Estimation of COVID-19 Impact in Virginia

May 27, 2020
(data current to May 26)
Biocomplexity Institute Technical report: TR 2020-067
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

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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:

• We are entering a period of transition, shifting to sustaining control through test and trace and other mitigations rather than strict social distancing.

• Model update this week shows possible paths forward, rebounds with and without new mitigations, uncertainty remains on timing of this transition.

• Data show fewer people “stay home”, as well as progress towards better detection.

• Intensity of rebound depends on degree of social distancing relaxation; intensity of new mitigations depends on testing volumes and tracing effectiveness.

• 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:** Intensity of social distancing rebound and control sustaining mitigations into the future are unknowable, thus explored through 5 scenarios
Mitigation Scenarios: 
Rebound Intensity x Detection Levels + Unmitigated

Pause from Social Distancing: Began on March 15th
- Lifted on May 15th (61 days), with two-week delay (75 days) for select counties*
- Intensity: Social distancing pauses and significantly reduces case growth

Intensity of Rebound: Relaxation of social distancing measures increases interactions in society, leading to two levels of transmission rates:
- Light: Interactions return to 1/6th of pre-pandemic levels, moderate increase in transmission
- Strong: Interactions return to 1/3rd of pre-pandemic levels, stronger increase in transmission

Detection Control: Increased Testing Capacity coupled with infection control measures
- Better Detection: Plays a role by limiting the period of infectiousness before isolation

Unmitigated: No social distancing or other types of mitigation

* Select counties as mentioned by recent releases from Governor Northam’s office

29-May-20
# Five Mitigation Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Rebound Intensity</th>
<th>Better Detection</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strong</td>
<td>No</td>
<td>Strong</td>
<td>Strong Rebound, Detection same</td>
</tr>
<tr>
<td>2</td>
<td>Light</td>
<td>No</td>
<td>Light</td>
<td>Light Rebound, Detection same</td>
</tr>
<tr>
<td>3</td>
<td>Strong</td>
<td>Yes</td>
<td>Strong – BetterDetection</td>
<td>Strong Rebound, Detection improved</td>
</tr>
<tr>
<td>4</td>
<td>Light</td>
<td>Yes</td>
<td>Light – BetterDetection</td>
<td>Light Rebound, Detection improved</td>
</tr>
<tr>
<td>5</td>
<td>NA</td>
<td></td>
<td>Unmitigated</td>
<td>No mitigation</td>
</tr>
</tbody>
</table>
### Full Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transmission</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmissibility ($R_0$)</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>Infection detection rate</td>
<td>15%</td>
<td>1 confirmed case becomes ~7 initial infections</td>
</tr>
<tr>
<td>Percent asymptomatic</td>
<td>50%</td>
<td>Infected individuals that don’t exhibit symptoms</td>
</tr>
<tr>
<td><strong>Onset to hospitalization</strong></td>
<td>5 days</td>
<td>Time from symptoms to hospitalization</td>
</tr>
<tr>
<td><strong>Hospitalization to ventilation</strong></td>
<td>3 days</td>
<td>Time from hospitalization to ventilation</td>
</tr>
<tr>
<td><strong>Duration hospitalized</strong></td>
<td>8 days</td>
<td>Time spent in the hospital</td>
</tr>
<tr>
<td><strong>Duration ventilated</strong></td>
<td>14 days</td>
<td>Time spent on a ventilator</td>
</tr>
<tr>
<td>Percent hospitalized</td>
<td>5.5% (~20% of confirmed)</td>
<td>Symptomatic individuals becoming hospitalized</td>
</tr>
<tr>
<td>Percent in ICU</td>
<td>20%</td>
<td>Hospitalized patients that require ICU</td>
</tr>
<tr>
<td>Percent ventilated</td>
<td>70%</td>
<td>ICU patients requiring ventilation</td>
</tr>
</tbody>
</table>

3 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) (Accessed 13APRIL2020)
4 Personal communications, UVA Health and Sentara (~500 VA based COVID patients)
Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2\textsuperscript{nd}

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate**: 12.3%

**Estimation of undetected infections**

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12\% of infections (close to 15\% used in model)

**Estimation of hospitalizations from infections**

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7\% of infections (close to 2.25\% used in model)
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

Impact of Interventions
Estimating Effects of Social Distancing

**VDH data shows reductions in growth rate starting in mid-March**

Weekly growth rate by date of onset
- Week before March 15 = 0.3
- Week after March 15 = -0.02 to 0.04

Crude reproductive number estimates
- 2.2 before March 15th
- 0.91 to 1.19 after March 15th

