COVID-19 Conversations

Marc Lipsitch, DPhil
Director, Center for Communicable Disease Dynamics, Harvard T. H. Chan School of Public Health

COVID19Conversations.org | #COVID19Conversations
COVID-19: theory of social distancing

Marc Lipsitch, DPhil
NAM/APHA
25Mar 2020
CCDD COVID-19 team

• Bill Hanage
• Caroline Buckee
• Michael Mina
• Yonatan Grad
• Ed Goldstein
• Xueting Qiu
• Aimee Taylor
• Mary Bushman
• Rene Niehus
• Pablo M de Salazar
• James Hay
• Stephen Kissler

• Tigist Menkir
• Taylor Chin
• Rebecca Kahn
• Christine Tedijanto
• Nishant Kishore
• Lee Kennedy-Shaffer
• Corey Peak (alum)
• Hsiao-Han Chang (alum)
• Matt Kiang (alum)
• Sarah McGough (alum)
• Francisco Cai (alum)

Collaborators
• Megan Murray
• Caitlin Rivers
• Eric Toner
• Qi Tan
• Ruoran Li
• Satchit Balsari
• Nick Menzies
• Gabriel Leung
• Joseph Wu
• Kathy Leung
• Ben Cowling
• Lauren Childs (alum)
Letting it go is a bad option

- Wuhan shut the city down when they had ~500 confirmed cases in a population of ~10 million
- They reached a per capita demand for ICU equal to fully occupying ICUs in the US, just for COVID-19
- 4 weeks from shutdown to peak ICU need

R Li, Q Tan, M Murray, C Rivers, E Toner, M Lipsitch preprint
Options:

• Catch nearly every case early, high test capacity, intense individual-level case interventions (isolation, tracing, quarantine), seal borders (islands): Singapore, Iceland, Vo (Italy,), Hong Kong, Taiwan, China outside Wuhan

• Many introductions undetected; widespread community transmission (Wuhan, Europe, USA): Case-focused interventions fail, need social distancing

Incidence for one-shot interventions w/out seasonality

- 4 weeks
- 8 weeks
- 12 weeks
- 20 weeks
Incidence for one-shot interventions w/out seasonality

- Social distancing of any duration results in a lower peak
- Long-term (12- or 20-week) intermediate distancing (20-40% reduction in $R_0$) yields the smallest overall peaks
Incidence for one-shot interventions with seasonality
Incidence for one-shot interventions with seasonality

- Social distancing > 20% can lead to a major resurgence of incidence in the fall/winter due to seasonal forcing.
Critical care demand lags behind incidence

With seasonality, 4-week intervention

Without seasonality, 12-week intervention
Summary: One shot

- If seasonality is negligible, then all social distancing helps, and long, moderate social distancing is best.
- If seasonality, then long, weakly effective social distancing is best, but strongly effective social distancing makes it worse by delaying the peak into the winter (more cases because more transmission, plus coincides with flu season).
- This is treacherous – please ask others, but we suspect there will be some seasonality, so one-shot could make things worse.
Cycled social distancing, $60\%$ $R_0$ reduction, no seasonality

Lag between intervention and peak ICU demand is $\sim 3$ weeks
Cycled social distancing, 60% $R_0$ reduction, with seasonality

Summer reduction in transmissibility keeps peak ICU utilization lower and lengths breaks between interventions.
Cycled social distancing, 60% $R_0$ reduction, with no seasonality with double the ICU capacity.
Cycled social distancing, 60% $R_0$ reduction, with seasonality with double the ICU capacity

Doubling ICU capacity allows higher on threshold, lengthens the time between interventions while accelerating herd immunity. Seasonality helps further.
Summary: cycled distancing

- If no seasonality, approx 4:1 on to off time, slow accumulation of herd immunity
- Seasonality helpful in this scenario: longer off time thanks to summer slowdown
- Doubling ICU capacity allows longer breaks and faster accumulation of herd immunity
- ***Must have good surveillance in place to avoid overshooting ICU capacity
Social distancing strategies for curbing the COVID-19 epidemic

Stephen M Kissler, Christine Tedijanto, Marc Lipsitch, Yonatan Grad

doi: https://doi.org/10.1101/2020.03.22.20041079v1
Exit strategy?

- If we can get cases down, and testing up, we could approach a situation like Singapore/Iceland/Taiwan/etc
  - Case numbers small enough that we can trace them all
  - Most cases are detected
  - Case-based interventions can become useful again as a mainstay of strategy

- Major caveat: importations
Synergy of social distancing and contact tracing/quarantine

- [https://www.medrxiv.org/content/10.1101/2020.03.05.20031088v1](https://www.medrxiv.org/content/10.1101/2020.03.05.20031088v1)

---

**Modeling the Comparative Impact of Individual Quarantine vs. Active Monitoring of Contacts for the Mitigation of COVID-19**

Corey M Peak, Rebecca Kohn, Yonatan H Grad, Lauren M Childs, Ruoran Li, Marc Lipsitch, Caroline O Buckee
doi: [https://doi.org/10.1101/2020.03.05.20031088](https://doi.org/10.1101/2020.03.05.20031088)
Objectives

How might the establishment of SARS-CoV-2 in the US affect coronavirus dynamics over the next five years?

