Estimation of COVID-19 Impact in Virginia

November 18th, 2020
(data current to November 17th)

Biocomplexity Institute Technical report: TR 2020-141
About Us

• Biocomplexity Institute at the University of Virginia
  • Using big data and simulations to understand massively interactive systems and solve societal problems
• Over 20 years of crafting and analyzing infectious disease models
  • Pandemic response for Influenza, Ebola, Zika, and others

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Biocomplexity COVID-19 Response Team

Overview

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

• **Approach:**
  • Calibrate explanatory mechanistic model to observed cases
  • Project infections for next 4 months
  • 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:

- **Virginia continues steady growth recording highest case rates of epidemic**
- VA mean weekly incidence (18.9/100K) is up again (from 16.8) though slower than nationally (60/100K from 46/100K).
- Projections are mostly up, showing potential for strain on health care system in some regions as early as December.
- Recent updates:
  - Ensemble of statistical and Machine Learning models integrated with Adaptive to guide projections
  - Horizon extended to March 1\textsuperscript{st}
  - Planning scenarios and case ascertainment rates remain as updated in previous weeks
- The situation is changing rapidly. Models will be updated regularly.
Situation Assessment
Surging Rates continue

- Majority of Districts have increasing rates
- Most growth in Southwest and North
- Some Districts remain steady or decreasing
Test Positivity by VDH District

Weekly changes in test positivity by district

- Increasing levels in many districts throughout the commonwealth

County level test positivity rates for RT-PCR tests.

**Green**: Test positivity <5.0% (or with <20 tests in past 14 days)

**Yellow**: Test positivity 5.0%–10.0% (or with <500 tests and <2000 tests/100k and >10% positivity over 14 days)

**Red**: >10.0% and not meeting the criteria for “Green” or “Yellow”
Goal: Define epochs of a Health District’s COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period’s slope to define the trajectory

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Description</th>
<th>Weekly Case Rate (per 100K) bounds</th>
<th># Districts (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Plateau</td>
<td>Steady level with minimal trend up or down</td>
<td>above -0.9 and below 0.5</td>
<td>4 (8)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>Sustained growth not rapid enough to be considered a Surge</td>
<td>above 0.5 and below 2.5</td>
<td>19 (17)</td>
</tr>
<tr>
<td>In Surge</td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>8 (8)</td>
</tr>
</tbody>
</table>
## District Trajectories

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Plateau</td>
<td>4 (8)</td>
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Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
Estimating Daily Reproductive Number

Nov 7th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Current $R_e$</th>
<th>Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>1.091</td>
<td>0.086</td>
</tr>
<tr>
<td>Central</td>
<td>1.138</td>
<td>0.209</td>
</tr>
<tr>
<td>Eastern</td>
<td>1.091</td>
<td>-0.008</td>
</tr>
<tr>
<td>Far SW</td>
<td>1.191</td>
<td>0.205</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.859</td>
<td>-0.094</td>
</tr>
<tr>
<td>Northern</td>
<td>1.172</td>
<td>0.111</td>
</tr>
<tr>
<td>Northwest</td>
<td>1.199</td>
<td>0.199</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

Changes in Case Detection

<table>
<thead>
<tr>
<th>Timeframe (weeks)</th>
<th>Mean days</th>
<th>% difference from overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>April (13-16)</td>
<td>8.6</td>
<td>51%</td>
</tr>
<tr>
<td>May (17-21)</td>
<td>5.6</td>
<td>-1%</td>
</tr>
<tr>
<td>June (22-25)</td>
<td>6.0</td>
<td>6%</td>
</tr>
<tr>
<td>July (26-30)</td>
<td>6.3</td>
<td>11%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.9</td>
<td>-14%</td>
</tr>
<tr>
<td>Sept (35-38)</td>
<td>4.4</td>
<td>-23%</td>
</tr>
<tr>
<td>Oct (39-43)</td>
<td>4.2</td>
<td>-26%</td>
</tr>
<tr>
<td>Overall (13-43)</td>
<td>5.7</td>
<td>0%</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

- Testing levels continue slow steady rise
- Positivity continues slow steady rise

