Estimation of COVID-19 Impact in Virginia

April 13, 2020
(data current to April 11, 2020)
Biocomplexity Institute Technical report: TR-2020-048
Who We Are

• Biocomplexity Institute at the University of Virginia
  • Using big data and simulations to understand massively interactive systems
• Over 20 years of crafting and analyzing infectious disease models
  • Pandemic response and support for Influenza, Ebola, Zika, others
• COVID-19 researchers on today's panel

Bryan Lewis
Research Associate Professor

Chris Barrett
Executive Director

Madhav Marathe
Division Director
Overview

• **Goal**: Understand impact of COVID-19 mitigations in Virginia

• **Approach**:
  • Calibrate explanatory mechanistic model to observed cases
  • Project infections through the end of summer
  • Consider a range of possible mitigation effects in "what-if" scenarios

• **Outcomes**:
  • Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  • Geographic spread over time, case counts, healthcare burdens
Key Takeaways

Projecting future cases precisely is impossible and unnecessary. Even without perfect projections, we can confidently draw conclusions:

• **Current social distancing efforts are working.**

• Under current conditions, Virginia *as a whole* will have sufficient medical resources for at least the next couple months.

• Lifting social distancing restrictions too soon can lead quickly to a second wave.

• Further modeling could elucidate the effectiveness of test-trace-isolate policies.

• The situation is changing rapidly. Models will be updated regularly.
Model Configuration and Data Analysis
Simulation Engine – PatchSim

- Metapopulation model
  - Represents each population and its interactions as a single patch
  - 133 patches for Virginia counties and independent cities
- Extended SEIR disease representation
  - Includes asymptomatic infections and treatments
- Mitigations affect both disease dynamics and population interactions
- Runs fast on high-performance computers
  - Ideal for calibration and optimization

Model Configuration

• **Transmission**: parameters are calibrated to the observed case counts
  • **Reproductive number**: 2.1 - 2.3
  • **Infectious period** (time of infectiousness before full isolation): 3.3 to 5 days

• **Initial infections**: Start infections from confirmed cases by county
  • Timing and location based on onset of illness from VDH data
  • Assume 15% detection rate, so one confirmed case becomes ~7 initial infections

• **Mitigations**: Duration and intensity of mitigations into the future are unknowable, thus explored through 5 scenarios
Mitigation Scenarios

• **Consider 5 possible futures**
  • Two levels of intensity with two durations and one with no effect

• **Start of social distancing:** March 15th, as measured from VDH data

• **Duration:** Lift on April 30th or lift on June 10th

• **Intensity of mitigation:**
  Slowing growth vs. Pausing growth
  • **Slowing** – Social distancing slows the growth, but new cases do increase
  • **Pausing** – Social distancing pauses growth, keeping new cases steady
  • Pausing scenarios track the data better

<table>
<thead>
<tr>
<th>Duration (lift date)</th>
<th>Intensity</th>
<th>Short Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 30th</td>
<td>Slowing</td>
<td>Slow - Apr30</td>
<td>Slowing intensity, lift April 30th</td>
</tr>
<tr>
<td>June 10th</td>
<td>Slowing</td>
<td>Slow - Jun10</td>
<td>Slowing intensity, lift June 10th</td>
</tr>
<tr>
<td>Apr 30th</td>
<td>Pausing</td>
<td>Pause – Apr30</td>
<td>Pausing intensity, lift April 30th</td>
</tr>
<tr>
<td>June 10th</td>
<td>Pausing</td>
<td>Pause – Jun10</td>
<td>Pausing intensity, lift June 10th</td>
</tr>
<tr>
<td>None</td>
<td>Unmitigated</td>
<td>Unmitigated</td>
<td>No effect of social distancing</td>
</tr>
</tbody>
</table>
## Full Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated Values</th>
<th>Description [Source]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissibility (R0)</td>
<td>2.2 [2.1 – 2.3]</td>
<td>Reproductive number *</td>
</tr>
<tr>
<td>Incubation period</td>
<td>5 days</td>
<td>Time from infection to Infectious *</td>
</tr>
<tr>
<td>Infectious period</td>
<td>3.3 - 5 days</td>
<td>Duration of infectiousness *</td>
</tr>
<tr>
<td>Proportion asymptomatic</td>
<td>50%</td>
<td>Proportion of infections that don’t exhibit symptoms *</td>
</tr>
<tr>
<td>Proportion hospitalized</td>
<td>5.5% (~20% of confirmed)</td>
<td>Symptomatic Infections becoming Hospitalized *</td>
</tr>
<tr>
<td>Proportion in ICU</td>
<td>20%</td>
<td>Hospitalized patients that require ICU *</td>
</tr>
<tr>
<td>Proportion ventilated</td>
<td>70%</td>
<td>Proportion of ICU requiring ventilation *</td>
</tr>
<tr>
<td>Onset to hospitalization</td>
<td>5 days</td>
<td>Time from symptoms to hospitalization *</td>
</tr>
<tr>
<td>Hospitalization to ventilation</td>
<td>3 days</td>
<td>Time from hospitalization to ventilation *</td>
</tr>
<tr>
<td>Duration hospitalized</td>
<td>10 days</td>
<td>Time spent in the hospital</td>
</tr>
<tr>
<td>Duration ventilated</td>
<td>14 days</td>
<td>Time spent on a ventilator †</td>
</tr>
<tr>
<td>Infection detection rate</td>
<td>15%</td>
<td>One confirmed case becomes ~7 initial infections #</td>
</tr>
</tbody>
</table>

# Li et al., Science 16 Mar 2020:eabb3221 [https://science.sciencemag.org/content/early/2020/03/24/science.abb3221](https://science.sciencemag.org/content/early/2020/03/24/science.abb3221)
Calibration Approach

• **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting

• **Model:** PatchSim initialized with disease parameter ranges from literature

• **Calibration:** fit model to observed data
  - Search transmissibility and duration of infectiousness
  - Markov Chain Monte Carlo (MCMC) particle filtering finds best fits while capturing uncertainty in parameter estimates

• **Project:** future cases and outcomes using the trained particles

Accessed 1pm April 12, 2020
Impact of Interventions
Estimating Effects of Social Distancing

• Anonymized open mobility data shows Virginia greatly reduced activities
  • Google: -44% retail & recreation, -18% grocery stores, -39% workplaces
  • Cuebiq: >50% reduction of average individual mobility compared to Year Avg.

