Estimation of COVID-19 Impact in Virginia

March 31st, 2021
(data current to March 29th – 31st)
Biocomplexity Institute Technical report: TR 2021-032
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


31-Mar-21
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 have flattened and now have some growth**

  • VA mean weekly incidence flat at 17.5/100K from 17/100K, US up (to 18.5 from 16.5 per 100K)
  
  • Progress is stalling, 84% of VA counties above mean rate of Summer 2020
  
  • Projections shifting to growth across Commonwealth, boosted by B.1.1.7

• Recent updates:
  
  • Currently challenged to estimate the impact on hospitalizations and deaths, as increased rates from Variant B.1.1.7 interact with decreases from vaccination of the most susceptible to these outcomes
  
  • Johnson & Johnson included in vaccine schedule and Seasonal Effects adjusted for spring and summer

• 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

• Majority of districts have plateaued or exhibit slow growth

• Higher levels than early Spring 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”

31-Mar-21

https://data.cms.gov/stories/s/q5r5-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>Declining</td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>11 (23)</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>11 (6)</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>13 (6)</td>
</tr>
<tr>
<td>In Surge</td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>
District Trajectories – last 10 weeks

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

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (prev week)</th>
</tr>
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<tbody>
<tr>
<td>Declining</td>
<td>11 (23)</td>
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<td>Plateau</td>
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</tr>
<tr>
<td>In Surge</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>
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
  • B.1.1.7 is most frequent and well studied

NIH-NIAID Bacterial-Viral Bioinformatics Resource Center

CoVariants.org

CDC Variant Tracking
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. Current estimates suggest VA may be at 50% (national frequency at ~45%)
- Virginia seems to keep pace with estimates based on growth rates indicating B.1.1.7 now predominates (eg reach 50% frequency) in late March
- **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.
- **A recent study** finds B.1.1.7 to have longer duration which may be the source of increased transmissibility and has implications for isolation durations
- **Evidence** continues to mount supporting increased risks of hospitalization and mortality for B.1.1.7 infected individuals

Variant B.1.1.7 may cause longer infections with similar peak viral concentration compared to non-B.1.1.7 May contribute to B.1.1.7's increased transmissibility. https://dash.harvard.edu/handle/1/37366884
SARS-CoV2 Variants of Concern

Lineage B.1.351

- Emerging strain initially identified in South Africa shows signs of vaccine escape, currently 312 reported cases in 31 states (including 30 now in Virginia)
- *Nature* study shows that plasma from the 2nd wave of infections in South Africa (with B.1.351 circulating) neutralized non-B.1.351 virus, suggesting targeted B.1.351 vaccines or treatments may remain effective against other variants
- An additional study corroborates recent study based on clinical trial data shows that convalescent serum neutralization is highly predictive of actual immune protection for infection, thus B.1.351 may require booster vaccinations, and provides estimates for timing
- Another study in *Cell* supports previous report that demonstrated that despite reduced antibody binding the Moderna vaccinated individuals able to neutralize the B.1.351 variant

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*

Update: several recent reports and preprints, including studies conducted by Pfizer as well as Moderna, have produced similar findings in terms of vaccine potency against B.1.1.7 and B.1.1.298 variants but substantially less neutralization resistance by B.1.351 than we measured. *Cell*

Corroborating: calibrated to titers of human convalescent sera reported in each study, a robust correlation was seen between neutralizing titer and efficacy ($\rho = 0.79$) and binding antibody titer and efficacy ($\rho = 0.93$) *MedArxiv*
SARS-CoV2 Variants of Concern

Lineage P.1
- Present in at least 172 cases in 22 states, shows signs of increased transmissibility and ability to evade immunity
- Caused a resurgence of hospitalizations in Manaus, Brazil which has now caused more deaths in last 3 months than all of 2020
- Study in Cell shows P.1 may be less resistant to neutralization than B.1.351

Lineage B.1.429
- Recently officially recognized as variant of concern, estimates of ~20% increase in transmission and some evasion of immunity
- Initially found in Southern California, coincided with surge in Nov and Dec, found in over half of sequenced samples in LA

Lineage B.1.526
- Initially identified in NY and found increasingly as cases in NY / NJ increase
- Recent study finds vaccine-elicited plasma neutralizes B.1.526 but less efficiently than other variants
Estimating Daily Reproductive Number

