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Optimal vaccine strategy to control COVID-19 pandemic in middle-income countries: Modelling case study of Thailand

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ABSTRACT

Thailand is facing the dilemma of which groups to prioritise for the limited first tranche of vaccinations in 2021. A mathematical modelling analysis was performed to compare the potential short-term impact of allocating the available doses to either the high-risk group (over 65-year-olds) or the high incidence group (aged 20-39). Vaccinating the high incidence group with a vaccine with sufficiently high protection against infection (more than 50%) could provide enough herd effects to delay the expected epidemic peak, resulting in fewer deaths within the 12-month time horizon compared to vaccinating the same number of the high-risk group. After 12 months, if no further vaccination or other interventions were deployed, this strategy would lead to more deaths. With the right vaccine efficacy profile, targeting the high incidence groups could be a viable short-term component of the Thai vaccination strategy. These results and emerging evidence on vaccines and susceptibility suggest prioritisation guidelines should be more nuanced.

1 INTRODUCTION

2 Towards the end of 2020, the first COVID-19 vaccines became available and this rapid development was
3 hailed as an unprecedented feat in science. However, many questions remain regarding the long-term
4 impact of the available vaccines, and their influence against new variants ¹⁻⁴. COVID-19 vaccines remain
5 scarce resources ⁵, and it is unlikely that most countries without vaccine manufacturers will have sufficient
6 supplies of vaccines for their entire eligible population ⁵⁻¹⁰. Furthermore, the global community does not
7 have the information to be sure what the most effective strategy is to use them to defeat COVID-19.
8 Evidence to support how best to allocate limited resources, for example which groups should be
9 prioritised for vaccination and which vaccines should be selected, would be useful to all countries that are
10 still awaiting vaccines.

11
12 The World Health Organization (WHO) has led the development of two major guidance documents for the
13 distribution and prioritisation of vaccine allocation within populations. The first is the Strategic Advisory
14 Group of Experts on Immunization's (SAGE's) Values Framework for the allocation and prioritisation of
15 COVID-19 vaccination that aims to ensure that successful COVID-19 vaccines are shared equitably among
16 and in countries ¹¹. The second guidance document is the Roadmap for prioritising population groups for
17 vaccines against COVID-19 ¹², focusing on prioritising subpopulations for vaccination in countries, based
18 on scenarios of vaccine supply and COVID-19 incidence. Despite these guidance documents, allocation
19 plans need to be contextualised as they are dependent on various factors, e.g., the country's population
20 demographics, underlying population health, local epidemiology of COVID-19 outbreak, health
21 infrastructure and staff, vaccine type and supply, and the current non-pharmaceutical interventions (NPIs)
22 implemented ¹³.

1 Although Thailand was the second country to identify COVID-19 within their population ^{14,15}, the
2 implementation of NPIs in the first half of 2020 successfully suppressed local transmission throughout the
3 latter part of the year. The tourism sector is a vital part of the Thai economy ¹⁶, which has suffered greatly
4 due to the NPIs in place (e.g., travel restrictions and quarantine requirements). Therefore, the potential
5 value of a COVID-19 vaccine in Thailand is different from many western countries where vaccines may
6 primarily be deployed to reduce morbidity and mortality. For Thailand, having COVID-19 vaccine may
7 allow the relaxation of certain NPIs in the country, allowing tourism and other sectors of the economy to
8 return to pre-COVID-19 normality. The context for COVID-19 vaccination in Thailand is quite specific.
9 Firstly, the number of available doses for the 12-month period starting from March 2021 is limited to
10 approximately 31 million people (based on the current plan)¹⁷. Secondly, the vast majority of the
11 population has not been exposed to the virus and, as of February 2021, Thailand has experienced few
12 cases (<30,000) and deaths (<100). Thus, if NPIs are relaxed after the vaccination campaign begins,
13 particularly international travel restrictions, we would expect a major epidemic peak to occur unless the
14 transmission blocking effect of the vaccines is as good as the summative effect of the NPIs that have been
15 in place. Unfortunately, there is a very high degree of uncertainty around the available vaccines'
16 transmission blocking effect ¹⁸. Lastly, Thailand has a relatively small high-risk group with only 13% of the
17 population above the age of 65. The high incidence group (ages 20-39), which is twice as large, is estimated
18 to have double the number of contacts per person.

