The Current State of COVID-19 in Colorado

03/10/2021

Prepared by the Colorado COVID-19 Modeling Group

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Summary

- The effective reproduction number remains below 1 at 0.73, while transmission control has increased to ~82%.
- Estimated current infection prevalence is 1 in 354 people in Colorado and has declined since last week.
- If Colorado remains on the current trajectory, state-wide hospital demand and infection prevalence will continue to decline. Infection prevalence will be comparable to last summer by late April.
- The benefits of vaccination continue to be realized. We estimate approximately 22% of Coloradans are currently immune due to vaccination and/or prior infection.
- Maintaining transmission control at the current level for at least 4 weeks will avoid a substantial burden of infection and deaths, compared with a drop now or in 2 weeks.
- The continued growth of the B.1.1.7 variant and the discovery of B.1.351 is cause for concern. Transmission control measures, rapid vaccine roll out and high vaccine uptake will be important for preventing deaths and increases in hospital demands if B.1.1.7 and/or other variants spread rapidly in Colorado.
- Infections appear to be increasing in some of the mountain regions. And spring break is beginning…

Snapshot of Current SARS-CoV-2 Transmission in Colorado Based on COVID-19 Hospitalization Data Through 03/08

Effective reproduction number: 0.73. *Infections are decreasing.*

Estimated prevalence of infections: Approximately 280 of every 100,000 Coloradans or 1 in every 354 Coloradans are currently infectious.

Estimated percent of the population immune: Approximately 22% of Coloradans are immune due to vaccination or prior infection.

Estimated percent of the population vaccinated: Approximately 18% of Coloradans have received at least one dose of a SARS-CoV-2 vaccine.

Introduction

We used our age-structured SEIRV (susceptible-exposed-infected-recovered-vaccinated) model and real-time COVID-19 hospital census, vaccination, and case data to characterize the current status of the COVID-19 epidemic in Colorado. We use estimates of the current state of the epidemic to generate projections of the potential future course of SARS-CoV-2 in Colorado under different scenarios of vaccine roll out, spread of variants of concern and transmission control measures. These include estimates of hospital needs, infections, and deaths under these different scenarios.

The model has been parameterized to Colorado-specific data whenever possible. For example, the length of time a COVID-19 patient is assumed to spend in the hospital varies by age and over time, and is based on data provided by Colorado hospitals. Links to model details are provided in the appendix at the end of this report.

The estimates presented in this report are based on hospitalization census data through 03/08 and vaccination data through 03/07.

Model Updates

Several model updates were implemented in recent weeks.

1. We now assume vaccination is 52% effective at preventing transmission 14 days after the first dose of the Pfizer and Moderna vaccines based on recent evidence of the impact of the first dose on infection (Dagan et al 2021 NEJM). We continue to assume the vaccine is 90% effective one week after the second dose.
2. We have removed the ICU compartment from the model and now group all COVID-19 hospitalizations together. This modification improves model efficiency and requires fewer assumptions, as the proportion of hospitalized COVID-19 patients requiring ICU care has declined over time.
3. Hospitalization rates appeared to decline over the summer, and recent data suggest hospitalization rates increased in the oldest age group in the fall. To account for this, hospitalization rates by age after September 30th were refit to COPHS data through February 2021, which results in modest changes in prevalence estimates over time.

These changes have led us to re-fit our models and update parameter estimates. These changes are detailed in the documentation linked in the appendix.

COVID-19 Hospitalizations

Figure 1 shows the daily number of people hospitalized with COVID-19 since March 2020, when the first case of SARS-CoV-2 was reported in Colorado. COVID-19 hospitalizations are a sensitive measure of SARS-CoV-2 transmission. While many SARS-CoV-2 infections are not captured by surveillance systems, we expect that almost all COVID-19 hospitalizations are identified.