March 29th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed $R_e$</th>
<th>Date Confirmed</th>
<th>Diff Last Week</th>
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<tbody>
<tr>
<td>State-wide</td>
<td>0.994</td>
<td></td>
<td>-0.013</td>
</tr>
<tr>
<td>Central</td>
<td>1.037</td>
<td></td>
<td>0.014</td>
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<tr>
<td>Eastern</td>
<td>1.014</td>
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<td>Far SW</td>
<td>1.122</td>
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<td>0.273</td>
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<tr>
<td>Near SW</td>
<td>0.884</td>
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<td>-0.021</td>
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<tr>
<td>Northern</td>
<td>1.011</td>
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<td>-0.034</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.925</td>
<td></td>
<td>-0.115</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


31-Mar-21
Changes in Case Detection

<table>
<thead>
<tr>
<th>Timeframe (weeks)</th>
<th>Mean days</th>
<th>% difference from overall mean</th>
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</thead>
<tbody>
<tr>
<td>July (26-30)</td>
<td>6.2</td>
<td>-8%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.9</td>
<td>-26%</td>
</tr>
<tr>
<td>Sept (35-38)</td>
<td>4.5</td>
<td>-32%</td>
</tr>
<tr>
<td>Oct (39-43)</td>
<td>4.5</td>
<td>-33%</td>
</tr>
<tr>
<td>Nov (44-47)</td>
<td>4.5</td>
<td>-33%</td>
</tr>
<tr>
<td>Dec (48-49)</td>
<td>4.2</td>
<td>-37%</td>
</tr>
<tr>
<td>Jan (00-04)</td>
<td>3.9</td>
<td>-41%</td>
</tr>
<tr>
<td>Feb (05-08)</td>
<td>3.4</td>
<td>-49%</td>
</tr>
<tr>
<td>Mar (09)</td>
<td>3.5</td>
<td>-48%</td>
</tr>
<tr>
<td>Overall (13-09)</td>
<td>6.7</td>
<td>--</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

1. Positivity starts to flatten and tick up a little after weeks of decline.

Days from Onset to Diagnosis and Test Positivity - Weekly

- July: 6.2 days
- Aug: 4.9 days
- Sept: 4.5 days
- Oct: 4.5 days
- Nov: 4.5 days
- Dec: 4.2 days
- Jan: 3.9 days
- Feb: 3.4 days
- Mar: 3.5 days

Overall (13-09) 6.7 days

Accessed 9:00am March 31, 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 ~50% reflecting some bias of the mechanism
- Nearly 80% Virginians have already or will choose to be vaccinated
- Top reasons for hesitancy: side effects, safety, distrust

Data Source: https://covidcast.cmu.edu
Vaccine Hesitancy in Virginia

Geographic distribution of Hesitancy clusters in Virginia:
• Rate of hesitancy assessed by those saying they would probably not, or definitely not take the vaccine if offered today
• Total of 111 locations covering ~8.2M residents

Red Clusters: High hesitancy rate
Blue Clusters: Low hesitancy rate

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Race and Ethnicity – Recent Rate Changes (per 100K)

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)

Correlations between Infection Rates and Poverty

High poverty and high case rates overlap in southside (red), but high rates occur with low poverty in Northern and Richmond area (light blue)
Other State Comparisons

**Trajectories of States**

- Nearly all states are plateaued, with 3 states in surge, most plateaued states show signs of growth.
- Missouri in decline only because of data artifact in reporting.

**Virginia and her neighbors**

- VA and nearly all in plateau with upward trends.
- Rates remain elevated, but significantly down from peaks in Jan.
Current Week vs. Summer Mean (June-Aug 2020)

Still some way to go to return to rates experienced during the summer of 2020 (June through August)

Recent Incidence Compared to Weekly Summer Mean by County
Mean: 7.98; Median: 1.14; IQR: 0.47-2.63

Recent Incidence Compared to Weekly Summer Mean by County
Mean: 2.6; Median: 1.96; IQR: 1.31-2.82

- 54% of US counties are above the summer mean case rate compared to 53% last week, slightly up
- 84% of VA counties are above the average rate for the summer compared to 81% last week, slightly up
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Universities still dominate the top 10 list
- Concentrations of high rates scattered across the Commonwealth
- 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>22974</td>
<td>Troy *</td>
<td>3,250</td>
</tr>
<tr>
<td>2</td>
<td>22807</td>
<td>Harrisonburg</td>
<td>1,930</td>
</tr>
<tr>
<td>3</td>
<td>22973</td>
<td>Stanardsville</td>
<td>1,630</td>
</tr>
<tr>
<td>4</td>
<td>23898</td>
<td>Zuni</td>
<td>1,520</td>
</tr>
<tr>
<td>5</td>
<td>24350</td>
<td>Ivanhoe</td>
<td>1,090</td>
</tr>
<tr>
<td>6</td>
<td>23315</td>
<td>Carrsville</td>
<td>1,040</td>
</tr>
<tr>
<td>7</td>
<td>23806</td>
<td>VSU Campus</td>
<td>820</td>
</tr>
<tr>
<td>8</td>
<td>23878</td>
<td>Sedley</td>
<td>790</td>
</tr>
<tr>
<td>9</td>
<td>23882</td>
<td>Stony Creek</td>
<td>730</td>
</tr>
<tr>
<td>10</td>
<td>24226</td>
<td>Clinchco</td>
<td>690</td>
</tr>
</tbody>
</table>