19
20 This study shares a modelling experience in the Thai context to help identify the optimal vaccine strategy
21 (i.e., the group that it would be most beneficial to vaccinate) to control the COVID-19 pandemic for the
22 following year. We aim to examine the impact that COVID-19 vaccines with different types of efficacy can
23 have on different target populations, and to compare the trade-offs including to determine the efficacy
24 threshold for when the vaccine strategy may change within a predefined 12-month time horizon in which

indirect effects may act to delay an epidemic. This analysis may be applicable to other countries with similar characteristics and facing similar challenges regarding COVID-19, such as Vietnam, Laos, and many small island countries who are heavily dependent on tourism and have low or no local transmission of COVID-19.

RESULTS

The WHO defines COVID-19 vaccine efficacy to include 3 parts: 1) reducing susceptibility; 2) reducing transmission from infected individuals (i.e., reduced infectivity); and 3) reducing severity¹⁹. As certain characteristics of the vaccine remain uncertain, these analyses aimed to explore plausible scenarios of different vaccine characteristics, including efficacy and protection duration. The target population that it is most beneficial to vaccinate may vary depending on the type of efficacy that a vaccine has. The two subpopulations that were considered for vaccination in these analyses were the high-risk population (the elderly over 65 years old), and the high incidence group (20–39 years old) who have been most responsible for transmission of COVID-19 in Thailand.

The three policy questions explored by the analyses are: 1) What is the impact of different types of vaccine efficacy? 2) Is vaccine efficacy or protection duration a more preferable vaccine characteristic? 3) When planning for vaccine allocation plan in Thailand, who should receive COVID-19 vaccines first? To answer these questions, various scenarios were explored, and the characteristics of these analyses are described in detail in the Methods section.

Analysis 1: What is the impact of different types of vaccine efficacy?

Table 1 shows the results from the set of efficacy scenarios explored for Analysis 1, where vaccine efficacy was assumed to be 70% for each type of efficacy and the protective duration was 1 year. The results showed that, for both vaccination scenarios of the high-risk and high incidence groups, the type of efficacy that reduced cases and deaths the most was when the vaccine efficacy reduced susceptibility. The vaccine efficacy that was least desirable when vaccinating the high-risk group was reduced transmission, whereas when vaccinating the high incidence group the least desirable efficacy type was reduced severity. The results showed that total cases were similar in the scenario of no vaccination, compared to scenarios where the vaccine reduced only severity for both vaccinated populations. The only scenarios where both total cases and total deaths were substantially reduced compared to the no vaccination scenario, was when the vaccine reduced susceptibility or transmission and was administered to the high incidence population. When the high-risk group were vaccinated, only total deaths were reduced substantially, but total cases remained similar to the no vaccination scenario.

Analysis 2: Is vaccine efficacy or protection duration a more preferable vaccine characteristic?

For Analysis 2, scenarios were explored where the vaccine efficacy was varied between 70% and 90% and duration protection was varied between 6 months and 1 year. These scenarios were conducted for vaccinating both the high incidence and high-risk groups, and for reduced susceptibility and reduced severity vaccine efficacy types. For this analysis, we focused on reductions in susceptibility or severity as vaccine characteristics because the results from Analysis 1 showed that these were always preferable, in terms of cases and deaths, to reduced transmission as a single characteristic of a vaccine.

1 The results in Table 2 showed that when the high incidence group were vaccinated, a longer protection
2 duration with a lower efficacy was more effective at reducing cases and deaths than a shorter protection
3 duration and higher vaccine efficacy, when efficacy was the form of reduced susceptibility. This
4 relationship was also true in the scenario where the high-risk group were vaccinated although the
5 difference in results between the two scenarios was much smaller (Figure 1). The detailed breakdown of
6 results from this analysis are displayed in Table S1 in the Supplementary Materials.

