SARS-CoV-2 (COVID-19) Modeling (Version 3.0),
May 13, 2020

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PROTECTING, MAINTAINING AND IMPROVING THE HEALTH OF ALL MINNESOTANS
Overview

- Overview of changes in Version 3 and their impacts
- Three key scenarios/new model capabilities
  - Stay-at-home order
  - Testing
  - CDC criteria for return (and medical advancement)
- Supplemental information
Timeline of Minnesota COVID-19 Model

- Version 1: March 2020
  - Based on early data available at the time
- Version 2: April 2020
  - Included more specifics about Minnesota cases, factors
- Version 3: May 2020
  - Integrates new details and capabilities
- Ongoing model updates planned within available capacity
The University of Minnesota and MDH created the Minnesota COVID-19 model as a tool to inform response strategies and resource planning.

Updated model documentation is available online [Minnesota COVID-19 Modeling (https://mn.gov/covid19/data/modeling)] including:

- References for parameter values
- Underlying data
- Model equations governing transitions of the population through COVID-19 health states

COVID-19 remains in early stages and new evidence is emerging

Ongoing model updates are needed to:

- Reflect the growing understanding of COVID-19 transmission and outcomes
- Incorporate newly emerging data from the U.S. and Minnesota
- Refine projections by fitting model Minnesota data on observed mortality and hospitalization data
- Add new model capabilities to illustrate potential mitigation strategies
▪ Epidemic and evidence **still very new**

▪ Extent and impact of **key metrics** uncertain

▪ Evolving **clinical protocols** with halting dissemination of evidence

▪ **U.S. case data are limited and incomplete**, affecting availability of robust estimates
Limited U.S. data

- First studies with U.S. patients in late March and April
  - 4,226 cases in U.S. study: outcomes (illness & death) were unknown for 2,001
  - 5,700 patients hospitalized with COVID-19 in NYC area: discharge or death status was only known for 46%
  - Among hospitalized Minnesota COVID-19 patients: nearly 32% remain in the hospital
Five Key Changes to Model Version 3

1. Structural changes to address
   - Asymptomatic infections
   - Deaths occurring outside of hospital

2. Restricted ICU metric to ventilated cases

3. Updated parameter estimates using newly available US data
Overview of Model Changes in Version 3

4. Incorporated new calibrated parameters, including
   - Proportion of 70+ year olds dying in non-hospital settings
   - Reduction in contacts under social distancing and under stay-at-home order

5. Fitted model to Minnesota deaths and hospitalizations through April 25
Model Fit to Observed Cumulative Deaths (through 4/25)

Cumulative Deaths

- Model Output
- MDH Data

Hospitalizations

- Model Output
- MDH Data

Days

(March 22) (April 25)
MN COVID-19 Model v.3: Outputs

What?

- **Less time** to peak epidemic
- Some **upward movement** in estimates for:
  - ICU demand, and
  - Full-epidemic mortality

Why?

- Calibration to **rising MN deaths**
- **Mitigation less effective** than assumed for:
  - Initial physical distancing (38%, not 50%)
  - Stay-at-home order (59.5%, not 80%)
- Changes to **ICU mortality** assumptions & data
### Model Changes:

**“Stay-at-Home Order in Place for 6 Weeks”**

<table>
<thead>
<tr>
<th>Scenario 4*</th>
<th>V 2.0 (incl. uncertainty)</th>
<th>V 3.0 (incl. uncertainty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks until peak</td>
<td>16 (13 to 21)</td>
<td>13 (11 to 13)</td>
</tr>
<tr>
<td>Weeks until ICU capacity reached</td>
<td>16 (13 to 21)</td>
<td>13 (12 to 13)</td>
</tr>
<tr>
<td>Top ICU (ventilator) demand</td>
<td>3,700 (2,700 to 4,900)</td>
<td>3,600 (2,000 to 5,200)§</td>
</tr>
<tr>
<td>Mortality (cumulative for 12 months)</td>
<td>21,800 (9,900 to 36,000)</td>
<td>29,000 (16,000 to 44,000)</td>
</tr>
<tr>
<td>Mortality (through end of May)</td>
<td>N/A</td>
<td>1,700 (1,400 to 2,000)</td>
</tr>
</tbody>
</table>