Google Mobility data shows VA greatly reduced activities, though is rebounding:
https://www.google.com/covid19/mobility/ (as of May 16th)
Estimating Effects of Better Detection

VDH data shows reductions in time from Symptom Onset to Diagnosis

Days to Diagnosis drops ~30% in recent weeks

• Mid March to Late April = 6.8 days
• Late April to Mid May = 4.7 days

Testing Encounters increase

• Late April = ~4K / day
• Mid May = ~7K / day
Estimating Daily Reproductive Number

Statewide and most regions follow similar pattern
- Spike, followed by a decline, to plateau, with recent decline
- This week: overall decline, some regions up

Methodology
- Wallinga-Teunis method as implemented in EpiEstim¹ R package
- Based on Date of Onset of Symptoms
- Uses serial interval to estimate $R_e$ over time: 6 days (2 day std dev)

Recent Estimates subject to revision as more data comes in
- Date of onset unstable in last 7-14 days

Future Interactions Drive Future Cases

Adherence to Social Distancing measures and Individual Choices about Personal Disease Control Practices will drive the next phase of the Epidemic

Challenges:

- Assessing the adherence with policies as actual behavior drives the epidemic
- Translating future policies to changes in transmission dynamics

Interactions can increase and cases can be driven lower, sustaining control

- Policies must carefully weigh local risk of spread, monitor local epidemiology, and tune policies and guidance to changing conditions
- Individuals must be ready to adhere to changes in policies and continue to practice good personal disease control practices
Agent-based Model Aided Policy Assessment

EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Translate changes in social interactions to transmission risk

**Synthetic Population**
- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations

**Detailed Disease Course of COVID-19**
- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments
Agent-Based Model Design

Study of "Stay Home" policy adherence
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from "staying at home"

Calibration to Current State
- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

Impacts on Reproductive number with release
- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels
Short-term Projections

Confirmed cases
Virginia - Daily Confirmed cases - Comparison

Hospitalizations
Virginia - Daily Hospitalized cases - Comparison

Ventilations
Virginia - Daily Ventilated cases - Comparison
Period of Transition: Sustaining Control

Virginia - Daily Confirmed cases - Comparison

Weekly New Confirmed Cases*

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Unmitigated</th>
<th>Light</th>
<th>Light – Better Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/24/20</td>
<td>159,643</td>
<td>5,339</td>
<td>5,339</td>
</tr>
<tr>
<td>5/31/20</td>
<td>126,034</td>
<td>5,774</td>
<td>5,229</td>
</tr>
<tr>
<td>6/7/20</td>
<td>77,114</td>
<td>6,030</td>
<td>5,052</td>
</tr>
<tr>
<td>6/14/20</td>
<td>43,790</td>
<td>7,075</td>
<td>5,232</td>
</tr>
<tr>
<td>6/21/20</td>
<td>22,734</td>
<td>7,960</td>
<td>5,280</td>
</tr>
<tr>
<td>6/28/20</td>
<td>11,108</td>
<td>8,916</td>
<td>5,314</td>
</tr>
<tr>
<td>7/5/20</td>
<td>5,432</td>
<td>9,941</td>
<td>5,314</td>
</tr>
<tr>
<td>7/12/20</td>
<td>2,630</td>
<td>10,919</td>
<td>5,246</td>
</tr>
<tr>
<td>7/19/20</td>
<td>1,266</td>
<td>11,896</td>
<td>5,183</td>
</tr>
<tr>
<td>7/26/20</td>
<td>586</td>
<td>12,849</td>
<td>5,143</td>
</tr>
<tr>
<td>8/2/20</td>
<td>266</td>
<td>13,651</td>
<td>5,046</td>
</tr>
<tr>
<td>8/9/20</td>
<td>95</td>
<td>14,176</td>
<td>4,934</td>
</tr>
</tbody>
</table>

*Numbers are medians of projections
Hospital Demand and Capacity by Region

**Capacities by Region – Light Rebound**
COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

* Assumes average length of stay of 8 days

**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>1 Strong</td>
<td>Late June to Mid August</td>
</tr>
<tr>
<td>2 Light</td>
<td>Mid July to Early Aug</td>
</tr>
<tr>
<td>3 Strong – Better Detection</td>
<td>None</td>
</tr>
<tr>
<td>4 Light – Better Detection</td>
<td>None</td>
</tr>
<tr>
<td>5 Unmitigated</td>
<td>Mid April to Late June</td>
</tr>
</tbody>
</table>

Social Distancing has postponed the time to when capacity could be exceeded 1 to 2 months
Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/
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References


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


Questions?

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