When and How to Adjust Non-Pharmacological Interventions Concurrent with Booster Vaccinations Against COVID-19 — Guangdong, China, 2022

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ABSTRACT

Introduction: With the large-scale roll-out of the coronavirus disease 2019 (COVID-19) booster vaccination effort (a vaccine dose given 6 months after completing primary vaccination) in China, we explore when and how China could lift non-pharmacological interventions (NPIs) against COVID-19 in 2022.

Methods: Using a modified susceptible-infectious-recovered (SIR) mathematical model, we projected the COVID-19 epidemic situation and required medical resources in Guangdong Province, China.

Results: If the number of people entering from overseas recovers to 20% of the number in 2019, the epidemic in 2022 could be controlled at a low level by a containment (215 local cases) or suppression strategy (1,397 local cases). A mitigation strategy would lead to 21,722 local cases. A coexistence strategy would lead to a large epidemic with 6,850,083 local cases that would overwhelm Guangdong’s medical system. With 50% or 100% recovery of the 2019 level of travelers from overseas, the epidemic could also be controlled with containment or suppression, but enormous resources, including more hotel rooms for border quarantine, will be required. However, coexistence would lead to an uncontrollable epidemic with 12,922,032 local cases.

Discussion: With booster vaccinations, the number of travelers from overseas could increase slightly in 2022, but a suppression strategy would need to be maintained to ensure a controllable epidemic.

INTRODUCTION

Non-pharmacological interventions (NPIs) have contributed substantially to the control of coronavirus disease 2019 (COVID-19) (1–2) and have bought time for vaccine development and promotion. With increasing vaccine coverage, some countries have relaxed NPIs. However, breakthrough infections, especially from viral variants, caused significant rebounds of COVID-19 epidemics (3) that were unable to be controlled without re-tightening NPIs (4).

Despite the effectiveness of NPIs, they negatively impact daily life and the economy (5). Given the well-documented high efficacy of COVID-19 booster doses (a dose of COVID-19 vaccine 6 months after completing a primary series) (6), China initiated a booster vaccination campaign, with an expectation to return to normal life and lift NPIs (7). With booster vaccinations, it is a concern that when and how NPIs could be lifted without devastating the healthcare system. This includes questions of how many medical resources, such as hospital beds, intensive care unit (ICU) beds, and hotel rooms for border quarantine, are necessary as different levels of NPIs are lifted.

To address these critical questions, we used real-world data from multiple sources as input to a susceptible-infectious-recovered (SIR) model that we augmented with additional compartments to more accurately represent COVID-19 epidemiology and control policy in China. For 2022, we projected the magnitude of the COVID-19 epidemic in Guangdong Province under different NPI lifting policies, booster dose uptake, and overseas importation pressures.

METHODS

Model Structure

Starting with an SIR framework, we introduced additional compartments to model risks, factoring in people entering from overseas, border quarantine, and booster vaccination coverage (Figure 1). Details of the model are in the Supplementary Material (available in http://weekly.chinacdc.cn).
COVID-19 Risk from Overseas Importation

We estimated the number of infected people entering Guangdong from overseas as follow:

\[ I_{in} = \sum \text{Passenger} \times 0.98\% \]

where Passenger denotes the number of passengers from overseas at date \( t \), which was obtained from flight data in VariFlight (https://www.variflight.com/en/). We used flight data from 2019 — the pre-pandemic level of passengers — to project flights in 2022 under various levels of restriction. We used the prevalence of COVID-19 cases imported from overseas at date 1) no border quarantine; 2) 7 days of quarantine; 3) 14 days of quarantine; 4) 7 days

Vaccine Effectiveness

Inactivated COVID-19 vaccines have been the most widely used vaccines in China; their effectiveness against infection is 65.70% for fully vaccination (8). With a booster dose, vaccine effectiveness (VE) is 88.00% (6). Therefore, we used 65.70% and 88.00% for the VE parameters, \( P_{\text{protect2}} \) and \( P_{\text{protect3}} \).

Vaccination reduces hospital admission, severe illness, and death. Based on previous studies (6, 8–10), we set the hospital admission rate, ICU admission rate, and fatality rate to 4.30%, 0.39%, and 0.80%, respectively, for fully vaccinated but infected individuals, and 0.30%, 0.03%, and 0.15%, respectively, for booster-vaccinated infected individuals.

Estimating the Effect of Local NPIs

Border Quarantine: We developed five scenarios of border quarantine of people coming from overseas to Guangdong in 2022: 1) no border quarantine; 2) 7 days of quarantine; 3) 14 days of quarantine; 4) 7 days
of quarantine for those entering before July, but no quarantine for those entering after July; and 5) 14 days of quarantine before July but 7 days for those entering after July.

A certain proportion of cases from overseas may not be detected during quarantine. Based on real-world data from Guangdong, 1.04% and 0.16% of cases from overseas were not detected during 7- and 14-day quarantines. We used these values to represent residual importation risk after testing negative during quarantine.

**Infection Detection Measures:** In our model, \( \mu \) denotes the rate of infected people being detected and quarantined. For different infection detection measures, the interval from infection to quarantine was obtained from real-world data in Guangdong (Supplementary Table S1, available in http://weekly.chinacdc.cn/).

**Personal Protection and Social Distancing:** A meta-analysis indicated that relative risk (RR) reduction from masks and social distancing were 0.47 and 0.75, respectively (2). Given that the combined effect of personal protection and social distancing was rarely reported, we used the lowest RR (0.47) to represent this combined effectiveness.

**Four Strategies Against COVID-19**

We modeled 4 strategies that differed by combination of NPIs: 1) containment: 14 days of border quarantine of incoming travelers; use of personal protection, social distancing, and use of sensitive measures for infection detection (fever monitoring and contact tracing); 2) suppression: 7 days border quarantine; use of personal protection, social distancing, and sensitive measures for infection detection; 3) mitigation: no border quarantine; use of personal protection, social distancing, and routine measures for infection detection (fever monitoring but no contact tracing); and 4) coexistence: no border quarantine, no personal protection, no social distancing, and only routine measures for infection detection.

**Transmission Coefficient (Beta)**

The transmission coefficient, \( \beta \), was estimated using real-world data from a local epidemic triggered by imported cases from Africa in first half of 2020. The data indicated that the \( \beta \) with best fit was 0.14 (\( R^2=84.71\% \), Root Mean Square Error=3.61). During that outbreak, vaccination was unavailable, and therefore this \( \beta \) represents transmission with local NPIs and no vaccination. Given viral variants can have higher transmission rates (transmissibility of variants can reach 1.97 times non-variant transmission) (11), we set \( \beta \) as \( 0.14 \times 1.97 = 0.27 \) to represent the transmission rate in 2022. We also set \( \beta \) as \( 0.27/0.47 = 0.57 \) to represent transmission without personal protection and social distancing.

Detailed definitions and values of compartments and parameters are presented in Supplementary Table S2 and Supplementary Table S3 (available in http://weekly.chinacdc.cn/). Statistical analyses were conducted with R software (version 3.6.2, R Foundation for Statistical Computing, Vienna, Austria). We used the R package “deSolve” for numerical treatment of our model’s system of differential equations in transmission dynamics analyses.

**RESULTS**

**Travelers from Overseas and Imported Infections**

From January 1 to November 14, 2021, 3,768 flights carried 349,987 people into Guangdong from overseas; 2,702 (0.77%) were infected. The percent was higher near the end of 2021 (0.98%). Using the percent infected as a multiplier, Figure 2 shows projected overseas travelers and numbers infected in 2022 under assumptions of 20%, 50%, and 100% of travelers from overseas compared with 2019.

