Estimation of COVID-19 Impact in Virginia

September 22\textsuperscript{nd}, 2021
(data current to September 18\textsuperscript{th} – 21\textsuperscript{st})

Biocomplexity Institute Technical report: TR 2021-106
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 has slowed, trends are very mixed across districts with majority also showing slow growth; case rates remain high as we may be cresting the peak of the Delta wave**

- VA 7-day mean daily incidence is slightly down to 42/100K from 43/100K; US is also slightly down to 48/100K (from 50/100K)

- Projections show a plateau and declining incidence in the near term, scenario based on last year’s transmission drivers show that significant future case growth remains possible

- Recent updates:
  - Added FallWinter2020 scenario which replays the transmission drivers of last Fall-Winter season
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

The situation continues to change. Models continue to be updated regularly.
Situation Assessment
Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 50% of counties with TPR > 10%

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>8 (12)</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 (4)</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>15 (7)</td>
</tr>
<tr>
<td>In Surge</td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>8 (12)</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>8 (12)</td>
</tr>
<tr>
<td>Plateau</td>
<td>4 (4)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>15 (7)</td>
</tr>
<tr>
<td>In Surge</td>
<td>8 (12)</td>
</tr>
</tbody>
</table>

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

Sept 20\textsuperscript{th} 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>1.047</td>
<td>-0.018</td>
</tr>
<tr>
<td>Central</td>
<td>1.049</td>
<td>0.012</td>
</tr>
<tr>
<td>Eastern</td>
<td>1.043</td>
<td>0.004</td>
</tr>
<tr>
<td>Far SW</td>
<td>1.059</td>
<td>-0.061</td>
</tr>
<tr>
<td>Near SW</td>
<td>1.013</td>
<td>-0.030</td>
</tr>
<tr>
<td>Northern</td>
<td>1.035</td>
<td>-0.053</td>
</tr>
<tr>
<td>Northwest</td>
<td>1.070</td>
<td>0.017</td>
</tr>
</tbody>
</table>

**Methodology**

- Wallinga-Teunis method (EpiEstim\textsuperscript{1}) 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

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Vaccination Administration Slows

Regional Vaccine courses initiated per day:
- Total counts of first dose of vaccines across regions
- Age-specific proportions of population vaccinated
Vaccination Acceptance by Region

Corrections to surveys:
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

<table>
<thead>
<tr>
<th>Region</th>
<th>COVIDcast accepting corrected</th>
<th>VDH proportion pop vaccinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>76%</td>
<td>71%</td>
</tr>
<tr>
<td>Eastern</td>
<td>74%</td>
<td>68%</td>
</tr>
<tr>
<td>Far SW</td>
<td>65%</td>
<td>57%</td>
</tr>
<tr>
<td>Near SW</td>
<td>70%</td>
<td>63%</td>
</tr>
<tr>
<td>Northern</td>
<td>85%</td>
<td>82%</td>
</tr>
<tr>
<td>Northwest</td>
<td>75%</td>
<td>70%</td>
</tr>
<tr>
<td>Virginia</td>
<td>78%</td>
<td>72%</td>
</tr>
</tbody>
</table>

Grey Bar: Survey measured and corrected acceptance
Green Bar: Proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county
Vaccine Acceptance Components over Time

Vaccine Acceptance adjusted to include scheduled appointments

- Steady rise in acceptance over the past couple months
- Unvaccinated Acceptance shows ~20% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Scheduled appointments for vaccination have increased through August but seem to be leveling off

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Vaccine Acceptance by Region- COVIDcast

Levels of Acceptance and potential acceptance in flux:
- Most regions (except Central and Far SW) see vaccine uptake in the “Definitely Yes”.
- Among the unvaccinated, about 20-30% remain in the Definitely/Probably “Yes” categories.
- About 50% of the Unvaccinated seem to be in the “Definitely Not” category.