* Same as Scenario 3 except shelter-in-place policy remains in force for 6 weeks

§ Assuming no ICU capacity constraints
Scenarios & Model Capabilities: An Illustration of Trade-offs
Unmitigated and Extended Stay-at-Home Orders

<table>
<thead>
<tr>
<th>Scenario 1 Unmitigated (blue)</th>
<th>Scenario 5 SHO till 5/18 (red)</th>
<th>Scenario 6 SHO till 5/31 (green)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks till peak</td>
<td>May 11</td>
<td>June 29</td>
</tr>
<tr>
<td>Top ICU/vent demand</td>
<td>4,991</td>
<td>3,397</td>
</tr>
<tr>
<td>Mortality (full pand.)</td>
<td>57,035</td>
<td>29,030</td>
</tr>
<tr>
<td>Mortality (thru May)</td>
<td>42,032</td>
<td>1,441</td>
</tr>
</tbody>
</table>

Stay-at-home order followed by three weeks soft opening (reduction of contacts by 38pct and ongoing physical distancing for vulnerable.)
Extended Stay-at-Home Orders & Testing

<table>
<thead>
<tr>
<th>Scenario 6</th>
<th>Scenario 5a</th>
<th>Scenario 6b</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHO till 5/31 (green)</td>
<td>worst test: 70% sens 10k tests (orange)</td>
<td>best test: 95% sens 20k tests (purple)</td>
</tr>
</tbody>
</table>

| Weeks till peak | July 6 | June 29 | July 13 |
|------------------------------------------------------------------|
| Top ICU/vent demand | 3,006 | 3,150 | 2,444 |
| Mortality (full epid.) | 28,231 | 26,914 | 22,589 |
| Mortality (thru May) | 1,388 | 1,430 | 1,375 |

At this point the impact of testing applies only to tested individuals by reducing their rate of contact (assuming social distancing for positives); tests are distributed to “I” states and non-“I” states, through probabilities of testing access. Reduced contact through contact tracing is currently not built into the model.
Extended Stay-at-Home Order, CDC Guidelines for “Opening Up” and Medical Advancement

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Weeks till peak</th>
<th>Top ICU/vent demand</th>
<th>Mortality (full epid.)</th>
<th>Mortality (thru May)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 6</td>
<td>July 6</td>
<td>3,006</td>
<td>28,231</td>
<td>1,388</td>
</tr>
<tr>
<td>Scenario 7</td>
<td>July 6</td>
<td>1,034</td>
<td>26,294</td>
<td>1,388</td>
</tr>
<tr>
<td>Scenario 8</td>
<td>July 6</td>
<td>1,034</td>
<td>25,392</td>
<td>1,388</td>
</tr>
</tbody>
</table>

Source: Guidelines: Opening Up America Again, White House/CDC, slide deck; assumes downward trajectory of hospitalizations for 14 days following the peak (or through Sept. 7, 2020). [https://www.whitehouse.gov/openingamerica/ 5/8/2020, 11:43:00PM] Rx treatment (Tx) only for hospitalized patients, 30% reduction in LOS & mortality
Consideration for Next Steps

▪ More and better data from U.S. epidemic
▪ Refined scenarios
  ▪ Treatment: evidence on home treatment
  ▪ Testing: incorporate impact of contact tracing
▪ Enhancements: cycling mitigation
Thank You!

