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

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Executive Director

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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

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**Accessed** 1pm April 12, 2020

Impact of Interventions
Estimating Effects of Social Distancing

• Anonymized 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 15\textsuperscript{th}
    • 1.1 after March 15\textsuperscript{th}

Google. COVID-19 community mobility reports. \url{https://www.google.com/covid19/mobility/}
Short-term Projections

**Confirmed cases**

**Hospitalizations**

**Ventilations**

Virginia - Daily Confirmed cases - Comparison


Virginia - Daily Hospitalized cases - Comparison

Virginia - Daily Ventilated cases - Comparison


Unmitigated, Slow-Apr30, Slow-Jun10, Pause-Apr30, Pause-Jun10
Stay the Course: Future Depends on Policy

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

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
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Questions?

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