Estimation of COVID-19 Impact in Virginia

April 28th, 2021
(data current to April 26th – April 27th)

Biocomplexity Institute Technical report: TR 2021-048

biocomplexity.virginia.edu
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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Model Development, Outbreak Analytics, and Delivery Team
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 rates in Virginia overall are declining with a few areas of growth**
- VA mean weekly incidence down to 13/100K from 16/100K, US down (16 from 19 per 100K)
- Population immunity in VA reaches ~50% from vaccines and natural immunity
- Projections show declining rate overall across Commonwealth
- Recent updates:
  - Updated estimates of regional vaccine hesitancy and folded into projections
  - Modeled impact of increased acceptance against future surges in the Fall

The situation continues to change. Models continue to be updated regularly.
Situation Assessment
Case Rate (per 100k) by VDH District

Recent upticks across multiple districts

- Most districts are plateaued but an increasing number show surging or slow growth
- Higher levels than early Summer 2020
Test Positivity by VDH District

Weekly changes in test positivity by district
• Some upticks/flattening in the positivity rates
• Nearly 75% of counties still in Red or Yellow categories

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/qSr5-giyu
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>Declining</td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>22 (9)</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>9 (18)</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>2 (7)</td>
</tr>
<tr>
<td>In Surge</td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>2 (1)</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>22 (9)</td>
</tr>
<tr>
<td>Plateau</td>
<td>9 (18)</td>
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<tr>
<td>Slow Growth</td>
<td>2 (7)</td>
</tr>
<tr>
<td>In Surge</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Current evidence supports that new variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations

- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future
SARS-CoV2 Variants of Concern

**Lineage B.1.1.7**

- B.1.1.7 has been detected in Virginia and has continued to rapidly grow though has been hard to track. Currently estimated to account for over 2/3 of circulating virus in US and VA’s volatile estimate is down to 43%, likely higher.

**Transmissibility:**

- *Science* study using two-strain model supports that increased transmissibility, duration of infectiousness, or increased transmission in children best fit the epi data observed in the UK across regions. Some combination of all also likely.

- *Study from Public Health England* shows contacts of B.1.1.7 cases are more likely (50%) to test positive than contacts of non-B.1.1.7 patients.

- *Study* shows B.1.1.7 patients have longer periods of infection.

**Severity:**

- *Evidence* continues to mount supporting increased risks of hospitalization and mortality for B.1.1.7 infected individuals.

- *Danish* study shows B.1.1.7 to have a 64% higher risk of hospitalization, while *Public Health Scotland* studies showed a range of 40% to 60%

- *Study in Nature* based on UK data estimates B.1.1.7 cases have 60% higher mortality.

- *Sequence based study of hospitalized patients in Lancet*, found no association with severity and death among hospitalized from B.1.1.7.

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**Table 1:** Absolute 28-day mortality risk associated with B.1.1.7 as expressed by non-B.1.1.7 variants, among individuals testing positive in the community

<table>
<thead>
<tr>
<th>Strain</th>
<th>Sex</th>
<th>Age</th>
<th>Race</th>
<th>VAX4</th>
<th>NOS4</th>
<th>S/N</th>
<th>% N</th>
<th>% H</th>
<th>% D</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.1.1.7</td>
<td>M</td>
<td>20</td>
<td>White</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>B.1.1.7</td>
<td>F</td>
<td>20</td>
<td>White</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Non-B.1.1.7</td>
<td>M</td>
<td>20</td>
<td>Black</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Non-B.1.1.7</td>
<td>F</td>
<td>20</td>
<td>Black</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

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PCR testing in England from Sept 2020 – Feb 2021 combined with contact tracing data found B.1.1.7 cases to have higher viral loads (based on PCR cycle thresholds) and increased likelihood of causing infections among contacts. B.1.1.7 increased transmission by ~50%.