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Reasons for Hesitancy vary across tiers of likeliness to accept the vaccine

- Probably Yes and Probably No most concerned about side effects & are waiting to see
- Definitely No are concerned about side effects but also don’t think they need the vaccine and don’t trust the government, though don’t need is declining
- Most other reasons are below 30% within these tiers of likeliness

Data Source: https://covidcast.cmu.edu
Mask Usage Increases

Self-reported mask usage has declined for months, but rebounded
• State-wide continues to rise, now outpaces US (65% vs. 64%)
• Progress in some counties has stalled or declined

Data Source: https://covidcast.cmu.edu
Mask Wearing by Vaccine Willingness

Among the different tiers of vaccine acceptance, mask wearing increasing

- Only those who would “definitely not” take the vaccine if offered have a low level of mask usage

- Probably Yes joins Definitely Yes and Vaccinated with highest mask wearing over 50%

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
SARS-CoV2 Variants of Concern

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

• Emerging 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

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WHO and Eric Topol

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22-Sep-21
SARS-CoV2 Variants of Concern

Previous Variants

**Alpha α - Lineage B.1.1.7**
- Virginia - 0.0% (B.1.1.7)
- Last Sample: 2021-09-02

**Beta β - Lineage B.1.351**
- Virginia - 0.0% (B.1.351)
- Last Sample: 2021-09-02

**Gamma γ - Lineage P.1**
- Virginia - 0.0% (P.1)
- Last Sample: 2021-09-02

Emerging Variants

**Lambda λ - Lineage C.37**
- Virginia - 0.0% (C.37)
- Last Sample: 2021-09-02

**Mu μ - Lineage B.1.621**
- Virginia - 0.0% (B.1.621)
- Last Sample: 2021-09-02

Delta continues to out compete Lambda and Mu in South America

Trevor Bedford Tweet & Nextstrain Analysis
SARS-CoV2 Variants of Concern

**Delta δ - Lineage B.1.617.2 and related subvariants**

- Delta plus δ+ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated possibly being transmissible
- **Recent study from Mayo clinic** shows Delta reducing the efficacy of mRNA vaccines (Pfizer more so than Moderna) along with other reports. Israeli study showed 64% efficacy against infection, however, a 3rd dose may counteract this reduction
- **Public Health Scotland study in Lancet** suggests Delta is 2x more likely to cause hospitalization than Alpha
- Subvariants AY.3 (15%) and AY.4 (1.5%) of Delta are more prevalent, these subvariants are mainly clustered in the US, others mainly outside of US
1. **Additional analysis** of PHE data shows that waning in effectiveness of vaccine is strongest in oldest population, especially amongst the clinically extremely vulnerable with underlying health conditions.

2. Delta produces more infectious particles per copy of detected viral RNA than Alpha, indicating its efficiency in replication and explaining a source of enhanced transmissibility. MedArxiv

3. Update on origin of SARS-CoV2, *paper from 2007* documents a clade of SARS-CoV that is genetically distinct from the SARS-CoV that caused first SARS outbreak in civets not far from Wuhan.

4. R.1 Lineage recently in the news with origins in Japan and initially found in US in Kentucky nursing home seems to have subsided and is likely outcompeted by Delta variant. Outbreak.info

5. Large claims data analysis (20M beneficiaries, with 5.5M fully vaxed) shows:
   a. In this highly vaccinated cohort (80%), there were many hospitalized breakthrough infections
   b. Strong effect of age for hospitalizations, more likely the older the person
   c. Strongest protection against hospitalization is being vaccinated after a COVID infection

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**Variants & Vaccines**

1. Underlying health conditions play a large part in the observed waning of protection against severe disease. Little waning is found among those without serious conditions

<table>
<thead>
<tr>
<th>Age group</th>
<th>Vaccine effectiveness (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-49</td>
<td>77.0 (70.3 to 82.3)</td>
</tr>
<tr>
<td>50-64</td>
<td>92.7 (90.3 to 94.6)</td>
</tr>
<tr>
<td>65+</td>
<td>78.7 (95% CI 52.7 to 90.4)</td>
</tr>
</tbody>
</table>

   Greater waning was observed among 65+ year-olds in a clinically extremely vulnerable group and 40 to 64-year-olds with underlying medical conditions compared to healthy adults. Preprint based on PHE data

2. Both Delta and Epsilon had significantly higher infectivity than Alpha, as measured by the number of infectious units per quantity of viral E gene RNA (6 and 4 times as much, p=0.0002 and 0.009 respectively) or subgenomic E RNA (11 and 7 times as much, p<0.0001 and 0.006 respectively).