**Projected Epidemic in 2022 by COVID-19 Strategy**

Modeling results were based on the percent of 2019 travel into Guangdong that occurs using the percent infected from real world data near the end of 2021 — 20%, 50%, and 100% of 2019 travel into Guangdong, called travel recovery.

**Containment:** With 2022 incoming travel at a 20% recovery of 2019 travel, a containment strategy controls the maximum daily infections at low level (Figure 3), with annual cases and deaths of 215 and 2 (Figure 4). As booster dose coverage increases, daily cases become lower (Figure 3). With higher percentages recovery of 2019 travel, the epidemic is still controlled by containment.

**Suppression:** With 20% recovery of travel, a suppression strategy controls the maximum daily infections at 7 (Figure 3), with 1,397 total cases and 13 deaths (Figure 4). If booster dose uptake is 85%, the
maximum daily number of local infections decreases to 2. With 50% and 100% of travel recovery, the cumulative number of cases is projected to become 3,547 and 7,277.

**Mitigation:** With 20% recovery of travel, a mitigation strategy results in a maximum of 63 infections per day, with 21,722 total cases and 205 deaths. A booster dose coverage of 85% reduces the maximum daily infections to 22. However, 50% and 100% travel recovery yields 55,205 and 113,519 total cases in Guangdong.

**Coexistence:** If most NPIs are lifted, 20% travel recovery brings the projected daily maximum of cases to 75,716, with annual cases and deaths of 6,850,083 and 64,626. With 50% and 100% travel recovery, Guangdong would suffer 10,081,389 or 12,922,032 cases in 2022.

### Projected Medical Resource Requirements by Strategy

**Containment:** At 20% travel recovery, at the peak of epidemic, 1,398 infected people, including locals and incoming travelers, will require quarantine and isolated treatment. Infected individuals are always hospitalized in China, implying the need for 1,398 hospital beds at epidemic peak. If only severe cases are hospitalized, 55 hospital beds and 5 ICU beds will be needed, but 90,448 hotel rooms will be needed for border quarantine. With 50% and 100% travel recovery, the peak needs for treatment will be 3,496 and 6,995 hospital beds and 226,119 and 452,238 quarantine rooms, respectively.

**Suppression strategy:** At 20% travel recovery, at the peak of the epidemic, 1,454 hospital beds will be needed. If only severe cases are hospitalized, 58 beds will be needed. Compared to containment, suppression requires fewer hotel rooms for imported quarantine (45,458), which is within Guangdong’s capacity. With 50% and 100% travel recovery, 3,639 and 7,295 hospital rooms will be needed at epidemic peak, and 113,645 and 227,289 quarantine hotel rooms will be needed, respectively.

**Mitigation:** With 20% travel recovery, 3,498 hospital beds will be needed at peak if all infected individuals are hospitalized; 170 hospital beds will be needed if only severe cases are hospitalized. A peak of 29 ICU beds would be needed. With travel recovery of 50% and 100% levels, 8,778 and 17,664 hospital beds will be needed.

**Coexistence:** With 20% travel recovery, 1,492,867 hospital beds would be required at peak. If only severe cases are hospitalized, 82,231 hospital beds will be required. With 50% and 100% travel recovery, Guangdong would have to arrange 2,389,533 and 3,249,552 hospital beds for treatment of infected individuals.

As shown in Supplementary Table S4 (available in http://weekly.chinacdc.cn/), the epidemic would require more medical resources with slower booster...
vaccination progress. More sensitive infection detection measures would slow the epidemic.

**DISCUSSION**

We developed dynamic severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission models to project the COVID-19 epidemic in Guangdong in 2022 under combinations of COVID-19 booster vaccination, increases of incoming international travel, and 4 NPI lifting strategies to identify appropriate NPI combinations that will keep...
FIGURE 4. Cumulative number of local COVID-19 cases and deaths, and the maximum required number of hospital beds, ICU beds, and hotel rooms for border quarantine under different scenarios. (A) Cumulative cases; (B) Cumulative deaths; (C) Required hospital beds (all infected persons hospitalized); (D) Required hospital beds (severe infected persons hospitalized); (E) Required ICU beds; (F) Required hotel rooms for imported quarantine.

Note: The grey dashed lines refer to the current capacity of medical resources in Guangdong Province. PP&SD refer to personal protection and social distancing; FC refers to fever clinic monitor; CC refers to close contact tracing; 20%, 50% and 100% refer to 20%, 50% and 100% travel recovery compared with 2019 incoming overseas travel.

Abbreviations: COVID-19=coronavirus disease 2019; ICU=intensive care unit.
the COVID-19 epidemic under control and utilize affordable levels of medical resources. If incoming international travel recovers to 20% of the level in 2019 and the infection rate of incoming travelers is the same as in 2021 in Guangdong, a suppression strategy may be considered in 2022. Suppression involves reducing incoming quarantine to 7 days, using personal protection and social distancing, and contact tracing during outbreaks. Under this scenario, the required medical resources will be within the current capacity of Guangdong. Our model also indicated that with increasing uptake of booster doses, the number of daily new infections decreased significantly. We project that a high booster dose vaccination rate of 85% will allow more incoming travel and decreased use of NPIs by the end of 2022.

Furthermore, several antiviral medicines against COVID-19 are being developed and some have been granted regulatory approval (12–13). Effective antivirals raise the possibility that infected people with mild symptomatic may be able to be safely treated at home, partially alleviating stress on the medical system.

This study was subject to several limitations. We assumed that reinfection would not occur. This assumption may cause the model to underestimate the epidemic magnitude and peak. We also did not consider the waning of booster-dose-induced immunity over time and assumed that the prevalence of imported COVID-19 in 2022 will be the same as it was in 2021. Additionally, we were under the assumption that the transmissibility of the virus in 2022 will be the same as the Delta variant. Given that the Omicron variant has higher transmissibility than Delta and that future variants may also have high transmissibility, our results may be underestimates. Our model used an SIR structure rather than an SEIR (susceptible, exposed, infectious, and recovered) structure for simulation. However, given that COVID-19 cases can transmit during the incubation period (14), SIR models have been used successfully (15) and we believe that an SIR structure reasonably simulates COVID-19 epidemics. Finally, our model did not consider vaccination effectiveness against SARS-CoV-2 infectiousness (VEI).

As booster vaccination increases in 2022, incoming international travel could increase slightly, but a suppression strategy should be maintained to ensure that the resulting COVID-19 epidemic can be maintained under control. High coverage of booster dose vaccinations along with the use of antiviral medicines and increasing the availability of medical resources, could allow for the possibility of lifting border restrictions and NPIs in the near future.

Conflicts of interest: No conflicts of interest.

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SUPPLEMENTARY MATERIAL

Study Location

The study used Guangdong Province of China as an example to project the epidemic magnitude of coronavirus disease 2019 (COVID-19) from January 1, 2022, to December 31, 2022. Guangdong Province is located in the southeast coastal area of China and has frequent international exchange. Guangdong is the most populous province in China with 126,012,500 residents and is the most developed province with the highest gross domestic product (GDP) (1–2). Guangdong has the highest total export-import volume in China (2). For these reasons, Guangdong faces considerable risk of COVID-19 in the global pandemic.