• VDH data shows reductions in growth rate starting in mid-March
  • Weekly average growth rate by date of onset
    • Week before March 15 = 0.3
    • Week after March 15 = 0.03
  • Equivalent reproductive number change
    • 2.2 before March 15th
    • 1.1 after March 15th

Short-term Projections

Confirmed cases
Virginia - Daily Confirmed cases - Comparison

- Unmitigated
- Slow-Apr30
- Slow-Jun10
- Pause-Apr30
- Pause-Jun10

Hospitalizations
Virginia - Daily Hospitalized cases - Comparison

- Unmitigated
- Slow-Apr30
- Slow-Jun10
- Pause-Apr30
- Pause-Jun10

Ventilations
Virginia - Daily Ventilated cases - Comparison

- Unmitigated
- Slow-Apr30
- Slow-Jun10
- Pause-Apr30
- Pause-Jun10

14-Apr-20
Weekly New Confirmed Cases

<table>
<thead>
<tr>
<th>Week ending</th>
<th>Unmitigated</th>
<th>Slow Jun10</th>
<th>Pause Jun10</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/12/20</td>
<td>11,846</td>
<td>5,518</td>
<td>2,469</td>
</tr>
<tr>
<td>4/19/20</td>
<td>25,712</td>
<td>8,502</td>
<td>2,599</td>
</tr>
<tr>
<td>4/26/20</td>
<td>53,562</td>
<td>13,076</td>
<td>2,742</td>
</tr>
<tr>
<td>5/3/20</td>
<td>101,876</td>
<td>19,881</td>
<td>2,944</td>
</tr>
<tr>
<td>5/10/20</td>
<td>164,527</td>
<td>29,567</td>
<td>3,151</td>
</tr>
<tr>
<td>5/17/20</td>
<td>200,184</td>
<td>42,312</td>
<td>3,345</td>
</tr>
<tr>
<td>5/24/20</td>
<td>182,818</td>
<td>57,679</td>
<td>3,558</td>
</tr>
<tr>
<td>5/31/20</td>
<td>136,652</td>
<td>73,380</td>
<td>3,770</td>
</tr>
<tr>
<td>6/7/20</td>
<td>84,016</td>
<td>85,874</td>
<td>3,962</td>
</tr>
<tr>
<td>6/14/20</td>
<td>46,350</td>
<td>89,390</td>
<td>4,144</td>
</tr>
<tr>
<td>6/21/20</td>
<td>23,363</td>
<td>85,226</td>
<td>4,470</td>
</tr>
<tr>
<td>6/28/20</td>
<td>11,366</td>
<td>91,648</td>
<td>7,850</td>
</tr>
</tbody>
</table>

Numbers are medians of projections

Stay the Course: Future Depends on Policy
Hospital Demand and Capacity by Region

Assumes average length of stay of 10 days
COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

Date ranges when regions are estimated to exceed surge capacity

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Date Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow – Apr30</td>
<td>Early May – Early June</td>
</tr>
<tr>
<td>Slow – Jun10</td>
<td>Early May – Mid June</td>
</tr>
<tr>
<td>Pause – Apr30</td>
<td>Mid June – Late July</td>
</tr>
<tr>
<td>Pause – Jun10</td>
<td>Mid July – Late August</td>
</tr>
<tr>
<td>Unmitigated</td>
<td>Late April – Mid May</td>
</tr>
</tbody>
</table>

Social Distancing postpones the time when capacity is exceeded 1 to 2.5 months
Timing estimates can be used for planning to augment existing capacities if needed
Ongoing Efforts and Improvements

• Incorporate age structure into transmission dynamics and stratify outcomes by age in these projections

• Incorporate Virginia-specific outcomes and durations which will better tailor these analyses to our Commonwealth

• Assess evidence for the role of seasonality, and incorporate if warranted

• Analyze Test-Trace-Isolate mitigations

• Connect forecast demand to VDH dashboard
Key Takeaways

Projecting future cases precisely is impossible and unnecessary. Even without perfect projections, we can confidently draw conclusions:

- **Current social distancing efforts are working.**
- Under current conditions, Virginia *as a whole* will have sufficient medical resources for at least the next couple months.
- Lifting social distancing restrictions too soon can lead quickly to a second wave.
- Further modeling could explore the effectiveness of test-trace-isolate policies.
- The situation is changing rapidly. Models will be updated regularly.
References


Google. COVID-19 community mobility reports. [https://www.google.com/covid19/mobility/](https://www.google.com/covid19/mobility/)


Questions?

Biocomplexity COVID-19 Response Team

Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Andrei Bura, Jiangzhuo Chen, Clark Cucinell, Allan Dickerman, Stephen Eubank, Arindam Fadikar, Joshua Goldstein, Stefan Hoops, Sallie Keller, Ron Kenyon, Brian Klahn, Gizem Korkmaz, Vicki Lancaster, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Fanchao Meng, Henning Mortveit, Mark Orr, Przemyslaw Porebski, SS Ravi, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Aaron Schroeder, Stephanie Shipp, Samarth Swarup, Alex Tellonis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Amanda Wilson, Dawen Xie