   - *This is the first report of the identification of naturally infected civets outside the Guangdong province. The discovery of civet-CoVs in the Hubei province should not be a surprise as SARS-CoV-like viruses were recently found in a bat species in the same province (36). Based on the phylogenetic analysis of S genes, the three new viruses are relatively divergent from one another and also from the viruses previously identified* (Fig. 1).

   - Preprint based on PHE data

3. Large slideshow summary of analysis of huge cohort of Medicare beneficiaries (20M, with 16M over 65, 5.5M fully vaccinated. Several important insights on the effects of waning efficacy, level of breakthrough infections causing hospitalisations, and risk factors associated with severe breakthrough infections [https://www.humetrix.com/powerpoint-vaccine.html](https://www.humetrix.com/powerpoint-vaccine.html)

   - Older age associated with increased breakthrough hospitalizations
   - Risk model for breakthrough hospitalization
   - Risk of breakthrough hospitalization increases with time elapsed after vaccine administration and risk increases by 3% per month post vaccination

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4. **Total & Breakthrough hospitalizations in the 65 Years and Older Cohort**

5. **Are there Age Differences in Vaccine Protection Against Breakthrough Hospitalizations in the 65 Years and Older Cohort?**

   - Older age associated with increased breakthrough hospitalizations

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6. **Risk Model for Breakthrough Hospitalization**

   - Risk of breakthrough hospitalization increases with time elapsed after vaccine administration and risk increases by 3% per month post vaccination

   - Risk model can be used to stratify risk over 65 years to select those most in need of booster vaccine.
1. **Public Health England report** verifies strong protection against hospitalization and highlights that longer intervals between vaccine doses can be more efficacious, but too long may also diminish efficacy.

2. Additional analyses on the PHE study above demonstrate the utility of additional doses for the most vulnerable populations, and benefits of dose gaps larger than 4 weeks.

3. **Updated analysis** on Israeli data that avoids Simpson’s paradox continues to demonstrate vaccines high effectiveness against severe disease, and illustrates that lumping the under 12 population (ineligible for vaccination) into analyses can further diminish measured effectiveness.

4. Study in *Science* illustrates the equivalency of low-dose Moderna mRNA vaccine with natural immunity, including longer term T-cell responses, suggesting potential for dose sharing (25 μg vs. 100 μg).

5. San Francisco schools limited outbreaks and found very limited number of cases in their schools through basic low-cost infection control measures: vaccines, ventilation, HFPA filter, monitor CO2 indoor masks, and eating outside.

A recent report PHE conducted a test negative case control design study to estimate VE against symptomatic disease, hospitalisation and death. They compared vaccination status in persons with symptomatic Covid-19 with vaccination status in persons who reported symptoms but had a negative test. This approach helps to control for biases related to health-seeking behaviour, access to testing, and case ascertainment.

https://www.science.org/doi/10.1126/science.abb9953

**Science** illustrates the equivalency of low-dose Moderna mRNA vaccine with natural immunity, including longer term T-cell responses, suggesting potential for dose sharing (25 μg vs. 100 μg).


https://www.ft.com/content/cf83b3a1-fe06-4c9f-999c-7500090aee7c

San Francisco schools limited outbreaks and found very limited number of cases in their schools through basic low-cost infection control measures: vaccines, ventilation, HFPA filter, monitor CO2 indoor masks, and eating outside.