Days from Onset to Diagnosis and Test Positivity - Weekly

- July: 6.3 days
- Aug: 4.9 days
- Sept: 4.4 days
- Oct: 4.2 days

Accessed 8:30am November 18, 2020

https://www.vdh.virginia.gov/coronavirus/
Mask usage in Virginia

State level mask usage as reported via Facebook surveys over the past month shows ranges from 83% to 89%
- Relatively stable over time
- Limited variance across the commonwealth
- ~3000 daily responses from VA

Data Source: https://covidcast.cmu.edu

Correlations seen at national level with mask use and case rate start to emerge across VA counties, due to surging growth and more limited survey results due to election.

Some county level fluctuations since beginning of Sept., though data quality may be affected by sample sizes.
Race and Ethnicity Attack Rates (per 100K)

Cumulative Race and Ethnicity Attack Rates (per 100k)

- Black and Latinx populations have much higher case, hospitalization, and death rates
- Disparity is more pronounced in some districts than others
- Based on 2019 census race-ethnicity data by county
Race and Ethnicity cases per 100K

Rates per 100K of each Racial-Ethnic population by Health District
- Each Health District’s Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size
- Overlapping labels removed for clarity

18-Nov-20
Impact across Density and Income

All zip codes show steady growth, with lowest incomes showing the most rapid upticks.

Full evolution of pandemic, shows shifts from denser and wealthier zip codes to poorer and less dense zip codes, followed by a repeat of the pattern. Recently see an uptick across the spectrum of density and income.
Other State Comparisons

Trajectories of States

Tests per Day and Test Positivity

- VA and few mid-Atlantic states maintain steady levels though with upward trends
- Many neighboring states have joined the rest of the nation with surging rates (34 total in US)

- VA’s test positivity rate continues to rise along with many of its neighbors
- Testing volumes remain steady and relatively high in most states
Growth Associated with Temperature and Humidity

- As weather cools and humidity drops, SARS-CoV2 survival and chance of transmission may rise
- Correlations with other factors are also strong for R (0, 7, 14 day delay) and confirmed cases (7 and 14 day delay)
- Weather variables better correlation with R estimates, while mobility and mask usage correlate well with case rates

[Diagram showing correlations between various factors such as Min temp, Mean temp, Humidity, Mask Usage, Grocery Mobility, and Transit Mobility]
Case Rates in the last week by zip code

- Concentrations of very high prevalence in many zip codes
- Several of the top ten zipcodes are home to prisons
- Southwest has considerable concentration of high prevalence zips
- Some counts are low and suppressed to protect anonymity, those are shown in white
Risk of Exposure by Group Size

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25 or 50)

- Assumes 3 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey)
- Moderate risk for groups of 50 across the commonwealth, especially in the southern half of the state
- Some zip codes have high likelihood of exposure even in groups of 25
Zip code level weekly Case Rate (per 100K)

Northwest

North

Eastern

Far Southwest

Near Southwest

Central
Zip Code Hot Spots

Hotspots across commonwealth

• More spread out but remain concentrated in the Southwest
• Captures some very high prevalence rates in some zips
Model Update – Adaptive Fitting
Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

- Allows history to be precisely captured, and used to guide bounds on projections

**Model:** An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

**External Seeding:** Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding
Using Ensemble Model to Guide Projections

An ensemble methodology that combines the Adaptive Fitting and machine learning and statistical models has been developed and refined

• **Models**: Adaptive Fitting, ARIMA, LSTM, AR, spatially driven AR, Kalman Filters (ENKF)
• This approach facilitates the use of other data streams (weather, mobility, etc.)
• Ensemble provides scaffolding for the Adaptive Fitting’s short-term projections
Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- Virginia Serology Study estimated 2.4% of Virginians estimated infected (as of Aug 15th)
- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 3.9% [1.7% – 7.1%] seroprevalence as of Aug 15th (still no updates on these data from CDC)

These findings are equivalent to an ascertainment ratio of ~3x, with bounds of (1x to 7x)

- Thus for 3x there are 3 total infections in the population for every confirmed case
- Uncertainty design has been shifted to these bounds (previously higher ascértinations as was consistent earlier in the pandemic were being used)