7
8 For the analogous scenarios where the vaccine reduced severity, the results showed that for the high
9 incidence group the total number of cases were slightly greater for the lower efficacy, longer duration
10 vaccine compared to the higher efficacy, shorter duration vaccine. However, the total number of deaths
11 in both scenarios were similar in both vaccine characteristic scenarios. For the high-risk group, the total
12 number of cases in both vaccine characteristic scenarios were similar, but the lower efficacy, longer
13 duration vaccine resulted in fewer deaths than the higher efficacy, shorter duration vaccine (Figure 2).
14 The detailed breakdown of these results can also be found in Table S2 in the Supplementary Materials.
15 For both types of efficacy explored, the results showed that a longer protection duration, of 12 months
16 compared to 6 months, provided more benefit than the vaccine efficacy change from 70% to 90% in all
17 scenarios apart from when the high incidence group was vaccinated with a vaccine that reduced severity.

18 19 Analysis 3: When planning for vaccine allocation plan in Thailand, who should 20 receive COVID-19 vaccines first?

21 The results from Analysis 1 showed that in the case where a vaccine only had a single type of efficacy, the
22 high incidence group should be prioritised if the vaccine reduced susceptibility or transmission. However,
23 if the vaccine reduced severity then the high-risk group should be prioritised for vaccination. To further

address this question, we considered scenarios where the vaccine had more than one types of efficacy. In this analysis, different combinations of reduced susceptibility and reduced severity levels as a result of vaccination were explored. If the prioritisation of groups for vaccination was based on the number of total deaths, then the results showed that when reduction in severity from vaccination was either 70% or 90% and reduced susceptibility was 0%, the preferred vaccine strategy was to prioritise the high-risk group. However, when the reduction in susceptibility was greater than 60%, then vaccinating the high incidence group resulted in fewer deaths within 12 months of the roll out and more deaths if the time horizon is extended (Figure 3).

Results are also presented from scenarios where the level of reduction in severity from vaccination was fixed at 70% or 90% and the effect of vaccination on susceptibility is varied incrementally between 0% and 70% or 0% and 90%, respectively (Figure S1 in the Supplementary Materials). The rationale for fixing the reduction in severity and varying the reduction in susceptibility is that the evidence from clinical trials on reductions in severity is established before evidence for reductions in susceptibility²⁰.

DISCUSSION

This timely study improves informed choice for decision makers by providing the details, benefits, risks and expected outcomes associated with each policy option. The findings also outlines the importance for manufacturers, funders and researchers to develop more evidence regarding the impact of vaccines on transmission, as the primary endpoints from the clinical trials for the available vaccines did not satisfactorily address these policy-relevant questions²⁰⁻²⁵, which remain of paramount importance for decision making. This study shows that reductions in susceptibility or transmission as a result of vaccination is a hugely important characteristic for a country similar to Thailand (in term of factors such as community transmission pattern, NPIs implemented, and risk of severe disease). Moreover, the type

1 of vaccine efficacy is not the only important characteristic to distinguish between the available vaccines;
2 vaccine protection duration is an equally important consideration in order to maximise the population
3 health impact from the vaccination programme. Similarly, the duration of protection from the current
4 vaccines is not well-understood, post-vaccination surveillance can play a crucial role in determining this.
5 Manufacturers, researchers and governments should help the global community by closely monitoring
6 vaccine effectiveness of the initial vaccination cohorts in countries like Israel, the United Kingdom (UK)
7 and the United States that have implemented these vaccines already on a large scale ²⁶.

8
9 The WHO SAGE's prioritisation roadmap of COVID-19 vaccines ¹² would recommend that in the Thai
10 context the high-risk group should be prioritised for vaccination, as a country with localised or limited
11 transmission. However, this study offers a different perspective by considering the potential benefits of
12 vaccinating alternative priority groups under various scenarios of characteristics of COVID-19 vaccine
13 efficacy. If a vaccine has an impact beyond just reductions in severity, this study shows that 60% or higher
14 percentage of reduction in transmission is pivotal in shifting prioritisation from the high-risk population
15 to the high incidence population, as they play a larger role in transmission in Thailand. There is now
16 emerging evidence that vaccines may be able to reduce transmission (reduce infectivity) by up to 67% ²⁷,
17 although the confidence interval for this estimate includes 0% so strategies which depend on this value
18 should be considered with caution. Given the results of our study and this new evidence, the WHO SAGE
19 and other authorities should reconsider the strategy of prioritising older populations over the younger
20 high incidence groups in populations with well-controlled community transmission, specific objectives and
21 time windows, and make their recommendations based on scenarios of vaccine characteristics and
22 coverage level combinations.