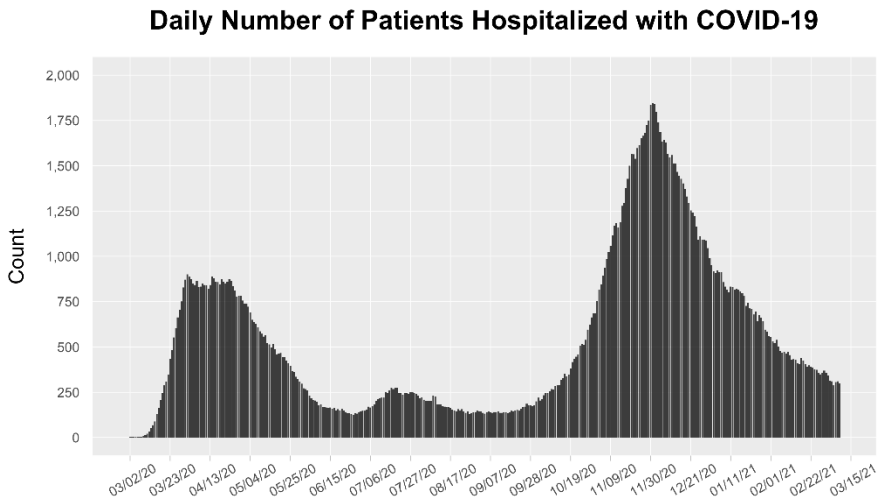


Figure 1 (above). Daily count of hospitalized COVID-19 cases through 03/08. The time series of COVID-19 hospitalizations in Colorado is based on hospitalization data provided by CDPHE through 4/07/2020 and the EMResource hospital census of COVID-19 hospitalizations starting 4/08/2020 (EMResource hospital census appeared to undercount COVID-19 hospitalizations before that date).

Transmission Control

Transmission control is an estimate of the collective impact of behaviors and policies such as mask wearing, physical distancing, case isolation, contact tracing, and moving activities outside on slowing the spread of infections from infected to susceptible individuals. When transmission control is 0%, spread of infections is uncontrolled, as in the very early days of the pandemic. When transmission control is close to 100%, the spread of the virus from an infected person to others is rare. We estimate transmission control for each two-week period since March 2020 (Figure 2). Transmission control is estimated by aligning model output to hospitalization data using model fitting approaches.

Our current estimate of transmission control is 82%. This estimate is for the period 02/13 to 02/23, given the lag between infection and hospitalization.

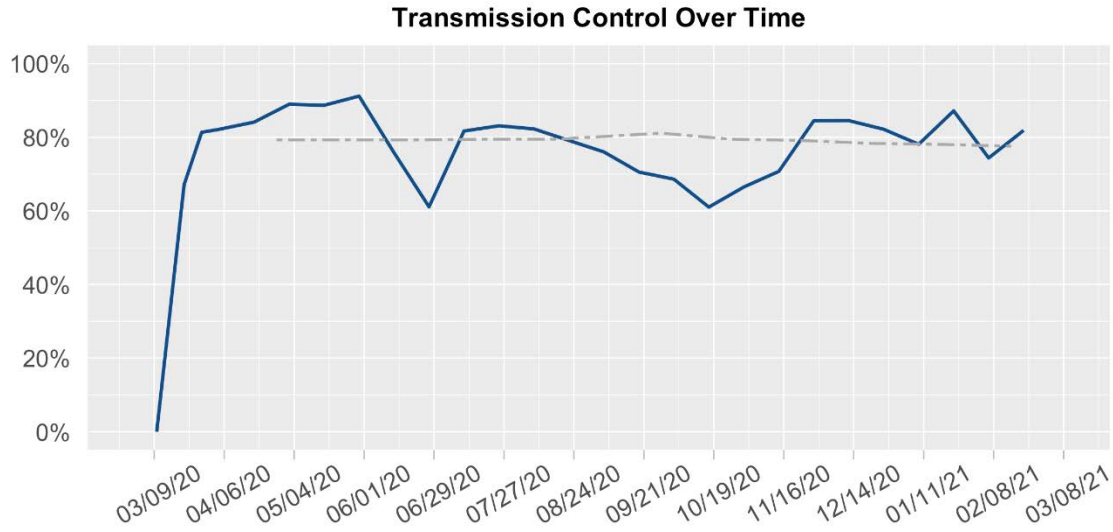


Figure 2 (above). The estimated transmission control value for each two-week period since the beginning of the epidemic. On the graph, the value is shown for the mid-point of each two-week period. Transmission control is estimated using model fitting approaches to align model output with COVID-19 hospitalizations. The grey dashed line indicates the estimated value of TC at which the effective reproduction number Re crosses 1.

