Estimation of COVID-19 Impact in Virginia

September 1st, 2021
(data current to August 28th – 31st)
Biocomplexity Institute Technical report: TR 2021-098
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 rates in Virginia continue to rise though the pace remains steady while initial surge states have peaked, case rates remain very high**
- VA mean weekly incidence up to 37/100K from 30/100K, US up to 48/100K (from 44/100K)
- Growth in vaccination rates remain higher than June and July with slight uptick
- Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact
- Recent updates:
  - Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination
  - Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall

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 30% of counties with TPR > 10%

**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

### District Trajectories

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Description</th>
<th>Weekly Case Rate (per 100K) bounds</th>
<th># Districts (prev week)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Declining</strong></td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Plateau</strong></td>
<td>Steady level with minimal trend up or down</td>
<td>above -0.9 and below 0.5</td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Slow Growth</strong></td>
<td>Sustained growth not rapid enough to be considered a Surge</td>
<td>above 0.5 and below 2.5</td>
<td>3 (2)</td>
</tr>
<tr>
<td><strong>In Surge</strong></td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>32 (33)</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>0 (0)</td>
</tr>
<tr>
<td>Plateau</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>3 (3)</td>
</tr>
<tr>
<td>In Surge</td>
<td>32 (32)</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

August 30th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed R_e</th>
<th>Date Confirmed</th>
<th>Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>1.111</td>
<td>-0.007</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>1.109</td>
<td>-0.028</td>
<td></td>
</tr>
<tr>
<td>Eastern</td>
<td>1.071</td>
<td>-0.021</td>
<td></td>
</tr>
<tr>
<td>Far SW</td>
<td>1.107</td>
<td>-0.010</td>
<td></td>
</tr>
<tr>
<td>Near SW</td>
<td>1.107</td>
<td>-0.017</td>
<td></td>
</tr>
<tr>
<td>Northern</td>
<td>1.113</td>
<td>0.023</td>
<td></td>
</tr>
<tr>
<td>Northwest</td>
<td>1.164</td>
<td>0.027</td>
<td></td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim<sup>1</sup>) 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

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>78%</td>
<td>68%</td>
</tr>
<tr>
<td>Eastern</td>
<td>75%</td>
<td>64%</td>
</tr>
<tr>
<td>Far SW</td>
<td>64%</td>
<td>54%</td>
</tr>
<tr>
<td>Near SW</td>
<td>68%</td>
<td>60%</td>
</tr>
<tr>
<td>Northern</td>
<td>89%</td>
<td>78%</td>
</tr>
<tr>
<td>Northwest</td>
<td>75%</td>
<td>67%</td>
</tr>
<tr>
<td>Virginia</td>
<td>79%</td>
<td>69%</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 has risen as vaccination rates have climbed

- Corrected Acceptance reflects the daily measured overall acceptance and has risen in the past couple days
- Unvaccinated Acceptance shows ~10% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Unvax acceptance has declined a bit and leveled off in last couple of weeks, final 10% may be waiting for FDA approval

Data Source: 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
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](https://covidcast.cmu.edu)
Reasons for Hesitancy of Probably No by Region

Near SW

Northwest

Northern

Far SW

Central

Eastern

Reasons for Hesitancy vary across Regions

- Side effects and waiting to see safety are primary
- Most movement in last couple weeks seen in trust of govt and efficacy

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 (64% vs. 62%)
- Progress in some counties has stalled or declined

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

- Slight decline for Definitely Yes, Probably Yes, and Probably No

- Vaccinated slightly higher in mask wearing than unvaccinated

Data Source: 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

<table>
<thead>
<tr>
<th>New WHO Name</th>
<th>Transmissibility</th>
<th>Immune Evasiveness</th>
<th>Vaccine Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancestral</td>
<td>−−</td>
<td>−−</td>
<td>✓</td>
</tr>
<tr>
<td>D614G</td>
<td>+</td>
<td>−−</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.1.7 Alpha</td>
<td>+++</td>
<td>−</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.351 Beta</td>
<td>+</td>
<td>+++</td>
<td>✓</td>
</tr>
<tr>
<td>P.1 Gamma</td>
<td>++</td>
<td>++</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.429 Epsilon</td>
<td>+</td>
<td>+</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.526 Iota</td>
<td>+</td>
<td>+</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.617.2 Delta</td>
<td>+++*</td>
<td>++#</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Relative transmissibility to B.1.1.7 yet to be fully defined
†Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1-dose of mRNA or AZ is only ~30% effective ‡May carry more immune escape than P.1, to be determined

