policy changes affected the model's accuracy. The standard error increased each evaluation time and along with the discrepancy between expected and observed cases. After one week (the incubation period), suspected and infected cases were detected and managed, facilitating the reduction of new cases, as shown in observed cases in Table 4.

DISCUSSION

The progression of the COVID-19 pandemic was related to many uncertain items. Many prediction models were presented, but the high risk of bias and qual-

Table 3. Expected and observed cases in the first week of policy.

Day Number	Date	Expected Cases	Observed Cases	Deviation	*p*-value
Day 24	2020-03-29	196	188	+8	0.01
Day 25	2020-03-30	214	203	+11	
Day 26	2020-03-31	234	207	+27	
Day 27	2020-04-01	256	218	+38	
Day 28	2020-04-02	280	227	+53	
Day 29	2020-04-03	306	237	+69	
Day 30	2020-04-04	345	240	+105	

Table 4. Expected and observed cases until the end of the policy.

Day Number	Date	Expected Cases	Observed Cases	Deviation
Day 31	2020-04-05	286	241	+45
Day 32	2020-04-06	310	245	+65
Day 33	2020-04-07	333	249	+84
Day 34	2020-04-08	358	251	+107
Day 35	2020-04-09	382	255	+127
Day 36	2020-04-10	410	257	+153
Day 37	2020-04-11	441	258	+183
Day 38	2020-04-12	478	260	+218
Day 39	2020-04-13	513	265	+248
Day 40	2020-04-14	552	266	+286

ity variation between models was considered[15]. An available model with parameters from the COVID-19 pandemic in China was used to predict the future number of patients[16]. The artificial intelligence approach also used previous data[17], taken from the 2003 SARS data, to predict the current pandemic. In our study, we chose this model to apply for short-term prediction in Vietnam with the 1.29% error[10], showing the closed prediction results as real cases by day. The highlight of this model in our study was abductive reasoning. It was a type of logical inference that starts with a set of observations and then searches for the simplest and most likely explanation for the observations. Through pair-wise comparisons based on abductive reasoning, the predictability was improved. Another method to evaluate the effect of the control measures is filling a two-parameter model ($ae^{b_0 t}$, $t \leq t_1$) and comparing it with the six-parameter models ($[(ae^{b_0 t_1})e^{b_1(t_1-t_2)}])e^{b_2(t-t_2)}$, $t \geq t_2$). In another way, it can be presented as a two-parameter model ($ae^{b_0 t}$, $t \geq t_1$) *vs.* a four-parameter model ($[(ae^{b_0 t_1})e^{b_1(t-t_1)}]$), $t_1 < t \geq t_2$).

The result of policy response in general and social distancing measures, in particular, showed crucial information for policymakers and governments of other countries[4,18]. In Vietnam, with limited resources, the government showed how to confront the COVID-19 pandemic. On April 14, 2020, two weeks after the social distancing policy, Vietnam had 266 confirmed cases and no fatalities due to the COVID-19 pandemic. Compared with many developed countries' healthcare systems, these results were notable. From the first case to those dates, cases were registered as follows: Vietnam (83 days = 266 cases), China (84 days = 83,306 cases), Korea (84 days = 10,564 cases), USA (84 days = 583,220 cases)[1].

Early quarantine, including new arrivals and local high-risk areas, was essential to prevent and control the potential infection sources. Quarantine for new arrivals was started on February 3, ten days after the first case was confirmed. All people (both Vietnamese people and foreigners) who entered Vietnam from mainland China had to be quarantined for at least 14 days. When the SARS-CoV-2 virus began spreading far outside mainland China on February 25, strong measures were conducted for all people who entered Vietnam from China, Italy, Iran, and South Korea with at least 14-days quarantine. In the context of escalating the new confirmed cases globally, on March 17, 2020, a 14-days quarantine was made mandatory for anyone arriving in Vietnam and the government decided to cancel foreign flights. It was the right decision because the contact tracing among flight passengers was timely and could lead to unexpected results[19]. A week after March 24, 2020, there was no statistically significant difference between the observed and expected cases. This can be explained by two following reasons: firstly, the infected cases that were available in former times were seen. Secondly, the process of determining verified cases normally took two days from the day of taking the sample at this time.

Paralleling with the quarantine of new arrivals, quarantine of local high-risk areas posed a critical issue, divided into two stages. Stage 1, with the first 16 cases, a 21-day quarantine was implemented in Vinh Phuc province, North of Hanoi, where migrant workers were returning from Wuhan, China. The hotspot was controlled, and Vietnam was successfully in Stage 1 with just 16 confirmed cases and recovery after treatment. Stage 2 began from the 17th confirmed case. That decision was made promptly with the collaboration among the Ministry of Health, the Ministry of Public Security, and local authorities to quarantine high-risk areas, such as Truc Bach Street (where the 17th case lived), Bach Mai Hospital (in Hanoi) and Buddha Bar (in Ho Chi Minh City), respectively. High-risk cases were tracked (the confirmed case was determined as F0, those in contact with F0 were F1, those in contact with F1 were F2, those in contact with F2 were F3, those in contact with F3 were F4, those contact with F4 were F5, etc.). After making the list of people closely connected to any F generation, quarantine in the Hospital was implemented for F0 and F1, as well as quarantine at home or military bases for F2 and F3, and quarantine at home for F4 and F5. In all quarantine areas in Vietnam, all people were under the observation of healthcare workers. The COVID-19 test was performed if needed, and further isolation and treatment were conducted if the test was positive for SARS-CoV-2 virus. The test kits were quickly developed by Vietnam Military Medical University, meeting World Health Organization standards. All people in quarantine areas were under control by focusing on measures within control.

According to social distancing measures, people had to stay at home. In the case of going outside, they had to have precise reasons, such as buying essential things for daily living and fundamental work necessary for this situation. Public transportation was also suspended. When they had to go outside, each citizen had to strictly follow preventative measures such as wearing face masks, hand hygiene, and keeping a safe distance (at least two meters) from each other. After April 15, provinces were classified into three groups, with 12 provinces at high risk, 15 provinces at medium risk, and others in the low-risk group. Social distancing measures was extended for high-risk provinces. In the other group, people had to take preventive measures such as wearing face masks, washing their hands, and keeping a distance of at least two meters from each other. Some public activity was still closed. This activity in the COVID-19 response showed effectiveness[20]. After April 22, social distancing was no longer applied, except in some small areas, but preventive measures were also kept. Three new cases were confirmed from April 15 to April 29. On April 29, there were 270 confirmed cases and 220 recovery cases in Vietnam, but the situation worldwide was worse, with over 3,000,000 confirmed cases and nearly 100,000 recovery cases. This reflected the notable results from early policy responses in Vietnam.

CONCLUSIONS

The effects of early policy response on the COVID-19 pandemic were significant after each stage of serial measurements through parameters of the predictive model. Our model can be considered in a future wave of the COVID-19 pandemic or another pandemic to predict progress and take the measure effectively.

Ethics Approval:

The Vietnam Military Medical University Ethics Committee approved the study.

Conflict of Interest:

The authors declare no conflicts of interest in this work.

Informed Consent:

Not applicable.

Authors' Contributions:

All authors made substantial contributions to conceptualization and design, data acquisition, data analysis, and interpretation, took part in the drafting of the initial manuscript and revising it critically, gave final approval of the version to be published, agreed to submit to the current journal, and agreed to be accountable for all aspects of the work.

Availability of Data and Materials:

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