1 Thailand's target vaccine supply is enough to vaccinate 50% of the population²⁸ even though vaccine
2 nationalism (where richer nations are vaccinating their population with COVID-19 vaccines while
3 developing countries struggle to access supplies and have to wait²⁹) may mean that Thailand receives less
4 than this target. Due to this limited supply, prioritisation of groups for vaccination is an unavoidable
5 decision for policymakers. The results of this study are being used for policy discussions in Thailand
6 regarding the prioritisation of groups for a COVID-19 vaccine amongst the general population. Health
7 professionals were already prioritised for vaccination, based on ethical justifications and in line with the
8 WHO SAGE's prioritisation roadmap of COVID-19 vaccines¹². Although these decisions are ultimately left
9 to policymakers, it is important for researchers to produce evidence as presented in this study to inform
10 policy debates. Countries facing similar situations to Thailand should consider the applicability of this
11 evidence to their local context.

12
13 The results of this study must be interpreted with caution. Firstly, the mathematical model was matched
14 to Thai contract patterns and national COVID-19 outbreak data. Thus, the findings regarding the impact
15 of COVID-19 vaccination are most applicable to Thailand or other similar settings with well-controlled
16 community transmission. Countries with different demographic and outbreak profiles should ideally
17 conduct their own studies to contextualise evidence for informing policy. For example, Moore et al found
18 that prioritising the vaccination of the high-risk group is by far the most effective strategy for reducing the
19 number of deaths in the UK, where there is active local transmission, a greater proportion of the
20 population is high-risk group, and higher case-fatality rates³⁰. Secondly, the vaccines under consideration
21 in this study were all hypothetical ones, so that the results of this study cannot be used to advocate for
22 individual vaccines that are currently available. The benefit of evaluating vaccines in this way is that we
23 considered a broader set of vaccine characteristics than the current evidence for real vaccines allows and
24 it will be more relevant to current policy questions as countries may be unable to rely solely on the supply

of a single vaccine. This evidence may allow countries to have a tailored policy for selecting the most appropriate vaccine for each population subgroup. Thirdly, we assumed equal vaccine effectiveness across all population groups and did not consider vaccine side-effects and uptake, which may be a key factor given that all available vaccines require two doses. Given the unique context of COVID-19, there is not suitable evidence to justify an alternative vaccine uptake rate in Thailand. Nevertheless, the importance of this parameter was recognised and will be reviewed when information becomes available from the roll-out of the vaccination program. Fourthly, the impact of all NPIs were assumed to be constant over time, but, in reality, they might vary over time. If this was the case, this would have implications for the predictions for the results and conclusions of this study. Fifthly, the strategy of targeting the high incidence group is critically contingent on further vaccination coverage in the following year; without this continued coverage, the epidemic, delayed by partial herd immunity provided by a transmission blocking vaccine, would lead to more deaths than the high-risk group strategy in the following year. Lastly, there is a lot of individual parameter uncertainty in the model, both for vaccine-related parameters and COVID-19 clinical parameters. Both types of parameter should be subject to close monitoring as part of vaccination programs to reduce this uncertainty. Many of these limitations should be addressed by evidence generations activities by monitoring and evaluation systems. Inputs from this study could be used to inform and develop these frameworks for monitoring and evaluation of COVID-19 vaccination programs at national, regional and global levels.

METHODS

Modelling structure

In this study, we adapted an opensource compartmental age-structured model which is based on the SEIR (Susceptible-Exposed-Infective-Recovered) structure developed by the COVID-19 International Modelling

Consortium (CoMo consortium) ^{31,32} (Figure S2 in Supplementary). In the model, the infected compartments were stratified by symptoms, severity and treatment seeking and access. There are four sub-compartments accounting for different severities of COVID-19 infection which are i) asymptomatic, ii) mild to moderate symptomatic, iii) ICU and iv) ICU with ventilator.