Model Structure

Based on the susceptible-infectious-recovered (SIR) modeling framework, we introduced several compartments to include import risk from overseas, imported (border) quarantine, vaccination, and exiting population (Figure 1). Two compartments were added to describe the imported infectors (I_{in}) and imported susceptibles (S_{in}). I_{in} shunts into imported infectors with (Q_{in,p}) and without quarantine or leaked after quarantine (I_{in,p}). S_{in} shunts into imported susceptible with (Q_{in}) and without quarantine (S_{in}). We divided the $S$ compartment into 3 sections: susceptible without vaccination ($S_{non-vaccine}$); susceptible with full vaccination ($S_{vaccine2}$); susceptible with booster dose vaccination ($S_{vaccine3}$). We further divided $S_{vaccine2}$/$S_{vaccine3}$ into 2 sections: vaccinated susceptible with immunity against COVID-19 ($S_{protect2}$/$S_{protect3}$); vaccinated susceptible without immunity against COVID-19 ($S_{non-protect2}$/$S_{non-protect3}$). $S_{non-protect2}$/$S_{non-protect3}$ and $S_{non-protect2}$ would gradually become infectors and flow into $I_{non-vaccine}$/$I_{vaccine2}$, and $I_{vaccine3}$ respectively, which would be later detected, quarantined, and treated in $Q_{non-vaccine}$/$Q_{vaccine2}$, and $Q_{vaccine3}$ respectively. Then the recovered infectors would enter recovery compartment $R$. We introduced Out to describe the exported population from Guangdong.

Model Equations

The system of differential equations in the model is as follows:

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\begin{align*}
\frac{dS_{non-vaccine}}{dt} &= -\beta S_{non-vaccine} \left( I_{non-vaccine} + I_{vaccine2} + I_{vaccine3} + I_{in,p} \right) + S_{non-vaccine} \times P_{out} \\
\frac{dS_{vaccine2}}{dt} &= S_{in,s} + Q_{in} - S_{vaccine2} \times P_{protect2} - S_{vaccine2} \times P_{non-protect2} - S_{vaccine2} \times P_{out} \\
\frac{dS_{protect2}}{dt} &= S_{vaccine2} \times P_{protect2} - v_3 \times P_{protect2} - \beta \times S_{non-protect2} \times \left( I_{non-vaccine} + I_{vaccine2} + I_{vaccine3} + I_{in,p} \right) \\
\frac{dS_{vaccine3}}{dt} &= v_3 \times P_{non-protect2} - S_{vaccine3} \times P_{protect3} - S_{vaccine3} \times P_{non-protect3} - S_{vaccine3} \times P_{out} \\
\frac{dS_{non-protect3}}{dt} &= S_{vaccine3} \times P_{protect3} + v_3 \times P_{protect2} - S_{protect3} - \beta \times S_{non-protect3} \times \left( I_{non-vaccine} + I_{vaccine2} + I_{vaccine3} + I_{in,p} \right) \\
\frac{dI_{in,p}}{dt} &= I_{in,p} \times (1 - P_Q) + Q_{in,p} \times P_{leak} - \mu \times I_{in,p} \\
\frac{dI_{vaccine2}}{dt} &= \beta S_{non-vaccine} \left( I_{non-vaccine} + I_{vaccine2} + I_{vaccine3} + I_{in,p} \right) - \mu \times I_{vaccine2} \\
\frac{dI_{vaccine3}}{dt} &= \beta S_{non-vaccine} \left( I_{non-vaccine} + I_{vaccine2} + I_{vaccine3} + I_{in,p} \right) - \mu \times I_{vaccine3} \\
\frac{dQ_{in}}{dt} &= \mu \times I_{in,p} + Q_{in,p} \times (1 - P_{leak}) - Q_{in} \times \delta
\end{align*}
\]
SUPPLEMENTARY TABLE S1. Interval from infection to quarantine for different infection detected measures.

| Infection detection measures                                      | Median interval | μ   |
|-------------------------------------------------------------------|-----------------|-----|
| Fever monitor                                                     | 6.5 days        | 1/6.5|
| Fever monitor + Contact trace                                     | 5 days          | 1/5 |
| Fever monitor + Contact trace + High risk group trace             | 4.5 days        | 1/4.5|
| Fever monitor + Contact trace + High risk group trace + Community nucleic acid screening | 4 days          | 1/4 |

SUPPLEMENTARY TABLE S2. Definitions and values of compartments in the transmission model.

| Compartment | Definition                                      | Value                                      |
|-------------|------------------------------------------------|--------------------------------------------|
| $I_n$       | Imported infected persons                       | Estimated from flight data and COVID-19 prevalence of imported population |
| $S_n$       | Imported susceptible                            | Ditto                                     |
| $I_{in,p}$  | Imported infected persons without quarantine or leaked after quarantine | No imported quarantine: $I_{in,p} = I_n$   |
| $Q_{in,p}$  | Imported infected persons with quarantine       | No imported quarantine: $Q_{in,p} = 0$    |
| $S_{in,s}$  | Imported susceptible without quarantine         | No imported quarantine: $S_{in,s} = S_n$   |
| $Q_{in,s}$  | Imported susceptible with quarantine            | No imported quarantine: $Q_{in,s} = 0$    |
| $S_{non-vaccine}$ | Susceptible without vaccination        | Initial value: 10% × 126,012,500            |
| $S_{vaccine2}$ | Susceptible with full vaccination            | Initial value: 90% × 126,012,500–10,000,000 |
| $S_{vaccine3}$ | Susceptible with booster vaccination | Initial value: 10,000,000                   |
| $S_{protect2}$ | Fully vaccinated susceptible with immunity     | $S_{vaccine2} × 65.70\%$                  |
| $S_{non-protect2}$ | Fully vaccinated susceptible without immunity | $S_{vaccine2}−S_{vaccine2} × 65.70\%$    |
| $S_{protect3}$ | Booster vaccinated susceptible with immunity   | $S_{vaccine3} × 88.00\%$                  |
| $S_{non-protect3}$ | Booster vaccinated susceptible without immunity | $S_{vaccine3}−S_{vaccine3} × 88.00\%$    |
| $I_{non-vaccine}$ | Infected persons without vaccination | Initial value: 0                           |
| $I_{vaccine2}$ | Infected persons with full vaccination         | Initial value: 0                           |
| $I_{vaccine3}$ | Infected persons with booster vaccination      | Initial value: 0                           |
| $Q_n$       | Quarantined imported infected persons          | Initial value: 0                           |
| $Q_{non-vaccine}$ | Quarantined infected persons without vaccination | Initial value: 0                           |
| $Q_{vaccine2}$ | Quarantined infected persons with full vaccination | Initial value: 0                           |
| $Q_{vaccine3}$ | Quarantined infected persons with booster vaccination | Initial value: 0                           |
| $R$         | Recovered population                            | Initial value: 0                           |

SUPPLEMENTARY FIGURE S1. The association between observed daily new cases and the predicted daily new cases with beta= 0.14 (beta with best fitness)
Abbreviations: RMSE=root mean square error
SUPPLEMENTARY TABLE S3. Definitions and values of parameters in the transmission model.

| Parameter | Definition | Scenario | Value |
|-----------|------------|----------|-------|
| \( \beta \) | Transmission coefficient | With personal protection and social distance | \( 0.14 \times 1.97 = 0.27 \) |
| | | Without personal protection and social distance | \( 0.27/0.47 = 0.57 \) |
| | | Fever monitor + contact trace | 1/5 |
| \( \mu \) | Rate from infected persons to quarantine | Fever monitor + contact trace + high risk group | 1/4.5 |
| | | Fever monitor + contact trace + high risk group + community nucleic acid screening | 1/4 |
| \( \delta \) | Rate from quarantine to recovery | All | 1/23 |
| \( P_0 \) | Proportion of imported quarantine | No imported quarantine | 0 |
| | | Imported quarantine | 1 |
| \( P_{\text{leak}} \) | Proportion of leaked infected persons under different imported quarantined period | 7-day imported quarantine | 1.04% |
| | | 14-day imported quarantine | 0.16% |
| \( P_{\text{protect2}} \) | Vaccine efficacy for full vaccination | All | 65.70% |
| \( P_{\text{protect3}} \) | Vaccine efficacy for booster vaccination | All | 88.00% |
| \( P_{\text{out}} \) | Proportion of exported population | All | Imported population/Guangdong population |

\[
\begin{align*}
\frac{dQ_{\text{non-vaccine}}}{dt} &= \mu \times I_{\text{non-vaccine}} - Q_{\text{non-vaccine}} \times \delta \\
\frac{dQ_{\text{vaccine2}}}{dt} &= \mu \times I_{\text{vaccine2}} - Q_{\text{vaccine2}} \times \delta \\
\frac{dQ_{\text{vaccine3}}}{dt} &= \mu \times I_{\text{vaccine3}} - Q_{\text{vaccine3}} \times \delta \\
\frac{dR}{dt} &= (Q_{\text{in}} + Q_{\text{non-vaccine}} + Q_{\text{vaccine2}} + Q_{\text{vaccine3}}) \times \delta + S_{\text{protect3}} - R \times P_{\text{out}}
\end{align*}
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**Estimation of Vaccination Rate**