A recent Financial Times article based on data from PHE raises important aspects in the case for boosters, namely 1) the dosage gap impact on immune resilience and 2) the likelihood of being infected based on waning immunity, age, and other aspects of vulnerability.

https://www.ft.com/content/481851a1-40d0-4df4-935a-7f0000000a77

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**Moderna** vaccine stimulated cellular immunity vaccine-generated spike-specific memory CD4+ T cells 6 months post-boost were comparable in quantity and quality to COVID-19 cases. Spike-specific CD8+ T cells were generated in 88% of subjects, with equivalent memory at 6 months post-boost compared to COVID-19 cases.

https://www.science.org/doi/10.1126/science.abj9853
Other State Comparisons

Trajectories of States

- More of the country has plateaued and started to decline
- Many states remain in surge, but show signs of slowing
- Case rates remain very high, but nationally rates are starting to come down

Virginia and her neighbors

- Nearly all states show signs of plateau or slowing growth, with several declining in the past week
- Case rates remain high
Age-Specific Case Rates

Case Rates (per 100K) by Age Groups

- Rapid growth in many regions in the 0-19 age range, many exceeding 20% of current case rates (nearly 10% for 0-9)
- Case rate in under 40 group far exceeds 40+ in all districts
County level Case Rates (per 100K) from last week compared to worst week of the entire pandemic

• Many counties exceed or have similar rates to the worst week

• Majority of VA experienced rates at 50% or more of the high rates experienced throughout the COVID-19 pandemic
Recent Cases Correlate with Vax Coverage

Mean cases per 100K vs. vaccine coverage
• States with lower vax coverage have had the worst case spikes

Virginia Counties
• Counties with higher vax coverage are maintaining lower case rates
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Color scaled adjusted to accommodate the very high prevalence levels this week
- Clusters of high prevalence in Southwest and Eastern
- Some counts are low and suppressed to protect anonymity, those are shown in white

### Case Rates in the last week by zip code

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code</th>
<th>Name</th>
<th>Prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24502</td>
<td>Lynchburg</td>
<td>3,580</td>
</tr>
<tr>
<td>2</td>
<td>24460</td>
<td>Millboro</td>
<td>2,610</td>
</tr>
<tr>
<td>3</td>
<td>22610</td>
<td>Bentonville</td>
<td>2,510</td>
</tr>
<tr>
<td>4</td>
<td>24248</td>
<td>Ewing</td>
<td>2,430</td>
</tr>
<tr>
<td>5</td>
<td>24260</td>
<td>Honaker</td>
<td>2,300</td>
</tr>
<tr>
<td>6</td>
<td>24482</td>
<td>Verona</td>
<td>2,250</td>
</tr>
<tr>
<td>7</td>
<td>22454</td>
<td>Dunnsville</td>
<td>2,220</td>
</tr>
<tr>
<td>8</td>
<td>23830</td>
<td>Carson</td>
<td>2,100</td>
</tr>
<tr>
<td>9</td>
<td>24421</td>
<td>Churchville</td>
<td>1,930</td>
</tr>
<tr>
<td>10</td>
<td>24472</td>
<td>Raphine</td>
<td>1,890</td>
</tr>
</tbody>
</table>

Point Prevalence by Zip Code

(2021-09-18)

- Units = Active Cases / 100,000
- Denotes zip codes with state prisons
- Contains Suppressed Data

Point Prevalence

High: 2100+
1400
700
Low: 0

Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-09-18.