Model Fit

We assess model fit by comparing the model-estimated number of hospitalizations to actual hospitalizations. Figure 3 shows the current estimated trajectory of hospitalizations, based on the most recent model-fit, compared to the daily reported number of people hospitalized with COVID-19. For reference, a line showing the estimated trajectory one-week prior is also shown. A figure showing model fit since the beginning of the pandemic is provided in the appendix.

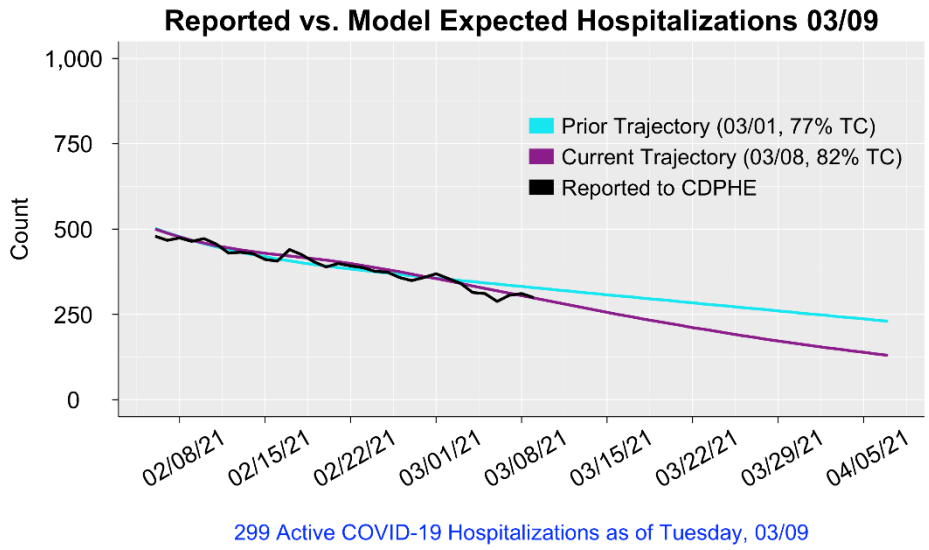


Figure 3 (above). The projected course of COVID-19 hospitalizations if Colorado were to remain on the current estimated trajectory (purple line) or on the trajectory estimated one week prior (turquoise line). Each trajectory is generated assuming Colorado rolls out vaccines on schedule, as described in the long-term projections.

The Effective Reproduction Number

The effective reproduction number (Re) is a measure of how rapidly infections are spreading or declining. When the effective reproduction number is below 1, infections are decreasing. When the effective reproduction number is above 1, infections are increasing. The effective reproduction number is estimated using our age-structured SEIR model fit to hospitalization data.

Our current estimate of Re is 0.73. Due to the lag between infections and hospitalizations, this estimate of Re reflects the spread of infections occurring on approximately 02/23. The estimated values of the reproduction number since March 2020 are shown in Figure 4.

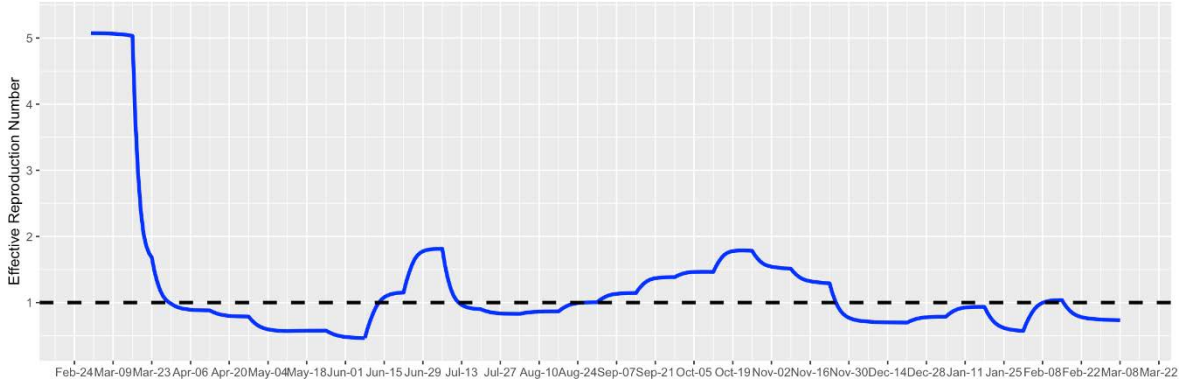


Figure 4 (above). Estimates of the effective reproduction number over time.

