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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Overview

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

• Approach:
  • Calibrate explanatory mechanistic model to observed cases
  • Project based on scenarios 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:

• **Case rate growth in Virginia continues to surge along with the nation, but remains below national average**

• VA mean weekly incidence (60/100K) up (from 52) as national levels also rebound (to 67/100K from 60/100K); Virginia records highest daily case rate in past week

• Projections are mostly up across commonwealth

• Recent updates:
  • Modified scenarios to be based on past control levels (best and fatigued)
  • Planning scenarios start changing transmission rates at end of the month (Jan 30)
  • Refined vaccination schedule to account for partial protection from first dose
  • Adjusted “rescaling” method and data sources to better accommodate recent trends

• The situation is changing rapidly. Models will be updated regularly.
Situation Assessment
Case Rate (per 100k) by VDH District

Surging Rates continue

• Majority of districts have increasing rates
• Many districts experiencing highest rates of pandemic
• 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 with many districts above 10% for several weeks

• 124 counties over 10% based on Jan 6 report

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”

https://data.cms.gov/stories/s/5qru-gjyu
## District Trajectories

**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 (prev week)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Declining</strong></td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>3 (10)</td>
</tr>
<tr>
<td><strong>Plateau</strong></td>
<td>Steady level with minimal trend up or down</td>
<td>above -0.9 and below 0.5</td>
<td>1 (3)</td>
</tr>
<tr>
<td><strong>Slow Growth</strong></td>
<td>Sustained growth not rapid enough to be considered a Surge</td>
<td>above 0.5 and below 2.5</td>
<td>14 (13)</td>
</tr>
<tr>
<td><strong>In Surge</strong></td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>17 (9)</td>
</tr>
</tbody>
</table>
District Trajectories – last 10 weeks

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (prev week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>3 (10)</td>
</tr>
<tr>
<td>Plateau</td>
<td>1 (3)</td>
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<td>Slow Growth</td>
<td>14 (13)</td>
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<tr>
<td>In Surge</td>
<td>17 (9)</td>
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</table>

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
Estimating Daily Reproductive Number

Jan 11th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed</th>
<th>Date Confirmed Diff</th>
<th>Last Week Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>1.138</td>
<td></td>
<td>-0.021</td>
</tr>
<tr>
<td>Central</td>
<td>1.164</td>
<td></td>
<td>-0.136</td>
</tr>
<tr>
<td>Eastern</td>
<td>1.282</td>
<td></td>
<td>0.096</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.960</td>
<td></td>
<td>-0.177</td>
</tr>
<tr>
<td>Near SW</td>
<td>1.291</td>
<td></td>
<td>0.167</td>
</tr>
<tr>
<td>Northern</td>
<td>1.015</td>
<td></td>
<td>-0.069</td>
</tr>
<tr>
<td>Northwest</td>
<td>1.086</td>
<td></td>
<td>-0.100</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim3) for cases by **confirmation date**
- Serial interval: 6 days (2 day std dev)
- Using Confirmation date since due to increasingly unstable estimates from onset date 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>7.8</td>
<td>44%</td>
</tr>
<tr>
<td>May (17-21)</td>
<td>5.7</td>
<td>6%</td>
</tr>
<tr>
<td>June (22-25)</td>
<td>5.8</td>
<td>8%</td>
</tr>
<tr>
<td>July (26-30)</td>
<td>6.2</td>
<td>14%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.9</td>
<td>-9%</td>
</tr>
<tr>
<td>Sept (35-38)</td>
<td>4.6</td>
<td>-16%</td>
</tr>
<tr>
<td>Oct (39-43)</td>
<td>4.5</td>
<td>-17%</td>
</tr>
<tr>
<td>Nov (44-47)</td>
<td>4.5</td>
<td>-17%</td>
</tr>
<tr>
<td>Dec (48-49)</td>
<td>4.1</td>
<td>-25%</td>
</tr>
<tr>
<td>Overall (13-49)</td>
<td>5.4</td>
<td>--</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

Testing levels limited during holiday break have rebounded

Positivity continues to climb

Days from Onset to Diagnosis and Test Positivity - Weekly

July 6.2 days
Aug 4.9 days
Sept 4.6 days
Oct 4.5 days
Nov 4.5 days
Dec 4.1 days
State level mask usage as reported via Facebook surveys has shown steady increase over past three months
• ~88% (early Nov) to ~94% (mid Jan)
• Some variance across the commonwealth
• ~3000 daily responses from VA

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

Correlations seen among VA counties between mask use and case rate are now stronger due to surging growth
Slope: -3.2; for every % we see a ~3/100K case rate difference
Staying Home is on the rise, and recreation down
- Uniform across regions
- Home activities don’t preclude transmission in small gatherings
Health Care Worker Prevalence (per 100K)