Medrxiv of 496 patients with samples positive for SARS-CoV-2 on PCR and who met inclusion criteria, 341 had samples that could be sequenced. 198 (58%) of 341 had B.1.1.7 infection and 143 (42%) had non-B.1.1.7 infection. We found no evidence of an association between severe disease and death and lineage (B.1.1.7 vs non-B.1.1.7) *Lancet*.
SARS-CoV2 Variants of Concern

**Lineage B.1.351**

- Emerging strain initially identified in South Africa shows signs of vaccine escape, currently under 1% of circulating virus

**Immune Escape:**

- Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well, however, vaccine induced immunity shows signs of effectiveness

  - **One study** supports a previous study based on clinical trial data showing that convalescent serum neutralization is highly predictive of actual immune protection for infection

  - **Another study in Cell** supports a previous report demonstrating that despite reduced antibody binding, the Moderna vaccinated individuals able to neutralize the B.1.351 variant

  - **New England Journal Study** shows that for people with prior infections who are then vaccinated (one dose of Pfizer) the boosted immunity is effective against B.1.351

  - Some evidence emerging that variants like B.1.351 may be more likely to cause secondary infections after vaccination. As more of the population is protected we may find B.1.351 and other immune evading variants becoming more prevalent.

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Despite reduced antibody binding to the B.1.351 RBD, sera from infected (acute and convalescent) and Moderna (mRNA-1273) vaccinated individuals were still able to neutralize the SARS-CoV-2 B.1.351 variant. *Cell*

Small Case control study suggests that among those infected after their 1st and 2nd dose, they are more likely to be B.1.351 in the earlier infections, and B.1.1.7 in the later breakthrough infections. *Medrxiv*

Six patients previously infected with the original virus received the BNT162b2 vaccine. Before vaccination, they had neutralizing activity against the B.1.1.7 and P.1 variants but not B.1.351. After one dose, neutralizing activity against all variants increased greatly. *NEJM*
SARS-CoV2 Variants of Concern

Lineage P.1
• At least 3.4% prevalence in US, likely higher, while Brazil suffering significant caseloads for prolonged period has 43% prevalence
• Study in *Cell* shows P.1 may be less resistant to neutralization than B.1.351

Lineage B.1.617
• Suspected of driving significant surge in India, so called “double mutant” possesses mutations similar to B.1.1.7, B.1.351, and B.1.429; suspected of being more transmissible and able to partially evade immunity
• A few cases already identified in UK and US as well
• Preliminary study from hard hit Maharashtra state shows vaccine induced and natural immunity convalescent sera can neutralize B.1.617 virus

Lineage B.1.429/427 and B.1.526 and subvariants
• Combined account for around 20% of circulating virus, share may be shrinking as B.1.1.7 outcompetes
• Evidence suggests these variants as slightly more transmissible and also exhibit some immune escape
Vaccination Developments

Breakthroughs

• Only 7k reported infections among the 87M people fully vaccinated in the US

• 7% hospitalized, 1% mortality (some portion of these are due to non-COVID reasons)

Measured Reductions in Viral Load & Symptoms

• Recent study of breakthrough infections in the UK based on over 300K individuals providing PCR tests

• Full vaccination slightly stronger than natural immunity for eliminating symptoms and driving the lowest viral load

• Various combinations of timings after 1st dose are effective in reducing symptoms and limiting viral load, just not as effective as full vaccination or natural immunity

• Reduced viral loads in asymptomatic infections of vaccinated individuals suggest some effectiveness against on-going transmission

As of April 20, 2021, more than 87 million people in the United States had been fully vaccinated against COVID-19. During the same time, CDC received reports of vaccine breakthrough infections from 45 U.S. states and territories.

<table>
<thead>
<tr>
<th>Total number of vaccine breakthrough infections reported to CDC</th>
<th>7,157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>4,580 (64%)</td>
</tr>
<tr>
<td>People aged ≥60 years</td>
<td>3,265 (40%)</td>
</tr>
<tr>
<td>Asymptomatic infections</td>
<td>2,078 (31%)</td>
</tr>
<tr>
<td>Hospitalizations*</td>
<td>498 (7%)</td>
</tr>
<tr>
<td>Deaths</td>
<td>88 (1%)</td>
</tr>
</tbody>
</table>

*167 (34%) of the 498 hospitalizations were reported as asymptomatic or not related to COVID-19. 11 (13%) of the 88 fatal cases were reported as asymptomatic or not related to COVID-19.

https://www.cdc.gov/vaccines/covid-19/health-departments/breakthrough-cases.html

Greater reductions in symptomatic infections and/or infections with a higher viral burden are reflected in reduced rates of hospitalisations/deaths, but highlight the potential for limited ongoing transmission from asymptomatic infections in vaccinated individuals.

https://www.ndm.ox.ac.uk/files/coronavirus/ciscommunityvaccinationpaper20210417complete.pdf