Guangdong Province has 126,012,500 residents (1). As of November 30, 2021, 86.67% residents in Guangdong were fully vaccinated. We assumed that the full vaccination (2 doses) rate could reach 90% by the beginning of 2022 in Guangdong. In the second half of 2021, full vaccination increased from 46.72% (on June 30) to 86.62% (on November 30). In other words, 46.72% and 86.62% of the population are eligible for booster doses on January 1 and June 1, 2022. In addition, 7.97 million people have received booster doses by November 30, and we predict that 10 million people could receive booster doses by January 1, 2022. As the roll-out of vaccination normally had a “fast, followed by slow, trend,” we set high and low vaccination scenarios: 1) 60% population boosted by June 30, 2022 and 85% population boosted by December 31, 2022; 2) 50% population boosted by June 30, 2022 and 75% boosted by December 31, 2022.

**Estimation of Vaccination Effectiveness**

Inactivated COVID-19 vaccines were widely used in China, and their vaccine efficacy against infection was 65.70% for the fully vaccinated according to a recent meta-analysis (3). According to a recent publication, the efficacy for booster doses was 88.00% (4). Therefore, \( P_{\text{protect2}} \) and \( P_{\text{protect3}} \) were set to be 65.70% and 88.00%, respectively.

Vaccination reduces hospital admission, severe illness, and death. According to US CDC, for unvaccinated and fully vaccinated infected people, hospital admission rates were 9.00% and 3.90%; intensive care unit (ICU) admission rates were 3.12% and 0.36%; and the fatality rates were 1.40% and 0.70% (5). Given that inactivated vaccines have lower efficacy than mRNA vaccines, we adjusted these rates based on the ratio between the efficacy of inactive and mRNA vaccine (3,6). The hospital admission rate, ICU admission rate, and fatality rate were set to
SUPPLEMENTARY TABLE S4. Predicted epidemic magnitude and required medical resource under different scenarios in 2022 in Guangdong Province.