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More on COVID-19 in MN
mn.gov/covid19/ | https://mn.gov/covid19/data/modeling.jsp |
We also wish to thank a number of anonymous reviewers of the programming code, the underlying methodology and data, as well as peers across the country whose expertise benefited this work on behalf of Minnesotans.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic reproduction number (R0)</td>
<td>2.38</td>
<td>3.87</td>
<td>3.87</td>
</tr>
<tr>
<td>Transmission probability (per contact between infected/susceptible persons)</td>
<td>0.009¶</td>
<td>0.035*</td>
<td>0.0295*</td>
</tr>
<tr>
<td>(0.025-0.045)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latent period</td>
<td>5 days</td>
<td>5 days</td>
<td>5.2 days</td>
</tr>
<tr>
<td>Infectious period</td>
<td>8 days</td>
<td>8 days</td>
<td>7.8 days</td>
</tr>
<tr>
<td>ICU duration</td>
<td>22.6 days</td>
<td>10.3 days</td>
<td>8 days</td>
</tr>
<tr>
<td>Hospitalization duration</td>
<td>8 days</td>
<td>13.3 days</td>
<td>11 days</td>
</tr>
<tr>
<td>Increased mortality factor with ≥ 1 comorbidity</td>
<td>7.6</td>
<td>7.6</td>
<td>1.0 (not used)</td>
</tr>
<tr>
<td>Increased mortality factor if ICU capacity exceeded</td>
<td>1.5 to 16.5</td>
<td>1.5 to 16.5</td>
<td>Assume death</td>
</tr>
<tr>
<td>Hospitalized cases requiring ICU (age ranges)</td>
<td>5.0% to 70.9%</td>
<td>5.0% to 70.9%</td>
<td>11.9% to 29.6%*</td>
</tr>
<tr>
<td>ICU mortality rate (age ranges)</td>
<td>0.000 to 0.111</td>
<td>0.000 to 0.111</td>
<td>0.0005 to 0.779§</td>
</tr>
</tbody>
</table>

¶ Corresponds to an R0 of 2.38;  
*Corresponds to an R0 of 3.87;  
* Restricted to ventilated cases  
§ Probability of dying
## Model Parameters Estimated Through Calibration

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<th>Parameter</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of cases detected prior to start of model simulation*</td>
<td>0.119 (input)</td>
<td>0.01</td>
<td>0.021</td>
</tr>
<tr>
<td>Hospitalized infections (age ranges)</td>
<td>0.1% to 27.3%</td>
<td>0.1% to 27.3%</td>
<td>10.3%**</td>
</tr>
<tr>
<td>Proportion of people aged 70 or older with a symptomatic infection die at home</td>
<td>N/A</td>
<td>N/A</td>
<td>0.139</td>
</tr>
<tr>
<td>Proportion of infections which are asymptomatic</td>
<td>0.0 (input)</td>
<td>0.25 (input)</td>
<td>0.41</td>
</tr>
<tr>
<td>Estimated contact reduction caused by the social distancing</td>
<td>0.5 (input)</td>
<td>0.5 (input)</td>
<td>37.6%</td>
</tr>
<tr>
<td>Estimated contact reduction caused by the stay at home order</td>
<td>0.8 (input)</td>
<td>0.8 (input)</td>
<td>55.1%</td>
</tr>
</tbody>
</table>

*case detection rate only used for model initialization

**calculate age-specific hospitalization probabilities, prophosp, the relative proportion of symptomatic cases by age is multiplied by the calibrated values for the probability of 80+ year-olds who are hospitalized.
Model Structure

V1 and V2

S → E_{1:4} → I_{1:10} → ICU → D

H → R

S-Susceptible
E-Exposed
I-Infected
H-Hospitalized
ICU-In ICU
R-Recovered
D-Dead

V3

S → E_1 ... E_n → R

I_1 ... I_n → H

Al_1 ... Al_n

S-Susceptible
E-Exposed
Al-Asymptomatic Infection
I-Infected
H-Hospitalized
ICU-ICU Eligible
R-Recovered
D-Dead