28-Apr-21
Estimating Daily Reproductive Number

April 26th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed $R_e$</th>
<th>Date Confirmed Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>0.779</td>
<td>-0.156</td>
</tr>
<tr>
<td>Central</td>
<td>0.788</td>
<td>-0.185</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.816</td>
<td>-0.129</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.816</td>
<td>-0.143</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.800</td>
<td>-0.221</td>
</tr>
<tr>
<td>Northern</td>
<td>0.779</td>
<td>-0.110</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.854</td>
<td>-0.121</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- 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>July (26-30)</td>
<td>6.2</td>
<td>-4%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.9</td>
<td>-24%</td>
</tr>
<tr>
<td>Sept (35-38)</td>
<td>4.5</td>
<td>-30%</td>
</tr>
<tr>
<td>Oct (39-43)</td>
<td>4.5</td>
<td>-31%</td>
</tr>
<tr>
<td>Nov (44-47)</td>
<td>4.5</td>
<td>-30%</td>
</tr>
<tr>
<td>Dec (48-49)</td>
<td>4.2</td>
<td>-34%</td>
</tr>
<tr>
<td>Jan (00-04)</td>
<td>3.9</td>
<td>-39%</td>
</tr>
<tr>
<td>Feb (05-08)</td>
<td>3.5</td>
<td>-46%</td>
</tr>
<tr>
<td>Mar (09-13)</td>
<td>3.6</td>
<td>-45%</td>
</tr>
<tr>
<td>Apr (14-14)</td>
<td>3.3</td>
<td>-49%</td>
</tr>
<tr>
<td>Overall (13-12)</td>
<td>6.4</td>
<td>-</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

- Positivity remains flat

Days from Onset to Diagnosis and Test Positivity - Weekly

- Days from onset to diagnosis
- Weekly PCR Test Positivity

Accessed 9:00am April 28, 2021

https://www.vdh.virginia.gov/coronavirus/
Vaccine Acceptance in Virginia

Acceptance remains high:

- Proportion of Virginians that have already or would definitely or probably accept vaccination if offered today
- Survey respondents are reporting high levels of vaccination of ~70% reflecting some bias of the mechanism
- Over 80% of Virginians have already or will choose to be vaccinated
- Top reasons for hesitancy: side effects, safety, distrust (increasing)
- Reasons for unnecessary vaccine: increasing levels of “not serious” disease in past 2 weeks

Data Source: https://covidcast.cmu.edu
Combined Surveys:
• Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
• Traditional phone-based survey administered several weeks ago for VDH vaccine messaging purposes is better sampled for true representativeness
• Correction approach:
  • Calculate an over-reporting fraction based on reported vaccinations (Apr 15-24) vs. VDH administration data
  • Cross-validate coarse corrections against traditional survey and found values were similar across regions, except in Eastern and Northwest which had more than 10% difference.
• Slight fluctuations compared to last week

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Changes in Race and Ethnicity Rates (per 100k) in past two weeks

- 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 regions 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)
Other State Comparisons

Trajectories of States

- Nearly all states are plateaued, with 2 jurisdictions now in surge, though all are leveling off
- Some states in West are growing but for most case growth is flat to slowly declining

Virginia and her neighbors

- VA and neighbors remain in plateau, with many showing slowly declining rates
- Levels remain high but slow and steady progress evident
Other State Comparisons - Hospitalizations

Shifting Age Distribution of cases being hospitalized
• Dual forces of vaccinations in older groups and severity of B.1.1.7 are dramatically shifting the age distribution of hospitalized patients
• Michigan’s hospitalizations are rising steeply, consist of more 20-59 year olds
• Massachusetts has significant B.1.1.7 prevalence but one of the highest vaccination levels
• Virginia has high vaccination and is maintaining lower levels of hospitalizations
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations in Southwest, which was preceded by cluster of increased HCW rates last week
- Still some universities in top 10
- Some counts are low and suppressed to protect anonymity, those are shown in white