| Recovery (%) of overseas incoming travel compared with 2019 | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|-------------------------------------------------------------|---------------------|---------------------|---------------------|------------------|------------------|-------------------|--------------------------|-----------------|----------------|--------------------------------------------|
| Booster vaccination rate=50% on June 30, 2022, Booster vaccination rate=75% on December 31, 2022. |
| 100% 0 day No A | 17,057,217 | 158,898 | 245,140 | 4,488,007 | 241,854 | 51,011 | 0 |
| 100% 0 day No A+B | 1,623,846 | 15,122 | 12,643 | 271,129 | 14,507 | 3,014 | 0 |
| 100% 0 day No A+B+C | 603,404 | 5,618 | 4,112 | 91,869 | 4,841 | 967 | 0 |
| 100% 0 day No A+B+C+D | 310,922 | 2,895 | 1,856 | 44,023 | 2,268 | 433 | 0 |
| 100% 7–0 days No A | 11,767,643 | 109,710 | 136,895 | 2,653,201 | 143,601 | 31,342 | 211,576 |
| 100% 7–0 days No A+B | 344,004 | 3,204 | 1,501 | 38,297 | 1,966 | 384 | 211,576 |
| 100% 7–0 days No A+B+C | 167,251 | 1,558 | 793 | 23,683 | 1,185 | 238 | 211,576 |
| 100% 7–0 days No A+B+C+D | 106,998 | 997 | 563 | 18,667 | 911 | 175 | 211,576 |
| 100% 7 days No A | 11,682,121 | 108,912 | 136,895 | 2,653,201 | 143,601 | 31,342 | 227,289 |
| 100% 7 days No A+B | 202,724 | 1,888 | 1,501 | 38,297 | 1,966 | 384 | 227,289 |
| 100% 7 days No A+B+C | 66,087 | 615 | 446 | 15,719 | 750 | 126 | 227,289 |
| 100% 7 days No A+B+C+D | 33,052 | 308 | 196 | 10,425 | 465 | 67 | 227,289 |
| 100% 14–7 days No A | 7,162,142 | 66,787 | 63,596 | 1,313,897 | 71,355 | 16,076 | 421,820 |
| 100% 14–7 days No A+B | 46,352 | 432 | 237 | 11,567 | 526 | 81 | 421,820 |
| 100% 14–7 days No A+B+C | 20,287 | 189 | 84 | 8,684 | 366 | 47 | 421,820 |
| 100% 14–7 days No A+B+C+D | 12,397 | 115 | 59 | 8,143 | 337 | 41 | 421,820 |
| 100% 14 days No A | 7,145,332 | 66,631 | 63,596 | 1,313,232 | 71,317 | 16,066 | 452,238 |
| 100% 14 days No A+B | 32,129 | 299 | 237 | 11,567 | 526 | 81 | 452,238 |
| 100% 14 days No A+B+C | 10,277 | 96 | 70 | 7,908 | 330 | 39 | 452,238 |
| 100% 14 days No A+B+C+D | 5,114 | 48 | 30 | 7,125 | 286 | 30 | 452,238 |
| 100% 0 day Yes A | 130,757 | 1,218 | 584 | 18,433 | 896 | 155 | 0 |
| 100% 0 day Yes A+B | 78,139 | 728 | 328 | 13,002 | 604 | 95 | 0 |
| 100% 0 day Yes A+B+C | 65,496 | 610 | 269 | 11,790 | 539 | 82 | 0 |
| 100% 0 day Yes A+B+C+D | 54,493 | 507 | 219 | 10,772 | 485 | 71 | 0 |
| 100% 7–0 days Yes A | 54,658 | 509 | 296 | 13,239 | 615 | 106 | 211,576 |
| 100% 7–0 days Yes A+B | 35,005 | 326 | 191 | 10,938 | 489 | 77 | 211,576 |
| 100% 7–0 days Yes A+B+C | 29,855 | 278 | 163 | 10,337 | 456 | 69 | 211,576 |
| 100% 7–0 days Yes A+B+C+D | 25,223 | 235 | 138 | 9,800 | 427 | 62 | 211,576 |
| 100% 7 days Yes A | 13,718 | 128 | 61 | 7,707 | 319 | 37 | 227,289 |
| 100% 7 days Yes A+B | 8,175 | 76 | 34 | 7,364 | 294 | 31 | 227,289 |
| 100% 7 days Yes A+B+C | 6,848 | 64 | 28 | 7,300 | 290 | 30 | 227,289 |
| 100% 7 days Yes A+B+C+D | 5,695 | 53 | 23 | 7,243 | 287 | 29 | 227,289 |
| 100% 14–7 days Yes A | 6,138 | 57 | 31 | 7,595 | 306 | 33 | 421,820 |
| 100% 14–7 days Yes A+B | 3,893 | 36 | 20 | 7,355 | 293 | 30 | 421,820 |
| 100% 14–7 days Yes A+B+C | 3,313 | 31 | 17 | 7,293 | 290 | 30 | 421,820 |
| 100% 14–7 days Yes A+B+C+D | 2,793 | 26 | 14 | 7,237 | 287 | 29 | 421,820 |
| 100% 14 days Yes A | 2,117 | 20 | 9 | 7,044 | 276 | 26 | 452,238 |
| Recovery (%) | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|-------------|---------------------|---------------------|---------------------|-----------------|-----------------|------------------|----------------------------|---------------------|----------------|-----------------------------------------------|
| 100%        | 14 days             | Yes                 | A+B                 | 1,260           | 12              | 5                | 7,006                      | 274                 | 452,238        | 26                             |
| 100%        | 14 days             | Yes                 | A+B+C               | 1,056           | 10              | 4                | 6,996                      | 274                 | 452,238        | 26                             |
| 100%        | 14 days             | Yes                 | A+B+C+D             | 878             | 8               | 4                | 6,987                      | 273                 | 452,238        | 26                             |
| 50%         | 0 day               | No                  | A                   | 14,593,265      | 136,568         | 195,326          | 3,655,505                  | 198,408             | 42,742         | 0                              |
| 50%         | 0 day               | No                  | A+B                 | 801,343         | 7,496           | 6,188            | 133,033                    | 7,149               | 1,499          | 0                              |
| 50%         | 0 day               | No                  | A+B+C               | 290,695         | 2,719           | 2,007            | 44,833                     | 2,369               | 476            | 0                              |
| 50%         | 0 day               | No                  | A+B+C+D             | 150,273         | 1,406           | 915              | 21,697                     | 1,120               | 214            | 0                              |
| 50%         | 7–0 days            | No                  | A                   | 8,932,401       | 83,812          | 93,142           | 1,846,408                  | 100,932             | 22,654         | 105,788                       |
| 50%         | 7–0 days            | No                  | A+B                 | 156,695         | 1,471           | 695              | 17,927                     | 921                 | 180            | 105,788                       |
| 50%         | 7–0 days            | No                  | A+B+C               | 77,912          | 732             | 370              | 11,232                     | 565                 | 115            | 105,788                       |
| 50%         | 7–0 days            | No                  | A+B+C+D             | 50,405          | 474             | 267              | 8,979                      | 440                 | 85             | 105,788                       |
| 50%         | 7 days              | No                  | A                   | 8,878,596       | 83,303          | 93,142           | 1,846,527                  | 100,941             | 22,655         | 113,645                       |
| 50%         | 7 days              | No                  | A+B                 | 92,166          | 862             | 695              | 17,927                     | 921                 | 180            | 113,645                       |
| 50%         | 7 days              | No                  | A+B+C               | 31,220          | 292             | 215              | 7,682                      | 366                 | 61             | 113,645                       |
| 50%         | 7 days              | No                  | A+B+C+D             | 15,868          | 148             | 96               | 5,171                      | 231                 | 33             | 113,645                       |
| 50%         | 14–7 days           | No                  | A                   | 4,392,446       | 41,293          | 34,343           | 727,727                    | 39,987              | 9,268          | 210,910                       |
| 50%         | 14–7 days           | No                  | A+B                 | 20,841          | 195             | 109              | 5,558                      | 251                 | 38             | 210,910                       |
| 50%         | 14–7 days           | No                  | A+B+C               | 9,440           | 89              | 39               | 4,274                      | 180                 | 23             | 210,910                       |
| 50%         | 14–7 days           | No                  | A+B+C+D             | 5846            | 55              | 28               | 4,033                      | 167                 | 20             | 210,910                       |
| 50%         | 14 days             | No                  | A                   | 4,381,380       | 41,188          | 34,309           | 726,863                    | 39,940              | 9,256          | 226,119                       |
| 50%         | 14 days             | No                  | A+B                 | 14,440          | 135             | 109              | 5,558                      | 251                 | 38             | 226,119                       |
| 50%         | 14 days             | No                  | A+B+C               | 4,843           | 45              | 34               | 3,925                      | 163                 | 19             | 226,119                       |
| 50%         | 14 days             | No                  | A+B+C+D             | 2,453           | 23              | 15               | 3,556                      | 143                 | 15             | 226,119                       |
| 50%         | 0 day               | Yes                 | A                   | 63,545          | 595             | 290              | 9,154                      | 445                 | 77             | 0                              |
| 50%         | 0 day               | Yes                 | A+B                 | 38,124          | 357             | 163              | 6,477                      | 301                 | 47             | 0                              |
| 50%         | 0 day               | Yes                 | A+B+C               | 31,990          | 300             | 134              | 5,876                      | 269                 | 41             | 0                              |
| 50%         | 0 day               | Yes                 | A+B+C+D             | 26,642          | 250             | 109              | 5,372                      | 242                 | 35             | 0                              |
| 50%         | 7–0 days            | Yes                 | A                   | 26,082          | 246             | 142              | 6,469                      | 302                 | 53             | 105,788                       |
| 50%         | 7–0 days            | Yes                 | A+B                 | 16,814          | 158             | 92               | 5,388                      | 242                 | 38             | 105,788                       |
| 50%         | 7–0 days            | Yes                 | A+B+C               | 14,366          | 135             | 79               | 5,103                      | 226                 | 34             | 105,788                       |
| 50%         | 7–0 days            | Yes                 | A+B+C+D             | 12,158          | 114             | 67               | 4,847                      | 212                 | 31             | 105,788                       |
| 50%         | 7 days              | Yes                 | A                   | 6,655           | 62              | 30               | 3,842                      | 159                 | 18             | 113,645                       |
| 50%         | 7 days              | Yes                 | A+B                 | 3,985           | 37              | 17               | 3,673                      | 147                 | 15             | 113,645                       |
| 50%         | 7 days              | Yes                 | A+B+C               | 3,342           | 31              | 14               | 3,643                      | 145                 | 15             | 113,645                       |
| 50%         | 7 days              | Yes                 | A+B+C+D             | 2,783           | 26              | 11               | 3,616                      | 143                 | 14             | 113,645                       |
| 50%         | 14–7 days           | Yes                 | A                   | 2,933           | 28              | 15               | 3,781                      | 153                 | 17             | 210,910                       |
| 50%         | 14–7 days           | Yes                 | A+B                 | 1,872           | 18              | 10               | 3,669                      | 146                 | 15             | 210,910                       |
| 50%         | 14–7 days           | Yes                 | A+B+C               | 1,596           | 15              | 8                | 3,639                      | 145                 | 15             | 210,910                       |
| 50%         | 14–7 days           | Yes                 | A+B+C+D             | 1,348           | 13              | 7                | 3,613                      | 143                 | 14             | 210,910                       |
Continued