WHO and Eric Topol
SARS-CoV2 Variants of Concern

**Alpha α - Lineage B.1.1.7**

**Prevalence:** Nationally low, decline from a high of 60% (VA reached about 80%)

**Transmissibility:** Estimated increase of 50% compared to previous variants. B.1.1.7’s mutations boost its overall levels of viremia; study from Public Health England shows contacts of B.1.1.7 cases are more likely (50%) to test positive

**Severity:** Increased risk of hospitalization (60%) and mortality (60%). 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 estimates 60% higher mortality

**Beta β - Lineage B.1.351**

**Prevalence:** Levels have remained low, as this variant’s transmissibility can’t compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

**Immune Escape:** Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is predictive of protection, however, vaccine induced immunity shows signs of effectiveness

**Gamma γ - Lineage P.1**

**Prevalence:** Nationally low, declining from a high of 12%

Study estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain data from Brazil demonstrating P.1’s continued dominance in Rio despite presence of B.1.1.7
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 (9%) and AY.4 (4%) of Delta are more prevalent, these subvariants are mainly may be more transmissible than Delta itself
Variants & Vaccines

1. Israeli study shows that natural immunity provides stronger protection (13x) against the Delta variant and potentially wanes less rapidly
2. School study in France demonstrates the benefits of weekly screening of students compared to symptom based testing
3. Scotland’s return to school following their large delta wave seems to be driving another surge, significant number of cases in the 15-19 range
4. Analysis of household transmission pairs in Singapore suggest that the serial interval for delta variant is similar to other Variants, thus transmission boost is mainly from increased infectivity

Using empirical contact data measured in a primary and a secondary school in France, and field estimates for adherence to screening from 683 schools during the spring 2021 wave, this France based study examines different screening protocols, using a cost-benefit analysis for varying epidemic conditions and vaccination scenarios. In a partially immunized school population, weekly screening would reduce the number of cases on average by 24% in the primary and 53% in the secondary school compared to symptom-based testing alone, if $R=1.3$ and 50% adhered to screening.

https://www.medrxiv.org/content/10.1101/2021.08.15.21262415v1.full.pdf

Recent Israel based study found vaccinees with no prior infection had a 13.06-fold (95% CI, 8.08 to 21.11) increased risk for breakthrough infection with the Delta variant compared to those previously infected, when the first event (infection or vaccination) occurred during January and February of 2021. The increased risk was significant ($P<0.001$) for symptomatic disease as well.

https://www.medrxiv.org/content/10.1101/2021.08.24.21262415v1

Using empirical contact data measured in a primary and a secondary school in France, and field estimates for adherence to screening from 683 schools during the spring 2021 wave, this France based study examines different screening protocols, using a cost-benefit analysis for varying epidemic conditions and vaccination scenarios. In a partially immunized school population, weekly screening would reduce the number of cases on average by 24% in the primary and 53% in the secondary school compared to symptom-based testing alone, if $R=1.3$ and 50% adhered to screening.

https://www.medrxiv.org/content/10.1101/2021.08.15.21261243v1.full.pdf

After controlling for confounding factors, our findings suggest no significant changes in the serial intervals for SARS-CoV-2 cases infected with the B.1.617.2 variant. This, in turn, lends support for the hypothesis of a higher $R$ in B.1.617.2 cases.

https://www.medrxiv.org/content/10.1101/2021.06.04.21258205v1.full-text

Scottish return to school potentially contributing to increase in cases. Overall in worse shape than 2020 heading into Fall.

https://twitter.com/chrischirp/status/1431312408631410691
Variant of Concern Trajectories
Other State Comparisons

Trajectories of States

- Most of the country remains in Surge, but several states have peaked and are now in decline
- Case rates remain high, but pace of growth has slowed

Virginia and her neighbors

- VA and many neighbors continue to surge
- Many neighbors are in surge and have reached very high case rates
Age-Specific Case Rates

Case Rates (per 100K) by Age Groups

- Rapid growth in many regions in the 0-19 age range
- Case Rate in under 40 group far exceeds 40+ in all districts
Hospitalizations across the US

Hospitalization rates remain low in VA, but rapid change is possible as seen in other states

- Hotspot states see rapid rise in hospitalizations especially among the younger age groups
- Nationally pediatric hospitalizations are at an all time high since the pandemic began