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code</th>
<th>Name</th>
<th>Prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22546</td>
<td>Rutherford Glen</td>
<td>1,980</td>
</tr>
<tr>
<td>2</td>
<td>22514</td>
<td>Milford</td>
<td>1,690</td>
</tr>
<tr>
<td>3</td>
<td>22652</td>
<td>Fort Valley</td>
<td>1,190</td>
</tr>
<tr>
<td>4</td>
<td>24312</td>
<td>Austinville</td>
<td>940</td>
</tr>
<tr>
<td>5</td>
<td>22580</td>
<td>Woodford</td>
<td>910</td>
</tr>
<tr>
<td>6</td>
<td>22850</td>
<td>Singers Glen</td>
<td>900</td>
</tr>
<tr>
<td>7</td>
<td>22610</td>
<td>Bentonville</td>
<td>800</td>
</tr>
<tr>
<td>8</td>
<td>23040</td>
<td>Cumberland</td>
<td>770</td>
</tr>
<tr>
<td>9</td>
<td>22904</td>
<td>Charlottesville</td>
<td>750</td>
</tr>
<tr>
<td>10</td>
<td>22427</td>
<td>Bowling Green</td>
<td>740</td>
</tr>
</tbody>
</table>

Point Prevalence by Zip Code (2021-04-24)

Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-04-24.
Note: New color ramp scale and new ascertainment ratio of 2:1.
Risk of Exposure by Group Size and HCW prevalence

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)

- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 23 in Ruther Glen, there is a 50% chance someone will be infected)

- **HCW prevalence**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator

![Graph showing Risk of Exposure by Group Size and HCW prevalence](image-url)
Current Hot-Spots

Case rates that are significantly different from neighboring areas or model projections

- **Spatial**: SaTScan based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations.

- **Temporal**: The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model’s projections.

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**Spatial Hotspots**

SaTScan Clusters and Getis-Ord Hot Spots

- SaTScan Clusters
  - 20546 Ruther Glen: 99%
  - 22514 Millbrook: 99%
  - 22580 Woodford: 99%
  - 22522 Fort Valley: 99%
  - 23040 Cumberland: 95%
  - 23094 Charlottesville: 95%
  - 24312 Augusta: 99%
  - 22427 Bowling Green: 95%

- Getis-Ord Gi* HotSpots
  - Hot Spot - 99% Confidence

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**Temporal Hotspots**

Weekly Point Prevalence Model Residuals

Model: 14APR Predicting Week ending 2021-04-23

- Moran's I = 0.027527, Z-Score = 0.449211, P-Value = 0.65232
  - No Residual Autocorrelation Detected
Overlap of Vaccination with Disease and Social Factors

Case rates that are significantly different from neighboring areas or model projections

- **Social Vulnerability:** Each county’s Social Vulnerability Index (CDC) compared with the level of vaccination
  - Pink: Low Vax-High SVI; Purple: High Vax-High SVI; White: Low Vax-Low SVI; Blue: High Vax-Low SVI
- **Cumulative Cases:** As a measure of the impact of the disease, total cumulative case rate to date compared to the level of vaccination
  - Blue: High Vax-Low Cases; Green: High Vax-High Cases; White: Low Vax-Low Cases; Orange: Low Vax-High Cases;

Social Vulnerability and Vaccinations

Cumulative Cases and Vaccinations

[Maps and charts showing vaccination rates and cumulative cases across different counties, with color coding for social vulnerability and cumulative cases.]
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

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional ‘surveillance’ for making scenario-based projections.

Also submitted to CDC Forecast Hub.
Seroprevalence updates to model design

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

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 7.6% [5.6% – 9.8%] seroprevalence as of Jan 7th – 21st, up from 5.7% a month earlier.

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x):

- Thus for 2x there are 2 total infections in the population for every confirmed case recently.
- This measure now fully tracks the estimated ascertainment over time.
- Uncertainty design has been shifted to these bounds (previously higher ascertainment ratios as was consistent earlier in the pandemic were being used).

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

Accessed 9:00am April 28, 2021
https://www.vdh.virginia.gov/coronavirus/
Scenarios – Transmission Control

• Variety of factors continue to drive transmission rates
  • Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices

• Plausible levels of transmission can be bounded by past experience
  • Assess transmission levels at the county level. BestPast from May 1, 2020 – present; FatigueControl from May 1, 2020 – Sept 1, 2020 or current whichever is highest.
  • 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
  • BestPast Control starts with 3 week delay to account for transition to higher levels of control

• Projection Scenario:
  • **BestPast Control:** Lowest level of transmission (5th percentile)
  • **Fatigued Control:** Highest level of transmission (95th percentile) increased by additional 5%
Scenarios – Variant B.1.17

• New Variant B.1.1.7 is best understood and is in Virginia
  • Transmission increase: 50% increase from the current baseline projection based on estimated prevalence in past and future
  • Increased Severity: 60% increase in likelihood of hospitalization and a 60% increase in mortality Nature
  • Emergence timing: Gradual frequency increase reaching 50% frequency on April 5th, a couple weeks after the national estimate in MMWR report from CDC and refined by Andersen et al.