| Recovery (%) of overseas incoming travel compared with 2019 | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|----------------------------------------------------------|---------------------|---------------------|--------------------|-----------------|-----------------|------------------|--------------------------|---------------------|-----------------|--------------------------------------------|
| 50%                                                      | 14 days             | Yes                 | A                  | 1,027           | 10              | 5                | 3,519                    | 138                 | 13              | 226,119                                    |
| 50%                                                      | 14 days             | Yes                 | A+B                | 614             | 6               | 3                | 3,501                    | 137                 | 13              | 226,119                                    |
| 50%                                                      | 14 days             | Yes                 | A+B+C              | 515             | 5               | 2                | 3,497                    | 137                 | 13              | 226,119                                    |
| 50%                                                      | 14 days             | Yes                 | A+B+C+D            | 429             | 4               | 2                | 3,493                    | 137                 | 13              | 226,119                                    |
| 20%                                                      | 0 day               | No                  | A                  | 11,686,806      | 109,823         | 141,719          | 2,723,780                | 148,882             | 32,851          | 0                                          |
| 20%                                                      | 0 day               | No                  | A+B                | 317,808         | 2,981           | 2,442            | 52,585                   | 2,834               | 598             | 0                                          |
| 20%                                                      | 0 day               | No                  | A+B+C              | 113,748         | 1,067           | 791              | 17,678                   | 935                 | 188             | 0                                          |
| 20%                                                      | 0 day               | No                  | A+B+C+D            | 58,924          | 553             | 363              | 8,606                    | 444                 | 85              | 0                                          |
| 20%                                                      | 7–0 days            | No                  | A                  | 5,950,980       | 56,140          | 53,179           | 1,087,845                | 60,016              | 13,851          | 42,315                                     |
| 20%                                                      | 7–0 days            | No                  | A+B                | 59,386          | 560             | 266              | 6,907                    | 355                 | 70              | 42,315                                     |
| 20%                                                      | 7–0 days            | No                  | A+B+C              | 29,908          | 283             | 142              | 4,359                    | 220                 | 45              | 42,315                                     |
| 20%                                                      | 7–0 days            | No                  | A+B+C+D            | 19,470          | 184             | 103              | 3,512                    | 173                 | 34              | 42,315                                     |
| 20%                                                      | 7 days              | No                  | A                  | 5,920,851       | 55,853          | 53,179           | 1,087,349                | 59,981              | 13,840          | 45,458                                     |
| 20%                                                      | 7 days              | No                  | A+B                | 34,910          | 327             | 266              | 6,907                    | 355                 | 70              | 45,458                                     |
| 20%                                                      | 7 days              | No                  | A+B+C              | 12,085          | 113             | 84               | 3,033                    | 144                 | 24              | 45,458                                     |
| 20%                                                      | 7 days              | No                  | A+B+C+D            | 6,199           | 58              | 38               | 2,059                    | 92                  | 13              | 45,458                                     |
| 20%                                                      | 14–7 days           | No                  | A                  | 2,129,633       | 20,142          | 15,028           | 323,588                  | 17,942              | 4,253           | 84,364                                     |
| 20%                                                      | 14–7 days           | No                  | A+B                | 7,849           | 74              | 42               | 2,176                    | 98                  | 15              | 84,364                                     |
| 20%                                                      | 14–7 days           | No                  | A+B+C              | 3,622           | 34              | 15               | 1,695                    | 71                  | 9               | 84,364                                     |
| 20%                                                      | 14–7 days           | No                  | A+B+C+D            | 2,260           | 21              | 11               | 1,605                    | 66                  | 8               | 84,364                                     |
| 20%                                                      | 14 days             | No                  | A                  | 2,123,723       | 20,085          | 15,002           | 323,001                  | 17,908              | 4,245           | 90,448                                     |
| 20%                                                      | 14 days             | No                  | A+B                | 5,438           | 51              | 42               | 2,176                    | 98                  | 15              | 90,448                                     |
| 20%                                                      | 14 days             | No                  | A+B+C              | 1,872           | 18              | 13               | 1,564                    | 65                  | 8               | 90,448                                     |
| 20%                                                      | 14 days             | No                  | A+B+C+D            | 958             | 9               | 6                | 1,421                    | 57                  | 6               | 90,448                                     |
| 20%                                                      | 0 day               | Yes                 | A                  | 24,995          | 235             | 115              | 3,647                    | 178                 | 31              | 0                                          |
| 20%                                                      | 0 day               | Yes                 | A+B                | 15,029          | 141             | 65               | 2,585                    | 120                 | 19              | 0                                          |
| 20%                                                      | 0 day               | Yes                 | A+B+C              | 12,619          | 119             | 54               | 2,346                    | 107                 | 16              | 0                                          |
| 20%                                                      | 0 day               | Yes                 | A+B+C+D            | 10,515          | 99              | 44               | 2,146                    | 97                  | 14              | 0                                          |
| 20%                                                      | 7–0 days            | Yes                 | A                  | 10,147          | 96              | 55               | 2,554                    | 119                 | 21              | 42,315                                     |
| 20%                                                      | 7–0 days            | Yes                 | A+B                | 6,566           | 62              | 36               | 2,136                    | 96                  | 15              | 42,315                                     |
| 20%                                                      | 7–0 days            | Yes                 | A+B+C              | 5,616           | 53              | 31               | 2,026                    | 90                  | 14              | 42,315                                     |
| 20%                                                      | 7–0 days            | Yes                 | A+B+C+D            | 4,757           | 45              | 26               | 1,926                    | 84                  | 12              | 42,315                                     |
| 20%                                                      | 7 days              | Yes                 | A                  | 2,615           | 25              | 12               | 1,534                    | 64                  | 7               | 45,458                                     |
| 20%                                                      | 7 days              | Yes                 | A+B                | 1,570           | 15              | 7                | 1,467                    | 59                  | 6               | 45,458                                     |
| 20%                                                      | 7 days              | Yes                 | A+B+C              | 1,318           | 12              | 6                | 1,455                    | 58                  | 6               | 45,458                                     |
| 20%                                                      | 7 days              | Yes                 | A+B+C+D            | 1,098           | 10              | 5                | 1,445                    | 57                  | 6               | 45,458                                     |
| 20%                                                      | 14–7 days           | Yes                 | A                  | 1,142           | 11              | 6                | 1,509                    | 61                  | 7               | 84,364                                     |
| 20%                                                      | 14–7 days           | Yes                 | A+B                | 732             | 7               | 4                | 1,465                    | 58                  | 6               | 84,364                                     |
| 20%                                                      | 14–7 days           | Yes                 | A+B+C              | 624             | 6               | 3                | 1,454                    | 58                  | 6               | 84,364                                     |
Continued

| Recovery (%) of overseas incoming travel compared with 2019 | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|-----------------------------------------------------------|---------------------|---------------------|--------------------|-----------------|------------------|-------------------|--------------------------|-------------------|----------------|-------------------------------------------|
| 20% 14–7 days Yes A+B+C+D 528 5 3 1,444 57 6 84,364 | 20% 14 days Yes A 403 4 2 1,407 55 5 90,448 | 20% 14 days Yes A+B 242 2 1 1,400 55 5 90,448 | 20% 14 days Yes A+B+C 203 2 1 1,398 55 5 90,448 | 20% 14 days Yes A+B+C+D 169 2 1 1,397 55 5 90,448 |