Infection Prevalence

Infection prevalence provides an estimate of the proportion of the population that is currently infected with SARS-CoV-2 and capable of spreading infections. At higher levels of infection prevalence, susceptible individuals are more likely to encounter infectious individuals among their contacts. Because many people experience no symptoms or mild symptoms of COVID-19, many infections are not identified by surveillance systems. The estimates we present here are intended to provide an approximation of all infections, including those not detected by the Colorado Electronic Disease Reporting System (CEDRS).

These estimates are generated using the model by assuming the most recent transmission control parameter (estimated for the period 02/13 to 02/23) remains at the estimated value through 03/08. These estimates are sensitive to the model assumptions, including assumptions about the probability an infected individual will be symptomatic and require hospital care, and assumptions about length of hospital stay, which vary by age.

We estimate that there are approximately 16,500 infectious individuals in Colorado at present (03/08): approximately 280 of every 100,000 Coloradoans or 1 in every 354 people. The estimated infection prevalence since March 2020 is shown in Figure 5.

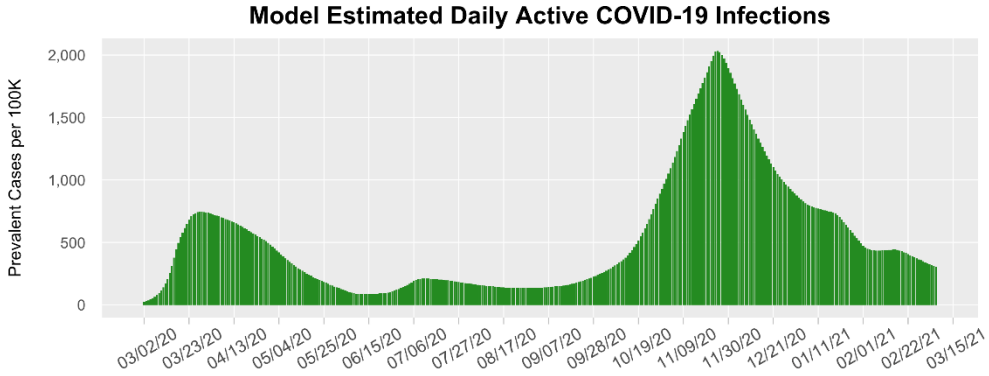


Figure 5 (above). Estimated daily number of people who are infectious and infected with SARS-CoV-2 (point prevalence). Estimate is shown per 100,000 population. The number of infectious individuals is inferred using the model and based on hospitalizations.

Case Detection

Comparing observed to model-estimated infections, **we estimate that approximately 37% of infections were detected by state surveillance systems, including both asymptomatic and symptomatic infections in the two- week period from 02/13 to 02/26** (Figure 6).