• Variant planning Scenario:
  • DominantB117: Current projected transmissibility continues to increase through June to a level 50% more transmissible
Scenarios – Vaccines

• Projected vaccine schedules constructed using current administration rates by dose and manufacturer for VA counties.

• Assumed vaccine efficacies
  • Pfizer/Moderna: 50% after first dose, 95% after second dose (3.5 week gap between doses)
  • J &J: 67% efficacy after first (and only) dose
  • Delay to efficacy from dose assumed to be 14 days
  • Immunity assumed to last duration of simulation (NEJM study shows long lasting, at least 7 months)

• J&J administration has resumed, till data available, assuming it will resume previous levels

• Administration Rate:
  • Pfizer: 137K courses initiated per week
  • Moderna: 72K courses initiated per week
  • J &J: 62K courses initiated per week
Scenarios – Seasonal Effects and Vaccines

Three scenarios combine these control effects and use the current vaccine schedule

• **Adaptive-DominantB117**: Boosting of transmissibility from the emergence and likely dominance of B.1.1.7
• **Adaptive-BestPast-DominantB117**: Best Past controls with transmission boost from B.1.1.7
• **Adaptive-FatigueControl-DominantB117**: Fatigued controls and transmission boost from B.1.1.7

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

Confirmed cases
Virginia Daily Confirmed - Comparison

- Adaptive-BestPast-DominantB117
- Adaptive-FatigueControl-DominantB117
- Adaptive-DominantB117

Estimated Hospital Occupancy

Daily Deaths
Virginia Daily Deaths - Comparison

Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized
Virginia Daily Hospitalized - Comparison
Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-BestPast-DominantB117

Adaptive projections by District

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

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

Capacities* by Region – Adaptive-FatigueControl-DominantB117

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

If Adaptive-FatigueControl-DominantB117 scenario:
• No regions approach capacities

* Assumes average length of stay of 8 days

https://nssac.bii.virginia.edu/covid-19/vmrddash/
Virginia’s Progress on Population Immunity

Natural Immunity and Vaccines combine to produce a population level of immunity

- How long immunity from infection with SARS-CoV2 lasts is not well understood but may vary based on severity of symptoms
  - We assume a conservative 6 month period of protection for these calculations
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future novel variants
- Population immunity depends on a very high proportion of the population getting vaccinated
  - Using regional vaccine acceptance

<table>
<thead>
<tr>
<th>Region</th>
<th>% immune (est.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>51%</td>
</tr>
<tr>
<td>Eastern</td>
<td>48%</td>
</tr>
<tr>
<td>Far SW</td>
<td>54%</td>
</tr>
<tr>
<td>Near SW</td>
<td>55%</td>
</tr>
<tr>
<td>Northern</td>
<td>47%</td>
</tr>
<tr>
<td>Northwest</td>
<td>54%</td>
</tr>
<tr>
<td>Virginia</td>
<td>50%</td>
</tr>
</tbody>
</table>

* As of April 25th 2021

28-Apr-21
Impact of Increased Vaccine Acceptance

Impact of increasing vaccine acceptance in all regions

- Optimistic Vaccination acceptance (VaxOpt) assumes 80% acceptance
- To further test Virginia’s resilience to new transmission surges, implement a Fall Surge
  - Highest rate from Fall 2020, with a 2 week ramp up starting on Sept 1\textsuperscript{st} 2021
- Population more resilient to Fall Surge (3-4 times fewer cases produced)
- In worst case of sustained Fatigue Control 120K cases averted
- In more realistic case Adaptive-DominantB117 scenario several thousand cases averted
COVID-19 Scenario Modeling Hub

Model Projection

https://covid19scenariomodelinghub.org/viz.html

Projected Incident Cases by Epidemiological Week and by Scenario

- Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and levels of control (moderate and low)
  - Similar to our current scenarios with regular updates, round 5 should be done in 1st week in May
Key Takeaways