Model parameters and outputs

The model uses publicly available country-specific data to define the population structure ³³ and mixing contact patterns ³⁴ as model inputs. The model also uses publicly available country-specific data on cases and mortality ³⁵ for visual calibration of model parameters to user-selected baseline scenarios. In this study the model was calibrated against the data from the first wave of the pandemic in Thailand. In the calibration, the reported daily new cases and deaths of COVID-19 infection were obtained from the government's online data, which assumes that 100% of all cases were identified and reported ³⁶. We believe that this assumption is reasonable as the first outbreak was mainly due to 3 clusters that occurred during the middle of March and there were several months of no cases in Thailand after the initial outbreak and no excess mortality ³⁵.

One other key set of parameters stratified by age was hospitalisation rates (AHR) and in-hospital fatality rates (IFR), which were derived from previous published information from Wuhan, China and available local data from Thailand from the 55 deaths up to 6th June 2020, respectively ³⁶. Virus-related parameters including the incubation period, duration of symptomatic infection, risk of asymptomatic infection, symptomatic infection (having clinical symptoms), admittance to ICU with and without a ventilator were adopted from the values used in the CoMo model. Given the gap in knowledge on immunity acquired post-infection, we assumed that natural immunity lasts an average of two years ^{31,32} (See details in Table S3 in Supplementary). The admission information for those with hospitalisation including the percentage

of patients requiring ICU/ventilator, length of stay, and probability of death given ICU/ventilator were derived from Thai data³⁷. We used an 18 month time horizon for all model simulations, which allows for a duration of 12 months post-vaccination. The primary model outputs were the number of COVID-19 cases by severity, as well as deaths.

Non-pharmaceutical interventions (NPIs)

As the model calibration was based on the pandemic of the first wave, NPIs applied in Thailand included hand hygiene and masking, social distancing, travel ban (or border closure) were tracked and incorporated in the model (Figure S3 and Table S4 in Supplementary). As test, trace and isolation (TTI) varied spatially and temporally, it was accounted for in the system dynamics via the force of infection, which changed over time. The infection rate and effective coverage of each NPI including hand hygiene and social distancing was estimated from visual calibration, by comparing the reported daily incidence and total cases and deaths against the model prediction when the time for introduction of each NPI was clearly stated. The baseline of 30% effective hand hygiene means reduction in the effective contact with infected people by 30% while 40% social distancing means reduction in number of daily contacts across age groups by 40%. The set of estimated parameters given the optimal fit to the surveillance data from the first outbreak during January to 6th June 2020 was used in the baseline scenario (Figure S4 and Table S4 in Supplementary).

Vaccine characteristics and implementation

The introduction of COVID-19 vaccination was expanded from the original CoMo model version 15.0, where we defined the vaccine efficacy by 3 characteristics; i) reduced susceptibility (Efficacy 1), ii) reduced transmissibility (Efficacy 2) and iii) reduced severity (Efficacy 3). Reduced susceptibility (Efficacy 1) means

1 direct reduction in infection rate among vaccinated group while reduced transmissibility (Efficacy 2)
2 means reduction in force of infection among infections of vaccinated group and reduced severity (Efficacy
3 3) means reduced symptoms and progression to hospitalisation among those with vaccination. We
4 assumed that only one vaccine was used at a time, with a one dose regimen. The supply of vaccines is
5 likely to be limited for Thailand, we therefore assumed that it would be approximately 9 million doses in
6 2021. The assumed vaccine supply approximately corresponds to the size of the smallest potential group
7 for vaccination, the high-risk group (over 65 years old), who account for approximately 9 million people
8 in Thailand. This assumed vaccine supply allowed reasonable comparison between vaccinating this group
9 and the high incidence group (aged 20 to 39 years). It is further assumed that given the limited doses of
10 vaccines, the Thai healthcare system would be capable of delivering the vaccine to reach the target
11 coverage within two months. As the protective duration of all the vaccines available is still unknown, we
12 assumed two scenarios, a short-term and long-term duration of protection of 0.5 or 1 year, respectively.
13 In the base case, a duration of protection of 1 year was assumed.