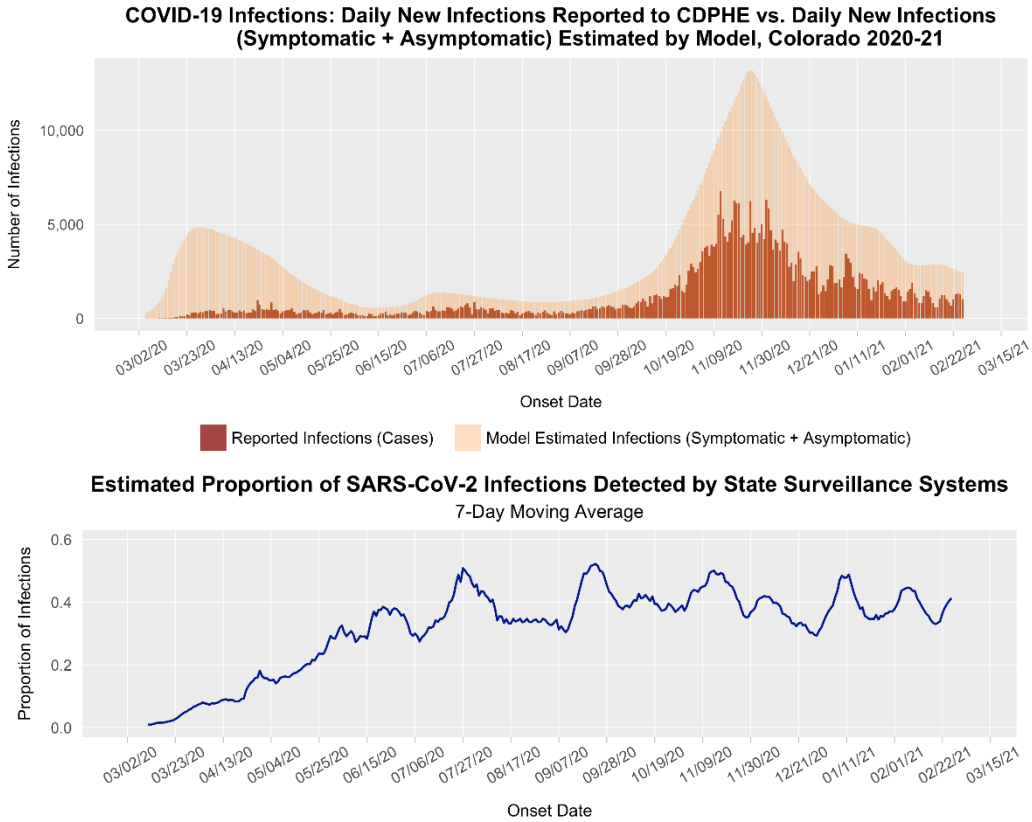


Figure 6 (above). Estimated daily number of new (incident) SARS-CoV-2 infections based on the total estimated by the SEIR model (light orange graph) and reported cases (dark orange graph) over time shown in the top panel. Lower panel shows the 7-day moving average of the estimated proportion of SARS-COV2 infections that are being captured by Colorado state surveillance systems, over time. The proportion detected is estimated by dividing the total number of new cases captured by state surveillance systems by the model-estimated number of new infections each day. The number of cases captured by the state surveillance systems is the number of cases reported by CDPHE, using the onset date of symptoms (if onset date is not available, onset date is imputed by CDPHE using a proxy distribution of recent onset dates). Data are shown through 02/26 to account for typical lags between symptom onset and case report.

Population Immunity

People can develop immunity to SARS-CoV-2 by vaccination and by prior infection. The proportion of the population immune is an important measure because as more people develop immunity, the spread of infections slows. When many people are immune, infectious individuals are less likely to encounter individuals who are still susceptible to infection (not immune).

Figure 7 shows the proportion of the population immune over time, estimated using our age-structured SEIR model and data on vaccinations in Colorado provided by CDPHE. This estimate has two components. It accounts for the number of people estimated to be immune due to vaccination (yellow line). In the model, the two-dose vaccines are assumed to be 52% effective at preventing infections 14 days after the first dose, and 90% effective one week after the second dose. Vaccination data by age are provided by CDPHE and we assume all individuals who receive first doses also receive second doses on schedule. This estimate also accounts for the number of people estimated to have immunity due to prior infection. In our model, immunity from symptomatic infection is assumed to last approximately one year, and immunity from asymptomatic infection is assumed to last approximately six months. This means people who were infected early in the pandemic may no longer be immune to infection unless they have been vaccinated. We include both detected and undetected infections. Our estimates account for overlap between the vaccinated population and those with immunity due to prior infection. We note that recent studies suggest vaccinations boost immunity in those previously infected.

We estimate that approximately 1,260,000 people in Colorado, or 22% of the Colorado population, are currently immune to SARS-CoV-2 as of 03/08.

In addition, we provide an estimate of the cumulative number of infections, noting that some people who were infected early in the pandemic may no longer be immune to infection unless they have been vaccinated. **We estimate that approximately 1,312,000 people in Colorado, or 22% of the population, have been infected to date (03/08).**

Projecting forward, Figure 8 shows theoretical herd immunity thresholds and the projected proportion of the population estimated to be immune through vaccination or prior infection at 70% TC through early June 2021.