Only includes zip with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.
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 26 in Harrisonburg, 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
Current Hot-Spots

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

- **Spatial**: SaTScan based hot spots compare clusters of zipcodes 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
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 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 March 31, 2021
https://www.vdh.virginia.gov/coronavirus/
Scenarios – Seasonal Effects

• 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 since May 1, 2020 through September 30, 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

• Projection Scenario:
  • **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: Several different studies have estimated the increase in transmission to be 30-55%, we use 50% increase from the current baseline projection
  • Increased Severity: Not included in this scenario yet. B.1.1.7 is known to cause more hospitalizations and deaths compared to previous SARS-CoV2 variants (see previous variant slides) however, evidence in US still sparse
  • Emergence timing: Gradual frequency increase reaching 50% frequency on March 30\textsuperscript{th}, one week after the national estimate in MMWR report from CDC and refined by Andersen et al.

• Variant planning Scenario:
  • VariantB117: Current projected transmissibility continues to increase through June to a level 50% more transmissible
Scenarios – Vaccines

- Projected vaccine schedules constructed using current administrations rates by dose and manufacturer for VA counties.

- Assumed vaccine efficacies
  - Pfizer/Moderna: 50% after first dose, 95% after second dose
  - J &J: 67% efficacy after first (and only) dose
  - Average 3.5 week gap between Pfizer/Moderna doses
  - Delay to efficacy from dose assumed to be 14 days

- Accelerated administration pace will reach vaccine hesitancy thresholds more quickly
  - Currently assuming 70% acceptance threshold for all counties
  - Under current administration rates, 50% of counties could hit this threshold
  - Might be earlier for counties with lower acceptance rate
Scenarios – Seasonal Effects and Vaccines

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

- **Adaptive**: No seasonal effects from base projection
  - If things continue as they are
- **Adaptive-FatigueControl**: Fatigued control seasonal effects
  - If we revert to slightly worst transmission experienced in last 6 months
- **Adaptive-VariantB117**: Boosting of transmissibility from the emergence of B.1.1.7
  - If new variants begin to predominate and boost transmission, this assumes current seasonal affects remain the same (eg like Adaptive)
- **Adaptive-FatigueControl-VariantB117**: Fatigued control and txm 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-FatigueControl-VariantB117
- Adaptive-FatigueControl
- Adaptive-VariantB117
- Adaptive

Estimated Hospital Occupancy

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

Daily Deaths

Daily Hospitalized
District Level Projections: Adaptive

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-Variant B117

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-FatigueControl

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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-VariantB117

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

If Adaptive-FatigueControl-VariantB117 scenario:
• Southwest & Eastern regions may reach surge bed capacity in late May to late June
• Eastern, Near SW approach initial bed capacity in June as well

* Assumes average length of stay of 8 days

https://nssac.bii.virginia.edu/covid-19/vmrddash/
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
  - We assume 90% of adults will ultimately get vaccinated in these calculations but slow rates may prevent this from happening before October 2021
Key Takeaways

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

• **Case rates in Virginia have flattened and now have some growth**
• VA mean weekly incidence flat at 17.5/100K from 17/100K, US up (to 18.5 from 16.5 per 100K)
• Progress is stalling, 84% of VA counties above mean rate of Summer 2020
• Projections shifting to growth across Commonwealth, boosted by B.1.1.7
• Recent updates:
  • Currently challenged to estimate the impact on hospitalizations and deaths, as increased rates from Variant B.1.1.7 interact with decreases from vaccination of the most susceptible to these outcomes
  • Johnson & Johnson included in vaccine schedule and Seasonal Effects adjusted for spring and summer
• The situation continues to change. Models continue to be updated regularly.
References


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

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Supplemental Slides
Mar 20th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date of Onset</th>
<th>Date Onset Diff</th>
<th>Last Week</th>
<th>( R_e )</th>
</tr>
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<td>State-wide</td>
<td>0.797</td>
<td>0.045</td>
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<td>0.797</td>
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<tr>
<td>Central</td>
<td>0.902</td>
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<tr>
<td>Northern</td>
<td>0.809</td>
<td>0.043</td>
<td></td>
<td>0.809</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.710</td>
<td>-0.081</td>
<td></td>
<td>0.710</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

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