Case Rates among health workers compared to population in last week

- Based on census counts of patient-facing health care workers (Practitioners and Technologists)
- Prevalence rates for week ending Jan 9th
- HCW burden remains high in some Eastern counties as well as Southwest
Recent Changes in Race and Ethnicity Rates (per 100k)

- Two week change in population level rates
- Black, Latinx and 2 or more races populations have much higher changes in rates; disparity is more pronounced in some districts than others
- Based on 2019 census race-ethnicity data by county

**Hospitalization Rate**

**Case Rate**

**Death Rate**
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
Impact across Density and Income

All zip codes show back into growth, wealthiest zip code now lags the rest significantly

Full evolution of pandemic, shows shifts from denser and wealthier zip codes to poorer and less dense zip codes
Other State Comparisons

Trajectories of States

- VA has rebounded and entered surging growth
- VA and her neighbors mirror the patterns across the nation
- All neighbors are growing though some remain lower relative recent very high peaks

Virginia and her neighbors

- After several weeks of decline many states are rebounding
- Most Southern states are surging
Case Rates in the last week by zip code

• Several of the top ten zip codes are home to prisons,
• Some counts are low and suppressed to protect anonymity, those are shown in white

Top 10 excluding prisons

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code</th>
<th>Name</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23829</td>
<td>Capron</td>
<td>37,980</td>
</tr>
<tr>
<td>2</td>
<td>24430</td>
<td>Craigsville</td>
<td>10,600</td>
</tr>
<tr>
<td>3</td>
<td>23821</td>
<td>Alberta</td>
<td>9,250</td>
</tr>
<tr>
<td>4</td>
<td>24352</td>
<td>Laurel Fork</td>
<td>7,240</td>
</tr>
<tr>
<td>5</td>
<td>24147</td>
<td>Rich Creek</td>
<td>6,880</td>
</tr>
<tr>
<td>6</td>
<td>23922</td>
<td>Burkesville</td>
<td>5,690</td>
</tr>
<tr>
<td>7</td>
<td>24263</td>
<td>Jonesville</td>
<td>5,470</td>
</tr>
<tr>
<td>8</td>
<td>22572</td>
<td>Warsaw</td>
<td>4,540</td>
</tr>
<tr>
<td>9</td>
<td>22454</td>
<td>Dunsville</td>
<td>3,890</td>
</tr>
<tr>
<td>10</td>
<td>24593</td>
<td>Spout Spring</td>
<td>3,590</td>
</tr>
</tbody>
</table>

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.
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)

- Assumes 3 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey)
- On left, minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 20 in Staunton, there is a 50% chance someone will be infected)
- Some zip codes have high likelihood of exposure even in groups of 25
New variants of SARS-CoV2

Emerging new variant with increased transmissibility but no evidence of higher severity

- Aliases: Variant VUI 202012/01 and Lineage B.1.1.7
- Variant has been detected in 10 states; most without travel history indicating local transmission
- This variant is still detected by PCR, and can be detected by proxy with an “S dropout”
- Evolution expected when virus under selective pressure
- Unlikely to alter efficacy of vaccines or other immune treatments
- NERVTAG suggests that “VUI-202012/01 demonstrates a substantial increase in transmissibility compared to other variants”
- Recent studies have been confirming that these variants aren’t likely to “escape” the current PCR tests nor approved vaccines
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 4.6% [3.0% – 6.6%] seroprevalence as of Nov 12th – 26th up from 4.1% a month earlier

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 ascertainment as was consistent earlier in the pandemic were being used)

https://covid.cdc.gov/covid-data-tracker/#national-lab

Virginia Coronavirus Serology Project
Interim findings by region and statewide - July 22, 2020

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of participants</th>
<th>Number antibody positive</th>
<th>Crude prevalence per 100 participants</th>
<th>Weighted prevalence*</th>
<th>(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>400</td>
<td>8</td>
<td>2.0</td>
<td>3.0</td>
<td>(0.5, 5.5)</td>
</tr>
<tr>
<td>East</td>
<td>707</td>
<td>9</td>
<td>1.3</td>
<td>1.5</td>
<td>(0.2, 3.2)</td>
</tr>
<tr>
<td>Northern</td>
<td>819</td>
<td>36</td>
<td>4.4</td>
<td>4.2</td>
<td>(2.5, 5.9)</td>
</tr>
<tr>
<td>Northwest</td>
<td>756</td>
<td>11</td>
<td>1.5</td>
<td>0.9</td>
<td>(0.2, 1.4)</td>
</tr>
<tr>
<td>Southwest</td>
<td>431</td>
<td>3</td>
<td>0.7</td>
<td>1.0</td>
<td>(0.2, 2.1)</td>
</tr>
<tr>
<td>Virginia</td>
<td>3,113</td>
<td>67</td>
<td>2.2</td>
<td>2.4</td>
<td>(1.4, 3.1)</td>
</tr>
</tbody>
</table>

* Weighted prevalence is reweighted by region, age, sex, race, ethnicity, and insurance status to match census population.