15 Base case scenario

16 Prior to the availability of the vaccine, there was assumed to be a small amount of local transmission in
17 the country spread from an original case upon day 1 in the model and no imported cases. To evaluate the
18 value of the vaccine, we assumed that following the roll-out of the vaccine there would be an
19 accompanying relaxation of travel restrictions and quarantine measures to allow imported cases to enter
20 the model. It was assumed that 100 cases of COVID-19 would be imported per day, based on expert
21 opinion from policymakers and representatives from the chamber of commerce. We assumed a constant
22 coverage of effective hand hygiene and facemask wearing of 30% among the population based on our
23 model visual calibration of the first outbreak. Social distancing measures were applied, which reduced
24 social contacts by 40% (excluding those at home, work and school).

Analyses

There were three main analyses to address the following questions: Analysis 1): What is the impact of different types of vaccine efficacy? Analysis 2) Is vaccine efficacy or protection duration a more preferable vaccine characteristic? Analysis 3: When planning for a vaccine allocation plan in Thailand, who should receive COVID-19 vaccines first? Table 3 describes the combinations of scenarios that were explored for each analysis.

Sensitivity analysis

The sensitivity analysis aimed to assess scenarios where the hypothetical vaccines have more than one type of vaccine efficacy, and reduced severity from vaccination is fixed at 70% or 90% and the effect of vaccination on susceptibility is varied incrementally between 0% and 70% or 0% and 90%, respectively. For each scenario, the percentage reduction of cases and deaths is compared to the base case where no vaccines are administered. These sensitivity analyses were conducted for two scenarios of vaccine protection durations of 6 months and 12 months, respectively. Additionally, these analyses were conducted in scenarios where either the high-risk or high incidence groups were the vaccinated population. The Figure S1 in supplementary materials also contain results from a sensitivity analysis where there is a trade-off in vaccine efficacy between reduced susceptibility and reduced severity at a fixed level of combined efficacy using the formula: $(1 - \text{overall efficacy}) = (1 - \text{efficacy}[1]) \times (1 - \text{efficacy}[3])$. Reduced transmission from vaccination was not explored in sensitivity analyses as the impact of reduced susceptibility is very similar to that of reduced transmission. The model code and the data used in this paper can be found at <https://github.com/slphyx/CoV19TH>.

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Competing interests.

The authors have no competing interests.

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1 **Table 1. Comparison of impact of vaccines with different types of efficacy on clinical**
2 **outcomes when vaccinated with high incidence and high-risk groups.**

	Vaccinated population	Asymptomatic	Mild-moderate	ICU patients	ICU with ventilators	Total infection	Total deaths
No Vaccine							
0-19	0	123,000	368,000	78,000	52,000	621,000	0
20-39	0	170,000	508,000	108,000	72,000	858,000	271
40-64	0	204,000	610,000	130,000	87,000	1,031,000	13,000
65+	0	28,000	83,000	18,000	12,000	140,000	25,000
Total	0	525,000	1,569,000	334,000	222,000	2,650,000	38,000
Vaccinating high incidence: Efficacy 1 – Reducing susceptibility							
0-19	0	82,000	247,000	53,000	35,000	417,000	0
20-39	9M	91,000	275,000	57,000	38,000	462,000	161
40-64	0	131,000	394,000	84,000	56,000	665,000	7,000
65+	0	17,000	51,000	11,000	7,000	86,000	14,000
Total	9M	321,000	968,000	205,000	136,000	1,630,000	21,000
Vaccinating high incidence: Efficacy 2 – Reducing transmission							
0-19	0	80,000	242,000	52,000	34,000	408,000	0
20-39	9M	104,000	324,000	66,000	44,000	538,000	184
40-64	0	128,000	387,000	82,000	55,000	652,000	7000
65+	0	17,000	49,000	10,000	7,000	84,000	13,000
Total	9M	329,000	1,002,000	210,000	140,000	1,681,000	21,000
Vaccinating high incidence: Efficacy 3 – Reducing severity							
0-19	0	123,000	368,000	78,000	52,000	622,000	0
20-39	9M	170,000	535,000	108,000	72,000	885,000	233
40-64	0	204,000	611,000	130,000	87,000	1,032,000	13,000
65+	0	28,000	83,000	18,000	12,000	140,000	25,000
Total	9M	525,000	1,598,000	334,000	222,000	2,679,000	38,000
Vaccinating high-risk: Efficacy 1 – Reducing susceptibility							
0-19	0	122,000	365,000	78,000	52,000	616,000	0
20-39	0	169,000	504,000	107,000	71,000	851,000	270
40-64	0	202,000	605,000	129,000	86,000	1,021,000	13,000
65+	9M	17,000	55,000	11,000	7,000	90,000	15,000
Total	9M	510,000	1,528,000	324,000	216,000	2,578,000	28,000
Vaccinating high-risk: Efficacy 2 – Reducing transmission							