**Booster vaccination rate=60% on June 30, 2022, booster vaccination rate=85% on December 31, 2022**

| 100% 0 day No A 12,922,032 120,710 173,218 3,249,552 176,074 38,187 0 | 100% 0 day No A+B 1,039,439 9,703 8,723 185,865 9,941 2,076 0 | 100% 0 day No A+B+C 455,636 4,253 3,413 75,665 3,979 797 0 | 100% 0 day No A+B+C+D 255,103 2,382 1,684 39,865 2,049 392 0 |
| 100% 7–0 days No A 6,452,568 60,385 66,137 1,322,321 72,100 16,346 211,576 | 100% 7–0 days No A+B 216,215 2,022 986 26,889 1,355 258 211,576 | 100% 7–0 days No A+B+C 122,459 1,146 566 18,760 925 188 211,576 | 100% 7–0 days No A+B+C+D 83,289 780 427 15,746 758 146 211,576 |
| 100% 7 days No A 6,349,818 59,421 66,137 1,322,321 72,100 16,346 227,289 | 100% 7 days No A+B 120,477 1,125 986 26,889 1,355 258 227,289 | 100% 7 days No A+B+C 49,339 460 368 13,910 654 107 227,289 | 100% 7 days No A+B+C+D 27,072 253 178 9,977 442 62 227,289 |
| 100% 14–7 days No A 2,228,354 20,868 17,956 376,505 20,556 4,784 421,820 | 100% 14–7 days No A+B 28,421 266 155 9,673 425 60 421,820 | 100% 14–7 days No A+B+C 14,878 139 59 8,157 338 42 421,820 | 100% 14–7 days No A+B+C+D 9,720 91 45 7,835 321 38 421,820 |
| 100% 14 days No A 2,209,689 20,693 17,956 376,471 20,552 4,782 452,238 | 100% 14 days No A+B 18,900 176 155 9,673 425 60 452,238 | 100% 14 days No A+B+C 7,664 72 57 7,631 315 36 452,238 | 100% 14 days No A+B+C+D 4,189 39 28 7,079 283 29 452,238 |
| 100% 0 day Yes A 113,519 1,061 556 17,664 856 148 0 | 100% 0 day Yes A+B 69,524 650 319 12,705 589 93 0 | 100% 0 day Yes A+B+C 58,636 548 263 11,567 528 80 0 | 100% 0 day Yes A+B+C+D 49,054 458 215 10,604 477 70 0 |
| 100% 7–0 days Yes A 45,163 423 241 12,029 553 96 211,576 | 100% 7–0 days Yes A+B 29,724 278 161 10,279 456 72 211,576 | 100% 7–0 days Yes A+B+C 25,542 239 139 9,803 430 65 211,576 | 100% 7–0 days Yes A+B+C+D 21,727 203 118 9,370 405 59 211,576 |
| 100% 7 days Yes A 11,914 111 58 7,612 314 36 227,289 | 100% 7 days Yes A+B 7,277 68 33 7,295 290 30 227,289 | 100% 7 days Yes A+B+C 6,134 57 27 7,244 287 29 227,289 | 100% 7 days Yes A+B+C+D 5,129 48 22 7,198 285 29 227,289 |
| 100% 14–7 days Yes A 5,104 48 25 7,469 300 32 421,820 |
Continued

| Recovery (%) of overseas incoming travel compared with 2019 | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|----------------------------------------------------------|---------------------|---------------------|--------------------|-----------------|------------------|------------------|--------------------------|---------------------|----------------|---------------------------------------------|
| 100% 14–7 days Yes A+B | 3,325 31 17 | 7,287 | 290 | 30 | 421,820 |
| 100% 14–7 days Yes A+B+C | 2,850 27 14 | 7,237 | 287 | 29 | 421,820 |
| 100% 14–7 days Yes A+B+C+D | 2,419 23 12 | 7,193 | 285 | 29 | 421,820 |
| 100% 14 days Yes A | 1,839 17 9 | 7,024 | 275 | 26 | 452,238 |
| 100% 14 days Yes A+B | 1,122 10 5 | 6,995 | 274 | 26 | 452,238 |
| 100% 14 days Yes A+B+C | 946 9 4 | 6,980 | 273 | 26 | 452,238 |
| 100% 14 days Yes A+B+C+D | 791 7 4 | 6,900 | 273 | 26 | 452,238 |
| 50% 0 day No A | 10,081,389 94,663 124,420 | 2,389,533 | 130,535 | 29,026 | 0 |
| 50% 0 day No A+B | 506,260 4,746 4,254 | 90,757 | 4,872 | 1,025 | 0 |
| 50% 0 day No A+B+C | 220,284 2,066 1,673 | 37,083 | 1,955 | 393 | 0 |
| 50% 0 day No A+B+C+D | 123,644 1,161 832 | 19,689 | 1,013 | 194 | 0 |
| 50% 7–0 days No A | 3,925,116 36,987 36,574 | 743,174 | 40,933 | 9,524 | 105,788 |
| 50% 7–0 days No A+B | 100,174 945 467 | 12,876 | 649 | 123 | 105,788 |
| 50% 7–0 days No A+B+C | 57,449 543 267 | 8,986 | 445 | 92 | 105,788 |
| 50% 7–0 days No A+B+C+D | 39,347 372 203 | 7,618 | 369 | 72 | 105,788 |
| 50% 7 days No A | 3,862,260 36,389 36,574 | 743,174 | 40,933 | 9,524 | 113,645 |
| 50% 7 days No A+B | 56,174 527 467 | 12,876 | 649 | 123 | 113,645 |
| 50% 7 days No A+B+C | 23,545 221 179 | 6,842 | 321 | 52 | 113,645 |
| 50% 7 days No A+B+C+D | 13,054 123 88 | 4,957 | 219 | 31 | 113,645 |
| 50% 14–7 days No A | 998,057 9,419 7,825 | 165,238 | 9,101 | 2,152 | 210,910 |
| 50% 14–7 days No A+B | 13,104 123 73 | 4,734 | 208 | 29 | 210,910 |
| 50% 14–7 days No A+B+C | 6,985 66 28 | 4,036 | 167 | 21 | 210,910 |
| 50% 14–7 days No A+B+C+D | 4,601 43 21 | 3,890 | 159 | 19 | 210,910 |
| 50% 14 days No A | 988,447 9,327 7,825 | 165,222 | 9,099 | 2,150 | 226,119 |
| 50% 14 days No A+B | 8,762 82 73 | 4,734 | 208 | 29 | 226,119 |
| 50% 14 days No A+B+C | 3,651 34 28 | 3,797 | 157 | 18 | 226,119 |
| 50% 14 days No A+B+C+D | 2,019 19 14 | 3,535 | 141 | 15 | 226,119 |
| 50% 0 day Yes A | 55,205 519 276 | 8,778 | 426 | 74 | 0 |
| 50% 0 day Yes A+B | 33,914 319 159 | 6,330 | 294 | 46 | 0 |
| 50% 0 day Yes A+B+C | 28,627 269 131 | 5,767 | 264 | 40 | 0 |
| 50% 0 day Yes A+B+C+D | 23,968 226 107 | 5,290 | 238 | 35 | 0 |
| 50% 7–0 days Yes A | 21,531 204 116 | 5,890 | 272 | 48 | 105,788 |
| 50% 7–0 days Yes A+B | 14,248 135 78 | 5,068 | 226 | 36 | 105,788 |
| 50% 7–0 days Yes A+B+C | 12,263 116 67 | 4,842 | 213 | 33 | 105,788 |
| 50% 7–0 days Yes A+B+C+D | 10,446 99 57 | 4,636 | 201 | 30 | 105,788 |
| 50% 7 days Yes A | 5,785 54 29 | 3,799 | 157 | 18 | 113,645 |
| 50% 7 days Yes A+B | 3,547 33 16 | 3,639 | 145 | 15 | 113,645 |
| 50% 7 days Yes A+B+C | 2,993 28 14 | 3,615 | 144 | 15 | 113,645 |
| 50% 7 days Yes A+B+C+D | 2,505 24 11 | 3,594 | 142 | 14 | 113,645 |
| Recovery (%) | Quarantine strategy | Personal protection | Case identification | Cumulative cases | Cumulative deaths | Maximum new cases | Maximum cases quarantined | Maximum hospital beds | Maximum ICU beds | Maximum hotel rooms for imported quarantine |
|--------------|---------------------|---------------------|--------------------|-----------------|------------------|-------------------|--------------------------|---------------------|----------------|------------------------------------------|
| 50%          | 14–7 days           | Yes                 | A                  | 2,438           | 23               | 12                | 3,721                    | 149                 | 16             | 210,910                                  |
| 50%          | 14–7 days           | Yes                 | A+B                | 1,596           | 15               | 8                 | 3,636                    | 145                 | 15             | 210,910                                  |
| 50%          | 14–7 days           | Yes                 | A+B+C              | 1,370           | 13               | 7                 | 3,612                    | 143                 | 15             | 210,910                                  |
| 50%          | 14–7 days           | Yes                 | A+B+C+D            | 1,165           | 11               | 6                 | 3,591                    | 142                 | 14             | 210,910                                  |
| 50%          | 14 days             | Yes                 | A                  | 893             | 8                | 4                 | 3,510                    | 138                 | 13             | 226,119                                  |
| 50%          | 14 days             | Yes                 | A+B                | 547             | 5                | 3                 | 3,496                    | 137                 | 13             | 226,119                                  |
| 50%          | 14 days             | Yes                 | A+B+C              | 461             | 4                | 2                 | 3,493                    | 137                 | 13             | 226,119                                  |
| 50%          | 14 days             | Yes                 | A+B+C+D            | 386             | 4                | 2                 | 3,489                    | 136                 | 13             | 226,119                                  |
| 20%          | 0 day               | No                  | A                  | 6,850,083       | 64,626           | 75,716            | 1,492,867                | 82,231              | 18,794         | 0                                        |
| 20%          | 0 day               | No                  | A+B                | 199,276         | 1,873            | 1,676             | 35,782                   | 1,925               | 407            | 0                                        |
| 20%          | 0 day               | No                  | A+B+C              | 86,381          | 812              | 661               | 14,658                   | 774                 | 156            | 0                                        |
| 20%          | 0 day               | No                  | A+B+C+D            | 48,561          | 457              | 330               | 7,819                    | 403                 | 77             | 0                                        |
| 20%          | 0 day               | No                  | A                  | 1,878,232       | 17,789           | 15,960            | 328,189                  | 18,216              | 4,325          | 42,315                                   |
| 20%          | 0 day               | No                  | A+B                | 38,329          | 363              | 181               | 5,024                    | 253                 | 48             | 42,315                                   |
| 20%          | 0 day               | No                  | A+B+C              | 22,137          | 210              | 103               | 3,507                    | 174                 | 36             | 42,315                                   |
| 20%          | 0 day               | No                  | A+B+C+D            | 15,221          | 145              | 79                | 2,990                    | 145                 | 29             | 42,315                                   |
| 20%          | 0 day               | No                  | A                  | 1,847,257       | 17,492           | 15,960            | 328,302                  | 18,220              | 4,325          | 45,458                                   |
| 20%          | 7 days              | No                  | A+B                | 21,580          | 203              | 181               | 5,024                    | 253                 | 48             | 45,458                                   |
| 20%          | 7 days              | No                  | A+B+C              | 9,166           | 86               | 70                | 2,711                    | 127                 | 21             | 45,458                                   |
| 20%          | 7 days              | No                  | A+B+C+D            | 5,112           | 48               | 35                | 1,976                    | 87                  | 12             | 45,458                                   |
| 20%          | 14–7 days           | No                  | A                  | 368,376         | 3,493            | 2,862             | 60,646                   | 3,357               | 800            | 84,364                                   |
| 20%          | 14–7 days           | No                  | A+B                | 5,002           | 47               | 28                | 1,871                    | 82                  | 11             | 84,364                                   |
| 20%          | 14–7 days           | No                  | A+B+C              | 2,693           | 26               | 11                | 1,605                    | 67                  | 8              | 84,364                                   |
| 20%          | 14–7 days           | No                  | A+B+C+D            | 1,782           | 17               | 8                 | 1,550                    | 63                  | 7              | 84,364                                   |
| 20%          | 14 days             | No                  | A                  | 364,523         | 3,456            | 2,862             | 60,640                   | 3,356               | 800            | 90,448                                   |
| 20%          | 14 days             | No                  | A+B                | 3,356           | 32               | 28                | 1,871                    | 82                  | 11             | 90,448                                   |
| 20%          | 14 days             | No                  | A+B+C              | 1,420           | 13               | 11                | 1,515                    | 62                  | 7              | 90,448                                   |
| 20%          | 14 days             | No                  | A+B+C+D            | 790             | 7                | 5                 | 1,413                    | 56                  | 6              | 90,448                                   |
| 20%          | 0 day               | Yes                 | A                  | 21,722          | 205              | 110               | 3,498                    | 170                 | 29             | 0                                        |
| 20%          | 0 day               | Yes                 | A+B                | 13,368          | 126              | 63                | 2,527                    | 117                 | 19             | 0                                        |
| 20%          | 0 day               | Yes                 | A+B+C              | 11,289          | 107              | 52                | 2,303                    | 105                 | 16             | 0                                        |
| 20%          | 0 day               | Yes                 | A+B+C+D            | 9,456           | 89               | 43                | 2,113                    | 95                  | 14             | 0                                        |
| 20%          | 7–0 days            | Yes                 | A                  | 8,371           | 80               | 45                | 2,328                    | 108                 | 19             | 42,315                                   |
| 20%          | 7–0 days            | Yes                 | A+B                | 5,557           | 53               | 30                | 2,010                    | 90                  | 14             | 42,315                                   |
| 20%          | 7–0 days            | Yes                 | A+B+C              | 4,787           | 46               | 26                | 1,923                    | 85                  | 13             | 42,315                                   |
| 20%          | 7–0 days            | Yes                 | A+B+C+D            | 4,081           | 39               | 22                | 1,843                    | 80                  | 12             | 42,315                                   |
| 20%          | 7 days              | Yes                 | A                  | 2,274           | 21               | 11                | 1,518                    | 63                  | 7              | 45,458                                   |
| 20%          | 7 days              | Yes                 | A+B                | 1,397           | 13               | 7                 | 1,454                    | 58                  | 6              | 45,458                                   |
| 20%          | 7 days              | Yes                 | A+B+C              | 1,180           | 11               | 5                 | 1,445                    | 57                  | 6              | 45,458                                   |
4.3%, 0.39%, and 0.80% for fully vaccinated infected people. A previous study demonstrated that risk of hospitalization, ICU admission, and death following booster doses were 6.50%, 8.10%, and 19.12% of full vaccination, respectively (4). Our study set hospital admission rate, ICU admission rate, and fatality rate as 0.30%, 0.03%, and 0.15% for booster vaccinated infected people, respectively.