22-Sep-21
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)

- **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 19 in Lynchburg, there is a 50% chance someone will be infected)

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**From Last Week**

**Group Size Needed for 50% Likelihood of ≥1 Infected**

- **Rank**
- **Zip Code Name**
- **Size**

**Group Size Needed for 50% Likelihood of ≥1 Infected**

- **Rank**
- **Zip Code Name**
- **Size**

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**Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-09-11**

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**Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-09-18**
HCW Prevalence

• **HCW prevalence**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator
  - Clusters of high HCW point prevalence in Buena Vista City and far southwest (Wythe County to Wise County)

• **HCW Ratio**: HCW Prevalence / Total Case Prevalence
  - (blue = higher case rate among public, red = higher case rate among HCW)

### HCW Prevalence

<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Buena Vista City</td>
<td>1590</td>
</tr>
<tr>
<td>2</td>
<td>Smyth County</td>
<td>1090</td>
</tr>
<tr>
<td>3</td>
<td>Galax City</td>
<td>1050</td>
</tr>
<tr>
<td>4</td>
<td>Wythe County</td>
<td>990</td>
</tr>
<tr>
<td>5</td>
<td>Alleghany County</td>
<td>930</td>
</tr>
<tr>
<td>6</td>
<td>Norton City</td>
<td>830</td>
</tr>
<tr>
<td>7</td>
<td>King George County</td>
<td>740</td>
</tr>
<tr>
<td>8</td>
<td>Dickenson County</td>
<td>720</td>
</tr>
<tr>
<td>9</td>
<td>Nottoway County</td>
<td>710</td>
</tr>
<tr>
<td>10</td>
<td>Scott County</td>
<td>870</td>
</tr>
</tbody>
</table>

**HCW Point Prevalence by Zip Code**

(2021-09-18)

### HCW to Public Prevalence Ratio

<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Galax City</td>
<td>1.7</td>
</tr>
<tr>
<td>2</td>
<td>Buena Vista City</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>Acomacox County</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**HCW Prevalence / Case Prevalence**

(2021-09-18)

Note: Scale differs from general public prevalence maps.
Current Hot-Spots

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

- **Spatial**: Getis-Ord Gi* 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
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

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 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

- **Outcomes:** Data driven by shift and ratio that has least error in last month of observations
  - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
  - Deaths: 11 days from confirmation, 1.45% of cases die
Scenarios – Transmission Conditions

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

• Waning Immunity: Mean of one year protection (rate of 0.0027) similar to Pfizer study

• Projection Scenarios:
  • Adaptive: Control remains as is currently experienced into the future with assumption that Delta remains as the majority strain
  • Adaptive-FallWinter2020: Starting this week the core drivers of transmission from Sept 2020 – Feb 2021 are coarsely replayed but boosted to account for Delta’s increased transmissibility
  • Adaptive-Surge Control: Starting in one week behaviors and mitigation efforts ramp up over a 2-week period culminating in a 25% reduction in transmission
Scenarios – FallWinter2020 Description

September 2020 – February 2021 saw a strong wave of transmission

• We analyze previous Fall-Winter’s wave vs. current Delta driven wave and observe surprising similarities
  • The distribution of fitted model transmissibility is nearly identical between these periods when corrected for Delta’s increased transmissibility

• FallWinter2020 tries to capture the “transmission drivers” from the past and use them as if they were to occur again this season but with Delta variant (compared to ancestral)
  • Use the above analysis of fitted model transmissibilities from Sept 2020 – Feb 2021 to guide the future transmissibility from Sept 2021 through Feb 2022, but add the enhanced transmissibility of Delta back in

Fitting:
Black line represents the coarsely fitted base transmissibility

* “Last year” is transplanted into 2021-22

Delta enhanced:
Blue trajectory represents current fitted and then projected transmissibility in FallWinter2020
Scenarios – Vaccination Conditions

Vaccine Characteristics
• **Pfizer/Moderna**: 50% after first dose, 95% after second dose (3.5 week gap) J & J : 67% efficacy after first dose
• Delay to efficacy from doses is 14 days, immunity lasts at least 7m ([NEJM study](NEJM))