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 14 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

• Variety of factors continue to drive transmission rates
  • Seasonal impact of weather patterns, new variants of the virus with enhanced transmissibility, travel and gatherings related to holidays, fatigue with infection control practices

• Plausible levels of transmission can be bounded by past experience
  • Assess transmission levels at the county level since May 2020
  • Use the highest and lowest levels experienced (excluding outliers) as plausible bounds for levels of control achievable
  • Transition from current levels of projection to the new levels over 2 months

• New planning Scenarios:
  • Best of the Past: Lowest level of transmission (5th percentile)
  • Fatigued Control: Highest level of transmission (95th percentile) increased by additional 5%
Scenarios – Vaccines

• Vaccination has started, and efforts are underway to increase its pace
  • Exact achievable rollouts and level of coverage are unknown

• Vaccine efficacy varies over course of vaccine
  • FDA EUAs show 50% efficacy achieved 2 weeks after first dose, and 95% two weeks after second dose
  • Assuming 3.5 week (average of Pfizer and Moderna) gap between doses

• Schedules
  • **Optimistic**: 25M courses in US (~660K in VA) starting in January, and continued 25M (~660K) per month,
  • **Pessimistic**: 12.5M people in US (~330K in VA) in January, then 25M (~660K) per month, with vaccine hesitancy leaving 50% of delivered vaccines unused.
  • Assume that vaccinations before January protect individuals but are not influencing transmission dynamics

Scenarios – Seasonal Effects and Vaccines

Three scenarios combine these seasonal effects and vaccine scenarios

• **Adaptive**: No seasonal effects from base projection paired with optimistic vaccine schedule

• **Adaptive-FatigueControl**: Fatigued control seasonal effects paired with pessimistic vaccine schedule

• **Adaptive-BestPastControl**: Best of the past control seasonal effects paired with optimistic vaccine schedule

• Counterfactuals with no vaccine (“NoVax”) are provided for comparison purposes
Model Results
Outcome Projections

Confirmed cases
Virginia Daily Confirmed - Comparison

- Adaptive-FatigueControl
- Adaptive-NoVax-FatigueControl
- Adaptive-NoVax-BestPastControl
- Adaptive-BestPastControl
- Adaptive
- Adaptive-NoVax

Estimated Hospital Occupancy

Daily Deaths
Virginia Daily Death - Comparison

Daily Hospitalized
Virginia Daily Hospitalized - Comparison
District Level Projections: Adaptive

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases rate (per 100K) by Region (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-BestPastControl

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases rate (per 100K) by Region (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-FatigueControl

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases rate (per 100K) by Region (grey with 7-day average in black) with simulation colored by scenario
Hospital Demand and Bed Capacity by Region

Week Ending | Adaptive | Adaptive-FatigueControl
---|---|---
1/10/21 | 33,297 | 33,298
1/17/21 | 38,230 | 38,234
1/24/21 | 42,524 | 42,580
1/31/21 | 46,142 | 46,494
2/7/21 | 48,872 | 50,207
2/14/21 | 50,232 | 54,228
2/21/21 | 49,776 | 58,589
2/28/21 | 47,436 | 62,628
3/7/21 | 43,482 | 66,818
3/14/21 | 38,870 | 70,870
3/21/21 | 33,802 | 73,814
3/28/21 | 28,472 | 75,178

Weekly confirmed cases

If Adaptive-FatigueControl scenario persists:

- All regions approach initial bed capacity this winter
- Surge capacity approached in Northern region in Feb to early March

* Assumes average length of stay of 8 days
Key Takeaways

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

- **Case rate growth in Virginia continues to surge along with the nation, but remains below national average**
- VA mean weekly incidence (60/100K) up (from 52) as national levels also rebound (to 67/100K from 60/100K); Virginia records highest daily case rate in past week
- Projections are mostly up across commonwealth
- Recent updates:
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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
### Dec 11th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date of Onset</th>
<th>Date Onset Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>0.977</td>
<td>-0.275</td>
</tr>
<tr>
<td>Central</td>
<td>0.854</td>
<td>-0.491</td>
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<td>-0.323</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.988</td>
<td>-0.301</td>
</tr>
<tr>
<td>Northern</td>
<td>0.949</td>
<td>-0.253</td>
</tr>
<tr>
<td>Northwest</td>
<td>1.054</td>
<td>-0.193</td>
</tr>
</tbody>
</table>

**Methodology**

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

Mask usage sample sizes
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

13-Jan-21
Medical Resource Demand Dashboard

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