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

• **Case rates in Virginia overall are declining with a few areas of growth**
  
• VA mean weekly incidence down to 13/100K from 16/100K, US down (16 from 19 per 100K)
  
• Population immunity in VA reaches ~50% from vaccines and natural immunity
  
• Projections show declining rate overall across Commonwealth
  
• Recent updates:
    • Updated estimates of regional vaccine hesitancy and folded into projections
    • Modeled impact of increased acceptance against future surges in the Fall
  
• The situation continues to change. Models continue to be updated regularly.
References


NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. [https://github.com/NSSAC/PatchSim](https://github.com/NSSAC/PatchSim)


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

Questions?

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Supplemental Slides
Estimating Daily Reproductive Number

April 17th 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>0.644</td>
<td>-0.076</td>
</tr>
<tr>
<td>Central</td>
<td>0.753</td>
<td>-0.056</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.700</td>
<td>-0.043</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.663</td>
<td>-0.135</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.755</td>
<td>0.049</td>
</tr>
<tr>
<td>Northern</td>
<td>0.616</td>
<td>-0.161</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.686</td>
<td>-0.070</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

### Weekly Cases and Hospitalizations

#### Weekly confirmed cases

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive-Dominant B117</th>
<th>Adaptive-BestPast-Dominant B117</th>
<th>Adaptive-Fatigued Control-Dominant B117</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/25/21</td>
<td>9,598</td>
<td>9,599</td>
<td>9,597</td>
</tr>
<tr>
<td>5/2/21</td>
<td>9,747</td>
<td>9,767</td>
<td>9,850</td>
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<tr>
<td>5/9/21</td>
<td>8,858</td>
<td>8,894</td>
<td>9,683</td>
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<tr>
<td>5/16/21</td>
<td>8,048</td>
<td>8,086</td>
<td>10,150</td>
</tr>
<tr>
<td>5/23/21</td>
<td>7,392</td>
<td>7,428</td>
<td>11,250</td>
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<tr>
<td>5/30/21</td>
<td>6,713</td>
<td>6,561</td>
<td>13,152</td>
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<tr>
<td>6/6/21</td>
<td>5,994</td>
<td>5,553</td>
<td>16,388</td>
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<tr>
<td>6/13/21</td>
<td>5,365</td>
<td>4,521</td>
<td>21,163</td>
</tr>
<tr>
<td>6/20/21</td>
<td>4,746</td>
<td>3,508</td>
<td>27,038</td>
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<tr>
<td>6/27/21</td>
<td>4,201</td>
<td>2,575</td>
<td>32,380</td>
</tr>
<tr>
<td>7/4/21</td>
<td>3,647</td>
<td>1,808</td>
<td>38,477</td>
</tr>
<tr>
<td>7/11/21</td>
<td>3,131</td>
<td>1,204</td>
<td>42,721</td>
</tr>
</tbody>
</table>

#### Weekly Hospitalizations

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive-Dominant B117</th>
<th>Adaptive-BestPast-Dominant B117</th>
<th>Adaptive-Fatigued Control-Dominant B117</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/25/21</td>
<td>750</td>
<td>750</td>
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</tr>
<tr>
<td>5/2/21</td>
<td>659</td>
<td>659</td>
<td>666</td>
</tr>
<tr>
<td>5/9/21</td>
<td>548</td>
<td>548</td>
<td>601</td>
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<tr>
<td>5/16/21</td>
<td>451</td>
<td>452</td>
<td>575</td>
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<tr>
<td>5/23/21</td>
<td>373</td>
<td>372</td>
<td>580</td>
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<tr>
<td>5/30/21</td>
<td>302</td>
<td>292</td>
<td>609</td>
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<tr>
<td>6/6/21</td>
<td>241</td>
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<td>654</td>
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<td>6/13/21</td>
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<td>159</td>
<td>707</td>
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<tr>
<td>6/20/21</td>
<td>161</td>
<td>112</td>
<td>771</td>
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<td>6/27/21</td>
<td>131</td>
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<td>784</td>
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<tr>
<td>7/4/21</td>
<td>103</td>
<td>48</td>
<td>748</td>
</tr>
<tr>
<td>7/11/21</td>
<td>81</td>
<td>29</td>
<td>659</td>
</tr>
</tbody>
</table>
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