Vaccine Administration Scenarios
• **Status quo (no label)**: COVIDcast corrected acceptance estimates (statewide mean is ~80% adults, 65% of population) reached by end of October.
• **Optimistic (VaxOpt)**: Expand VA mean acceptance to include ”probably not” (~85% adults) with addition of childhood (5-11 yo) rollout starting in Nov 1st. This follows the same rates as observed of adolescents and results in a net increase of ~10% of population by end of February. Additionally, all counties guaranteed to reach a minimum of 65%, max of 95% by end of October
• Acceptance at county level = regional acceptance +/- relative current vax
• Front-loaded rollout (two-thirds of the remaining in half the time)
# Projection Scenarios – Combined Conditions

<table>
<thead>
<tr>
<th>Name</th>
<th>Txm Controls</th>
<th>Vax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive</td>
<td>C</td>
<td>SQ</td>
<td>Likely trajectory based on conditions remaining similar to the current experience</td>
</tr>
<tr>
<td>Adaptive-VaxOpt</td>
<td>C</td>
<td>VO</td>
<td>Vaccination through October reaches an optimistically high level of expanded coverage (85%)</td>
</tr>
<tr>
<td>Adaptive-SurgeControl</td>
<td>25%</td>
<td>SQ</td>
<td>Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta</td>
</tr>
<tr>
<td>Adaptive-FallWinter2020</td>
<td>FallWinter 2002</td>
<td>SQ</td>
<td>Transmission rates coarsely follow the rates from last September through this February but are boosted by Delta’s enhanced transmissibility</td>
</tr>
</tbody>
</table>

**Transmission Controls:**
- C = Current levels persist into the future
- 25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
- FallWinter2020 = Transmission rates from Sept 2020 – Feb 2021 are coarsely replayed but boosted by Delta’s increased transmissibility

**Vaccinations:**
- SQ = Status quo acceptance leads to low rates of vaccination through the summer
- VO = Vaccination acceptance optimistically expands with increased rates through the summer
Model Results
Outcome Projections

Confirmed cases
Virginia Daily Confirmed - Comparison

- Adaptive-SurgeControl
- Adaptive
- Adaptive-VaxOpt
- Adaptive-FallWinter2020
- Adaptive-FallWinter2020-VaxOpt

Estimated Hospital Occupancy

Death ground truth from VDH “Event Date” data, most recent dates are not complete
Outcome Projections – Closer Look

Confirmed cases

Virginia Daily Confirmed - Comparison

- Adaptive-SurgeControl
- Adaptive
- Adaptive-VaxOpt
- Adaptive-FallWinter2020
- Adaptive-FallWinter2020-VaxOpt

Daily Hospitalized

Death ground truth from VDH “Event Date” data, most recent dates are not complete
District Level Projections: Adaptive

Projections by Region

Near SW
Northwest
Northern
Far SW
Central
Eastern

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-VaxOpt

Projections by Region

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-SurgeControl

Projections by Region

- Near SW
- Northwest
- Northern
- Far SW
- Central
- Eastern

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-FallWinter2020

Projections by Region

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-FallWinter2020-VaxOpt

**Projections by Region**

- Near SW
- Northwest
- Northern
- Far SW
- Central
- Eastern

**Projections by District**

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario.
Impact of expanded vaccine acceptance

Expanded Vax coverage with higher adult coverage & 5-11 year olds in Nov

• Even with declining transmission rates coming off of a Delta wave, expanded vax coverage can reduce case counts by ~140K, in addition to providing further resilience to future waves

• Expanded vaccination coverage including children can further curtail the impact of a Fall Winter Surge by up to ~240K cases
Virginia’s Progress on Population Immunity

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

• Duration of immunity from infection with SARS-CoV2 still not well understood
  • We assume a conservative 6 month period of protection for these calculations
  • Do not factor in variant immune escape
  • Natural immunity is well calibrated to recent seroprevalence surveys

• 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 variants

• Population immunity depends on a very high proportion of the population getting vaccinated
  • Current models track measured seroprevalence

Region % pop immune (est.)*

Central 62%
Eastern 58%
Far SW 54%
Near SW 56%
Northern 66%
Northwest 61%
Virginia 61%