Infection Detection Measures

In the dynamic transmission model, $\mu$ denotes the rate from infected persons to quarantine people. For assessing different local infection detection measures, we obtained information on the interval from infection to quarantine from real-world data in Guangdong Province.

Estimation of Transmission Coefficient ($\beta$)

We collected real world time series data of imported and local infected persons in a Guangdong epidemic during March 15, 2020 to April 15, 2020. This epidemic was triggered by imported cases from Africa. Based on the real-world data, we conducted an SIR model to calculate a contact transmission coefficient $\beta$ value with the best fit. Vaccination had not started during or prior to this outbreak. Its $\beta$ value therefore represents the transmission rate with local non-pharmacological interventions (NPIs) but without vaccine-induced immunity. We found that the $\beta$ with best fitness was 0.14 ($R^2=84.71\%$, Root Mean Square Error=3.61).

Given viral variants could have higher transmission rates (transmissibility of variants could reach 1.97 times of non-variant) (7), we thus set $\beta$ as 0.14×1.97=0.27 to represent the transmission rate in 2022.

A meta-analysis found that the relative risk (RR) reductions associated with mask wearing and social distancing were 0.47 and 0.75, respectively (8). Given that the effects of combinations of personal protection and social distancing were rarely reported, in our study we used the lowest risk reduction (RR=0.47) to represent the effectiveness of personal protection together with social distancing. We set $\beta$ as 0.27/0.47=0.57 to represent the transmission rate without personal protection and social distancing.

Medical Resources Against COVID-19 in Guangdong Province

As of December 28, 2020, 7,091 hospital beds and 156 ICU beds (estimated by the number of total ICU beds multiplying by the proportion of infectious diseases) could be used for infectious disease cases in Guangdong Province (9). If 50% of these hospital beds could be used for COVID-19 treatment, 3,546 hospital beds and 78 ICU beds would be available. In addition, 419 hotels with 47,636 rooms could be used for quarantine of travelers.
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