Source: https://covid.cdc.gov/covid-data-tracker/#new-hospital-admissions
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 14th out of 51 states in fully vaccinated coverage

Virginia Counties
• Counties with higher vax coverage are maintaining lower case rates (e.g., Albemarle, Fairfax city)
• Many counties with low vax coverage starting to rise as Delta surge reaches more remote areas of state
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Clusters of high prevalence in Southwest and Eastern
- 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>24631</td>
<td>Oakwood</td>
<td>3,890</td>
</tr>
<tr>
<td>2</td>
<td>24431</td>
<td>Crimora</td>
<td>2,540</td>
</tr>
<tr>
<td>3</td>
<td>24314</td>
<td>Bastian</td>
<td>1,840</td>
</tr>
<tr>
<td>4</td>
<td>23301</td>
<td>Accomac</td>
<td>1,770</td>
</tr>
<tr>
<td>5</td>
<td>23967</td>
<td>Saxe</td>
<td>1,750</td>
</tr>
<tr>
<td>6</td>
<td>24479</td>
<td>Swoope</td>
<td>1,710</td>
</tr>
<tr>
<td>7</td>
<td>24472</td>
<td>Raphine</td>
<td>1,680</td>
</tr>
<tr>
<td>8</td>
<td>24312</td>
<td>Austinville</td>
<td>1,640</td>
</tr>
<tr>
<td>9</td>
<td>24422</td>
<td>Clifton Forge</td>
<td>1,640</td>
</tr>
<tr>
<td>10</td>
<td>23417</td>
<td>Onancock</td>
<td>1,630</td>
</tr>
</tbody>
</table>

Point Prevalence by Zip Code (2021-08-28)

Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-28.

University of Virginia
Biocomplexity Institute
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 17 in Oakwood, there is a 50% chance someone will be infected)

From Last Week

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code Name</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24631 Oakwood</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>24431 Crimora</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>24314 Basilian</td>
<td>37</td>
</tr>
<tr>
<td>4</td>
<td>23301 Accommac</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>23967 Saxe</td>
<td>39</td>
</tr>
<tr>
<td>6</td>
<td>24479 Swoope</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>24472 Raphine</td>
<td>41</td>
</tr>
<tr>
<td>8</td>
<td>24312 Austinvillie</td>
<td>42</td>
</tr>
<tr>
<td>9</td>
<td>24422 Clifton Forge</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>23417 Onancock</td>
<td>42</td>
</tr>
</tbody>
</table>

Group Size Needed for 50% Likelihood of ≥1 Infected

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code Name</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>390</td>
</tr>
<tr>
<td></td>
<td></td>
<td>390</td>
</tr>
<tr>
<td></td>
<td>High : 450+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>390</td>
<td></td>
</tr>
<tr>
<td></td>
<td>330</td>
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</tr>
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<td></td>
<td>270</td>
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<td></td>
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<tr>
<td></td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low : 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NaN</td>
<td></td>
</tr>
</tbody>
</table>

*Only includes cases with zip ≥ 150 and no suppressing data.

* Denotes zip codes with state prisons.
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 far southwest (Wise & Dickinson Counties) and south of Richmond (Lunenburg and Prince Edward to Surry Counties)

- **HCW Ratio**: HCW Prevalence / Total Case Prevalence
  - (blue = higher case rate among public, red = higher case rate among HCW)
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.
Non-COVID Respiratory Illness Update

Other Respiratory Viruses on the rise and are on way towards a much earlier than usual flu and cold season

- Very little true Influenza detected still, mostly other respiratory viruses
- Much higher non-COVID ILI activity now compared to previous decade
- Southeast is already above ILI season threshold, driven by RSV
- Virginia is currently at ~2.4% ILI activity which is similar to early Nov 2017 (last very strong influenza season)

Virginia ILI 2020-21  Virginia RSV 2019-21

Data & Images: CDC FluView
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 17.1% [13.1% – 21.4%] seroprevalence as of June 15th – 30th up from 15.8% 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 were consistent earlier in the pandemic were being used)

http://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 8:45am September 1, 2021
https://www.vdh.virginia.gov/coronavirus/
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

• Projection Scenario:
  • **Adaptive:** Control remains as is currently experienced into the future with assumption that Delta remains as the majority strain
  • **Adaptive-Fall:** Control remains as is currently experienced into the future, with an increase in transmission that is 20% stronger than the highest experienced in Fall-Winter of 2020-21 starting on Nov 1st
  • **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
  • **Adaptive-SpringControl:** Immediate return to the mean levels of transmission experienced in May 2021
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)

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 rollout starting in November further boosting 10% of population by end of January. Also, all counties reaching 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)
Scenarios – Delta $\delta$ Variant Condition

Variant Delta $\delta$ has exhibited ability to outcompete other variants and now is nearly the sole variant in the US and most states.