* As of Sept 19, 2021 (updated to account for entire population)
Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive FallWinter2020
COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

Adaptive FallWinter2020 scenario shows that even with Delta enhanced severity:
• No regions should exceed their surge capacities
• Some regions may exceed initial capacities
* Assumes average length of stay of 8 days

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

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

- **Case rate growth in Virginia has slowed, trends are very mixed across districts with majority also showing slow growth; case rates remain high as we may be cresting the peak of the Delta wave**
- **VA 7-day mean daily incidence is slightly down to 42/100K from 43/100K; US is also slightly down to 48/100K (from 50/100K)**
- **Projections show a plateau and declining incidence in the near term, scenario based on last year’s transmission drivers show that significant future case growth remains possible**
- **Recent updates:**
  - Added FallWinter2020 scenario which replays the transmission drivers of last Fall-Winter season
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

The situation continues to change. Models continue to be updated regularly.
Additional Analyses
Estimating Daily Reproductive Number – Redistributed weekend gap

Sept 13\textsuperscript{th} Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed</th>
<th>$R_e$</th>
<th>Date Confirmed Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td></td>
<td>0.984</td>
<td>-0.019</td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td>0.942</td>
<td>0.034</td>
</tr>
<tr>
<td>Eastern</td>
<td></td>
<td>0.939</td>
<td>0.034</td>
</tr>
<tr>
<td>Far SW</td>
<td></td>
<td>1.070</td>
<td>0.134</td>
</tr>
<tr>
<td>Near SW</td>
<td></td>
<td>1.043</td>
<td>0.024</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>1.014</td>
<td>0.100</td>
</tr>
<tr>
<td>Northwest</td>
<td></td>
<td>0.983</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Skipping Weekend Reports biases estimates
Redistributed Monday to fill in weekend, and then estimate $R$ from "smoothed" time series

Virginia

Methodology

- Wallinga-Teunis method (EpiEstim\textsuperscript{1}) 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

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

• **Scenario Modeling Hub**: Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios

• **Genomic Surveillance**: Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.

• **Mobility Data driven Mobile Vaccine Clinic Site Selection**: Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify
COVID-19 Scenario Modeling Hub

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 impact of the Delta variant (high and low)

• Round 9 released to assist in support of 5-11 vax consideration (ACIP meeting Sept 22-23)

• Rounds 4-8 now available

Round 4 Results were published May 5th, 2021 in **MMWR**

[https://covid19scenariomodelinghub.org/viz.html](https://covid19scenariomodelinghub.org/viz.html)
COVID-19 Scenario Modeling Hub – Round 7

Round 7 scenarios explore the effects of a variant similar to Delta (B.1.617.2) against different backgrounds of vaccination. Includes some vax escape

**Vaccinations in 5-11 start in Nov**
- Follows same rates as adolescents

**Emerging Variant Impact** (5% prevalence on Nov 15)
- 50% boost as it eventually predominates

[https://covid19scenariomodelinghub.org/viz.html](https://covid19scenariomodelinghub.org/viz.html)
Modeling Hub – Round 9 Prelim Results

US National Daily Confirmed - Comparison

- noChildVax_noVar
- ChildVax_noVar
- noChildVax_Var
- ChildVax_Var

Projected Incident Cases by Epidemiological Week and by Scenario for Round 7

[Visualization showing projected incident cases by epidemiological week and scenario for Round 7.]

View: Ensemble

https://covid19scenariomodelinghub.org/viz.html
Data Recommended Mobile Vax Clinic Sites

Detailed and Timely Locations

Data Delivered and Disseminated to Locals
Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors.

Demographic Groups: Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

Data Included: Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of location in the Southside frequented by 20-40 year olds
Overlap of locations between groups

State Level

Different groups visit different areas
- Least overlap between Black and Latinx
- Overlap in ages highest, but drops with large gaps
- Districts have different overlap patterns
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?

Biocomplexity COVID-19 Response Team

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22-Sep-21
Supplemental Slides
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