	Vaccinated population	Asymptomatic	Mild-moderate	ICU patients	ICU with ventilators	Total infection	Total deaths
0-19	0	122,000	365,000	78,000	52,000	616,000	0
20-39	0	169,000	504,000	107,000	71,000	851,000	270
40-64	0	202,000	604,000	129,000	86,000	1,021,000	13,000
65+	9M	27,000	88,000	17,000	11,000	143,000	24,000
Total	9M	519,000	1,561,000	330,000	220,000	2,630,000	37,000
Vaccinating high-risk: Efficacy 3 – Reducing severity							
0-19	0	123,000	368,000	78,000	52,000	622,000	0
20-39	0	170,000	508,000	108,000	72,000	858,000	270
40-64	0	204,000	611,000	130,000	87,000	1,032,000	13,000
65+	9M	28,000	92,000	18,000	12,000	149,000	16,000
Total	9M	525,000	1,579,000	334,000	223,000	2,661,000	29,000

- 1
- 2 Note. ICU = intensive care unit. M = million people. This analysis assumed there was 30% hand hygiene
- 3 and 40% social distancing policy implemented.

Table 2. Comparison of impact of vaccines efficacy and protection duration on clinical outcomes when vaccinated with high incidence and high-risk groups.

Population vaccinated	Characteristic of vaccine	Efficacy type	
		Reduced susceptibility	Reduced severity
High incidence	Long duration, lower efficacy (1 year with 70% efficacy)	21,000 deaths, 1,630,000 cases	38,000 deaths, 2,679,000 cases
	Short duration, higher efficacy (0.5 year with 90% efficacy)	24,000 deaths, 1,858,000 cases	38,000 deaths, 2,661,000 cases
High-risk	Long duration, lower efficacy (1 year with 70% efficacy)	28,000 deaths, 2,578,000 cases	29,000 deaths, 2,660,000 cases
	Short duration, higher efficacy (0.5 year with 90% efficacy)	31,000 deaths, 2,595,000 cases	31,000 deaths, 2,657,000 cases

1 **Table 3. Analysis characteristics**

Analysis	Vaccine characteristics	Vaccine duration	Populations vaccinated	NPIs
1 and 3	<ul style="list-style-type: none"> • Reduced susceptibility • Reduced transmission • Reduced severity • No vaccine 	<ul style="list-style-type: none"> • 1 year 	<ul style="list-style-type: none"> • High-risk (65+) • High incidence (20-39) 	<ul style="list-style-type: none"> • 30% hand hygiene and mask wearing • 40% social distancing
2	<ul style="list-style-type: none"> • Reduced susceptibility • Reduced transmission • Reduced severity 	<ul style="list-style-type: none"> • 6 months • 1 year 	<ul style="list-style-type: none"> • High-risk (65+) • High incidence (20-39) 	<ul style="list-style-type: none"> • 100 imported cases per day

2

Figures

Figure 1

Comparison between vaccine efficacy to reduce susceptibility 70% with 1 year duration vs 90% with 0.5 year in both high incidence and high-risk groups

Figure 2

Comparison between vaccine efficacy to reduce severity at 70% with 1 year duration versus 90% with 0.5 year in both high incidence and high-risk groups

3A) Varied Efficacy1 (from 0% to 70%) and varied Efficacy3 (from 0% to 70%)