Calibration Approach

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

- **Calibration:** fit model to observed data and ensemble’s forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak

- **Project:** future cases and outcomes generated using the collection of fit models run into the future
  - Mean trend from last 7 days of observed cases and first week of ensemble’s forecast used
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories
Scenarios – Seasonal Effects

- Societal changes in the past month have led to an increase in transmission rates, these could continue to drive transmission
  - Seasonal impact of weather patterns
  - More interactions at places of learning
  - Travel related to holidays and traditional large family gatherings
  - Fatigue with infection control practices
- Population’s behaviors determine the level of control of transmission we can achieve
- Three scenarios capture possible trajectories starting Nov 26\textsuperscript{th}, 2020
  - Adaptive: No change from base projection
  - Adaptive-MoreControl: 15% decrease in transmission starting Nov 26\textsuperscript{th}, 2020
  - Adaptive-LessControl: 15% increase in transmission starting Nov 26\textsuperscript{th}, 2020
Model Results
Outcome Projections

Confirmed cases
Virginia Daily Confirmed - Comparison

Estimated Hospital Occupancy

Daily Deaths

Cumulative Confirmed cases

University of Virginia

BIOCOMPLEXITY INSTITUTE

18-Nov-20
District Level Projections: Adaptive

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario
District Level Projections: Adaptive-MoreControl

Adaptive projections by District

- Projections that best fit recent trends
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Hospital Demand and Bed Capacity by Region

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

If Adaptive-LessControl scenario persists:
• All regions may approach initial bed capacity this winter
• Far SW earliest (mid December); Northern, Northwest (early January); remaining late January.

* Assumes average length of stay of 8 days

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive</th>
<th>Adaptive-LessControl</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/8/20</td>
<td>9,343</td>
<td>9,343</td>
</tr>
<tr>
<td>11/15/20</td>
<td>10,388</td>
<td>10,388</td>
</tr>
<tr>
<td>11/22/20</td>
<td>11,053</td>
<td>11,059</td>
</tr>
<tr>
<td>11/29/20</td>
<td>12,045</td>
<td>12,066</td>
</tr>
<tr>
<td>12/06/20</td>
<td>13,130</td>
<td>14,107</td>
</tr>
<tr>
<td>12/13/20</td>
<td>14,487</td>
<td>17,462</td>
</tr>
<tr>
<td>12/20/20</td>
<td>15,986</td>
<td>20,995</td>
</tr>
<tr>
<td>12/27/20</td>
<td>17,599</td>
<td>25,115</td>
</tr>
<tr>
<td>1/3/20</td>
<td>19,230</td>
<td>29,488</td>
</tr>
<tr>
<td>1/10/20</td>
<td>20,804</td>
<td>34,030</td>
</tr>
<tr>
<td>1/17/20</td>
<td>22,270</td>
<td>38,009</td>
</tr>
<tr>
<td>1/24/20</td>
<td>23,360</td>
<td>41,416</td>
</tr>
</tbody>
</table>
Key Takeaways

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

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• Recent updates:
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  • Horizon extended to March 1st
  • Planning scenarios and case ascertainment rates remain as updated in previous weeks

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References


Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/
Questions?

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Supplemental Slides
Mask usage sample sizes

Mean case rate (per 100k)

Mean mask Use (%)
Test positivity across VA counties

- CMS weekly summary (used for guiding nursing homes testing protocol)
- Data: COVID-19 Electronic Lab Reporting (CELR); HHS Unified Testing Dataset;
- County level testing counts and test positivity rates for RT-PCR tests.
  - **Green**: Test positivity <5.0% or with <20 tests in past 14 days
  - **Yellow**: Test positivity 5.0%-10.0% or with <500 tests and <2000 tests/100k and >10% positivity over 14 days
  - **Red**: >10.0% and not meeting the criteria for “Green” or “Yellow”

Red on Oct 21 (4-week back)

Red on Nov 11 (latest)

https://data.cms.gov/stories/s/q5r5-giuy
Agent-based Model (ABM)

EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing

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
ABM Social Distancing Rebound Study 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
Medical Resource Demand Dashboard

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