**Transmissibility:** Delta’s relative transmissibility compared to Alpha is better understood (60% more transmissible) and its weighted growth fits a 60% growth advantage well.

**Immune Escape:** Delta has been observed to evade immunity, both natural and vaccine-induced, however, uncertainty remains high thus this is **NOT** factored into the model.

**Severity:** Delta, similar to Alpha, appears to cause more severe disease (estimates range from 50-200%), model assesses severity in last month and assumes this remains constant into the future.

**Variant is stable, thus captured by Adaptive Scenario:**

- Delta now accounts for nearly all sequenced variants, subvariants AY.3 and AY.4 are growing.
## Projection Scenarios – Combined Conditions

<table>
<thead>
<tr>
<th>Name</th>
<th>Txm Controls</th>
<th>Fall Boosted Txm</th>
<th>Vax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive</td>
<td>C</td>
<td>No</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>No</td>
<td>VO</td>
<td>Vaccination through October reaches an optimistically high level of expanded coverage (85%)</td>
</tr>
<tr>
<td>Adaptive-Fall</td>
<td>C</td>
<td>Yes</td>
<td>SQ</td>
<td>Same as Adaptive, with increased transmissibility driven by seasonality and/or another variant starting Nov 1st</td>
</tr>
<tr>
<td>Adaptive-Fall-VaxOpt</td>
<td>C</td>
<td>Yes</td>
<td>VO</td>
<td>Optimistically expand vaccination with increased transmissibility driven by seasonality and/or another variant starting Nov 1st</td>
</tr>
<tr>
<td>Adaptive-SurgeControl</td>
<td>25%</td>
<td>No</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-SpringControl</td>
<td>Spring</td>
<td>No</td>
<td>SQ</td>
<td>Transmission rates return to rates experienced in May 2021 with status quo vaccination and increasing prevalence of Delta</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
- Spring = Transmission rates return to May 2021 levels

**Fall Boosted Txm:**
- No = No boosting of transmission later in the Fall or Winter
- Yes = Transmission rate increases to 20% more than the worst of Fall-Winter 2020-21 on Nov 1st

**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
Outcome Projections

Confirmed cases
Virginia Daily Confirmed - Comparison

- Adaptive
- Adaptive-VaxOpt
- Adaptive-SpringControl
- Adaptive-Fall
- Adaptive-Fall-VaxOpt
- Adaptive-SurgeControl

Estimated Hospital Occupancy

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

Daily Hospitalized
District Level Projections: Adaptive

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-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

Universities

BIOCOMPLEXITY INSTITUTE
District Level Projections: 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: SpringControl

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-Fall

Projections by Region

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

Projections by District

- Alleghany
- Blue Ridge
- Chickahominy
- Henrico
- Three Rivers
- Eastern Shore

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario.
District Level Projections: Adaptive-Fall-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 to higher overall adult coverage and with 5-11 rollout in November

• Even if transmission rates decline after a Delta wave, expanded vax coverage can reduce case counts by ~30K, in addition to providing further resilience to future waves

• A Fall Surge can rebound declining rates following the Delta wave

• Expanded vaccination coverage including children can further curtail the impact of a Fall Surge by up to 120K 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

<table>
<thead>
<tr>
<th>Region</th>
<th>% pop immune (est.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>58%</td>
</tr>
<tr>
<td>Eastern</td>
<td>55%</td>
</tr>
<tr>
<td>Far SW</td>
<td>49%</td>
</tr>
<tr>
<td>Near SW</td>
<td>52%</td>
</tr>
<tr>
<td>Northern</td>
<td>64%</td>
</tr>
<tr>
<td>Northwest</td>
<td>57%</td>
</tr>
<tr>
<td>Virginia</td>
<td>58%</td>
</tr>
</tbody>
</table>

* As of August 29, 2021 (updated to account for entire population)
Hospital Demand and Bed Capacity by Region

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

Adaptive scenario shows that even with Delta enhanced severity:
• No regions should exceed their 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 rates in Virginia continue to rise though the pace remains steady while initial surge states have peaked, case rates remain very high**
  - VA mean weekly incidence up to 37/100K from 30/100K, US up to 48/100K (from 44/100K)
  - Growth in vaccination rates remain higher than June and July with slight uptick
  - Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact

- Recent updates:
  - Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination
  - Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall

- The situation continues to change. Models continue to be updated regularly.
Additional Analyses
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 8 in planning
- Round 7 now available

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

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 by Nov 30**
- LowVacc – 70% overall coverage
- HighVacc – 80% overall coverage

**Emerging Variant Impact** (5% prevalence on May 29th)
- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

---

### Table: Wet and Dry Transmissibility

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Low Var</th>
<th>High Var</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vaccination:</strong></td>
<td></td>
<td></td>
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<tr>
<td>High Vacc (Low hesitancy)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Scenario A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaccination:</td>
<td></td>
<td></td>
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<tr>
<td>- Coverage saturates at 80%</td>
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<tr>
<td>nationally among the vaccine-</td>
<td></td>
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<tr>
<td>eligible population* by</td>
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<tr>
<td>December 31, 2021**</td>
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<tr>
<td>- VE is 50%/90% for</td>
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<tr>
<td>Delta variant, against</td>
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<tr>
<td>symptoms (1st/2nd dose)</td>
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<tr>
<td>- JS no longer used</td>
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<tr>
<td><strong>Scenario B</strong></td>
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<tr>
<td><strong>Scenario C</strong></td>
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<tr>
<td>Vaccination:</td>
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<td></td>
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<tr>
<td><strong>Scenario D</strong></td>
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<tr>
<td>- JS no longer used</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: VE = vaccine efficacy, JS = Johnson & Johnson.
Modeling Hub – Round 7 Prelim Results

Virginia Daily Confirmed - Comparison

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

https://covid19scenariomodelinghub.org/viz.html
COVID-19 Scenario Modeling Hub – Round 8 (ongoing)

Round 8 scenarios targeted at exploring the effect of waning immunity (natural and vaccine-induced) and varying levels of protection after waning

Waning Rates

- Slow – exp. waning with mean=3yrs
- Fast – exp. waning with mean=1yr
- No waning (Sc A) as baseline

Protection after Waning

- Age stratified protection from infection
- 80% or 90% protection from hosp/death

**Slow Waning**

**Fast Waning**

<table>
<thead>
<tr>
<th>High Protection</th>
<th>Slow waning of natural and vaccine-induced immunity (from no waning to exponential waning with mean of 3 yrs)</th>
<th>Fast waning of natural and vaccine-induced immunity (exponential waning with mean of 1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Waning:</td>
<td>- Vaccine-induced and natural immunity retain their initial protection throughout the simulation period</td>
<td>Waning: - Exponentially distributed immune waning with mean of 1 year (time to transition to partially immune state)</td>
</tr>
<tr>
<td>In partially immune state:</td>
<td>- Protection from infection is:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 70% ≤ 65yrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 35% &gt; 65yrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Protection from hospitalization and death is 90%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low Protection</th>
<th>Exponentially distributed immune waning with mean of 3 years (time to transition to partially immune state)</th>
<th>Exponentially distributed immune waning with mean of 1 year (time to transition to partially immune state)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In partially immune state:</td>
<td>- Protection from infection is:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 50% ≤ 65yrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 25% &gt; 65yrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Protection from hospitalization and death is 80%</td>
<td></td>
</tr>
</tbody>
</table>

[https://covid19scenariomodelinghub.org/](https://covid19scenariomodelinghub.org/)
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.
Data Recommended Mobile Vax Clinic Sites

Overlap of locations between groups

State Level

<table>
<thead>
<tr>
<th>Group</th>
<th>Age 20-30</th>
<th>Age 20-40</th>
<th>Age 30-40</th>
<th>Whole Population</th>
<th>Race Black</th>
<th>Ethnicity Latinx</th>
<th>Unvaccinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>19</td>
<td>16</td>
<td>18</td>
<td>10</td>
<td>9</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Latinx</td>
<td>19</td>
<td>23</td>
<td>22</td>
<td>18</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Whole Population</td>
<td>18</td>
<td>22</td>
<td>25</td>
<td>8</td>
<td>8</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>Percent Overlap</td>
<td>-5</td>
<td>10</td>
<td>25</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>25</td>
</tr>
</tbody>
</table>

Different groups visit different areas

- Least overlap between Black and Latinx
- Overlap in ages highest, but drops with large gap
- Districts have different overlap patterns

2-Sep-21
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
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