Overall 70% efficacy				
Vaccine duration 1 year	%Death reduction		%Case reduction	
	Elderly	High Incidence	Elderly	High Incidence
Eff1_0% & Eff3_70%	24.64%	-0.14%	-0.40%	-1.09%
Eff1_10% & Eff3_66.7%	24.92%	3.74%	0.04%	2.59%
Eff1_20% & Eff3_62.5%	25.15%	8.28%	0.48%	6.74%
Eff1_30% & Eff3_57.1%	25.37%	13.73%	0.93%	11.48%
Eff1_40% & Eff3_50%	25.65%	20.10%	1.37%	16.93%
Eff1_50% & Eff3_40%	25.90%	27.41%	1.81%	23.23%
Eff1_60% & Eff3_25%	26.18%	35.77%	2.25%	30.44%
Eff1_70% & Eff3_0%	26.48%	44.64%	2.70%	38.47%

Vaccine duration 0.5 year				
Vaccine condition	%Death reduction		%Case reduction	
	Elderly	High Incidence	Elderly	High Incidence
Eff1_0% & Eff3_70%	15.01%	0.21%	-0.24%	-0.31%
Eff1_10% & Eff3_66.7%	15.83%	2.84%	0.02%	1.84%
Eff1_20% & Eff3_62.5%	16.61%	5.93%	0.29%	4.16%
Eff1_30% & Eff3_57.1%	17.37%	9.39%	0.56%	6.72%
Eff1_40% & Eff3_50%	18.20%	13.53%	0.83%	9.58%
Eff1_50% & Eff3_40%	18.91%	18.40%	1.10%	12.81%
Eff1_60% & Eff3_25%	19.77%	24.02%	1.38%	16.50%
Eff1_70% & Eff3_0%	20.55%	30.38%	1.65%	20.70%

3B) Varied Efficacy1 (from 0% to 90%) and varied Efficacy3 (from 0% to 90%)

Overall 90% efficacy				
Vaccine duration 1 year	%Death reduction		%Case reduction	
	Elderly	High Incidence	Elderly	High Incidence
Eff1_0% & Eff3_90%	31.40%	-0.27%	-0.45%	-1.26%
Eff1_10% & Eff3_88.9%	31.67%	3.56%	-0.01%	2.41%
Eff1_20% & Eff3_87.5%	31.96%	8.10%	0.43%	6.54%
Eff1_30% & Eff3_85.7%	32.16%	13.48%	0.88%	11.25%
Eff1_40% & Eff3_83%	32.43%	19.78%	1.32%	16.67%
Eff1_50% & Eff3_80%	32.67%	27.09%	1.77%	22.94%
Eff1_60% & Eff3_75%	32.92%	35.43%	2.21%	30.11%
Eff1_70% & Eff3_66.7%	33.22%	44.27%	2.65%	38.12%
Eff1_80% & Eff3_50%	33.51%	53.31%	3.10%	46.72%
Eff1_90% & Eff3_0%	33.83%	62.14%	3.55%	55.51%

Vaccine duration 0.5 year				
Vaccine condition	%Death reduction		%Case reduction	
	Elderly	High Incidence	Elderly	High Incidence
Eff1_0% & Eff3_90%	19.09%	0.05%	-0.27%	-0.41%
Eff1_10% & Eff3_88.9%	19.28%	2.43%	-0.01%	1.73%
Eff1_20% & Eff3_87.5%	19.44%	5.14%	0.26%	4.05%
Eff1_30% & Eff3_85.7%	19.62%	8.23%	0.53%	6.59%
Eff1_40% & Eff3_83%	19.79%	11.72%	0.80%	9.44%
Eff1_50% & Eff3_80%	19.97%	15.86%	1.07%	12.66%
Eff1_60% & Eff3_75%	20.19%	20.51%	1.35%	16.33%
Eff1_70% & Eff3_66.7%	20.32%	25.93%	1.62%	20.51%
Eff1_80% & Eff3_50%	20.52%	31.80%	1.89%	25.23%
Eff1_90% & Eff3_0%	20.71%	38.18%	2.17%	30.49%

Figure 3

Sensitivity analysis when varying the level of reduction in susceptibility (Efficacy 1) and varying the level of reduction in severity (Efficacy 3) at both 70% and 90% with different assumption of vaccine protective duration, 1 and 0.5 year

This is a list of supplementary files associated with this preprint. Click to download.

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