Potential scenarios:

- SARS-CoV-2 will enter into circulation with the other four coronaviruses
- SARS-CoV-2 will drive the other betacoronaviruses to extinction and enter circulation, leaving only itself and the alpha coronaviruses
- SARS-CoV-2 will drive the other betacoronaviruses to extinction, cause a major epidemic, and will die out itself

Dynamics will depend on duration of immunity to SARS-CoV-2, cross-immunity between coronaviruses, and seasonal forcing
Estimated seasonality of seasonal CoV from NREVSS data
We found evidence of seasonal forcing, cross-immunity between the betacoronaviruses, and rapidly waning immunity

Blue = effect of CoVHKU1, gold = effect of CoVOC43, red = seasonal forcing
We built an SEIR model to describe current transmission dynamics and project future scenarios.

Assumptions:

- Strains have same incubation and infectious periods.
- Co-infection doesn’t lead to any differences in disease progression.
Model provided good fit to observed incidence proxy and effective reproduction numbers
Scenarios: winter vs. summer introduction

40 week immunity to SARS-CoV-2
30% cross immunity from SARS-CoV-2 to other betacoronaviruses
Hospital and ICU demand
- Can protect HC with distancing
- 3-4 week delay from closedown to peak ICU demand
- Lingering ICU for weeks

Ruoran Li, Caitlin Rivers, Qi Tan, Megan Murray, Eric Toner, Marc Lipsitch
Work in progress

- Travel and introductions into Africa
- Scenarios for interventions: starting, stopping
- Ethics of vaccine trials, ethics of vaccine distribution
- More on bed capacity
- Comparing individual quarantine to active monitoring of symptoms for containment
- Diagnostics and serodiagnostics (Mina)
CCDD COVID-19 team

- Bill Hanage
- Caroline Buckee
- Michael Mina
- Yonatan Grad
- Ed Goldstein
- Xueting Qiu
- Aimee Taylor
- Mary Bushman
- Rene Niehus
- Pablo M de Salazar
- James Hay
- Stephen Kissler

- Tigist Menkir
- Taylor Chin
- Rebecca Kahn
- Christine Tedijanto
- Nishant Kishore
- Lee Kennedy-Shaffer
- Corey Peak (alum)
- Hsiao-Han Chang (alum)
- Matt Kiang (alum)
- Sarah McGough (alum)
- Francisco Cai (alum)

Collaborators

- Megan Murray
- Caitlin Rivers
- Eric Toner
- Satchit Balsari
- Nick Menzies
- Gabriel Leung
- Joseph Wu
- Kathy Leung
- Ben Cowling
Scenarios: post-pandemic dynamics

104 week immunity to SARS-CoV-2
70% cross immunity from SARS-CoV-2 to other betacoronaviruses
Fully agree with broad outlines of Imperial report

• Long-term distancing is only alternative to overwhelming health care system
• Both may occur if our control measures are inadequate
• Neither is attractive
Projecting the transmission dynamics of SARS-CoV-2 through the post-pandemic period

Stephen Kissler†, Christine Tedijanto‡, Edward M. Goldstein, Yonatan H. Grad, Marc Lipsitch*

†Department of Immunology and Infectious Diseases, Harvard T.H. Chan School of Public Health, Boston, MA, USA
‡Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA

* Correspondence to: mlipsitc@hsph.harvard.edu
† denotes equal contribution
We found evidence of seasonal forcing, cross-immunity between the betacoronaviruses, and rapidly waning immunity.
In uncontrolled epidemics, timing of introduction matters a lot

40 week immunity to SARS-CoV-2
30% cross immunity from SARS-CoV-2 to other betacoronaviruses
Scenarios for interventions
Model (with Imperial parameters)

\[
\begin{align*}
S &\xrightarrow{\beta(t) \sum(I_*)} E \\
&\quad \xrightarrow{p_H} I_H \\
&\quad \xrightarrow{p_C} I_C \\
E &\xrightarrow{p_R} I_R \\
I_H &\xrightarrow{\gamma} H_H \\
H_H &\xrightarrow{\delta_H} R_H \\
I_C &\xrightarrow{\gamma} H_C \\
H_C &\xrightarrow{\delta_C} C_C \\
C_C &\xrightarrow{\xi_C} R_C \\
\end{align*}
\]

Minor illness/asymptomatic arm
Hospitalization arm
Critical care arm
Model (with Imperial parameters, +/- seasonality)

\[ \beta(t) \sum(I_*) \]

\( \text{No seasonality} \)

\( \text{Seasonality} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t) \sum(I_*) \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)

\( \beta(t)/\gamma = R_0(t) \)

\( \min(R_0) = 1.4 \)

\( \max(R_0) = 2.1 \)

\( 3.8\text{-week shift} \)