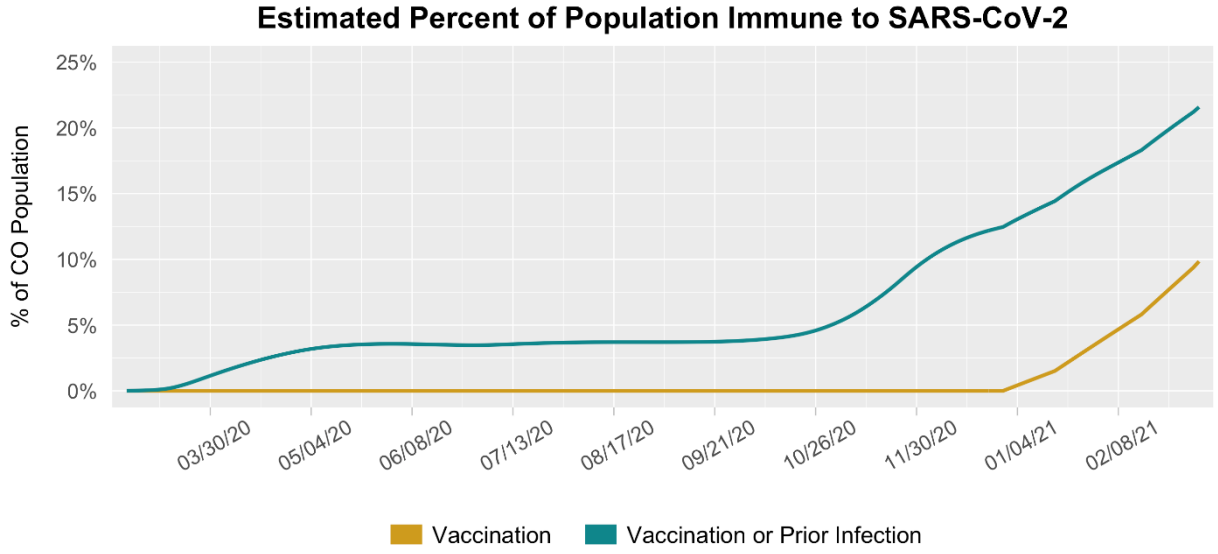


Figure 7 (above). Estimated percent of the population in Colorado assumed to be immune to SARS-CoV-2 due to infection and/or vaccination through 03/08.

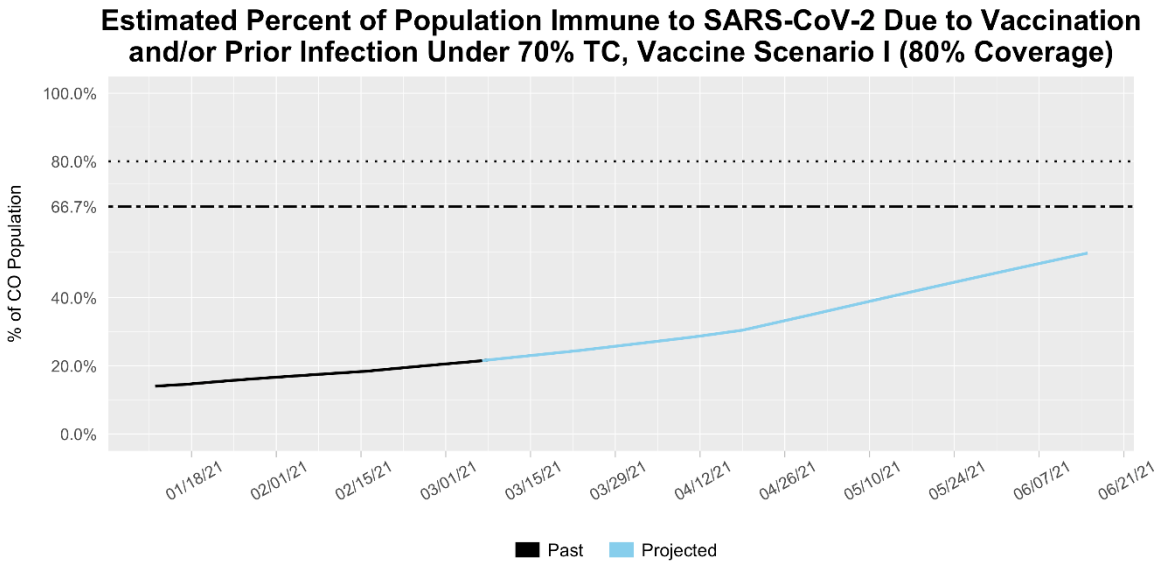


Figure 8 (above). Estimated percent of the population immune due to vaccination and/or prior infection, under Vaccine Scenario I, assuming transmission control switches to 70% indefinitely on 03/12. Dashed lines indicate herd immunity thresholds, which are estimated to be at 66.7% at R0 = 3 and 80% at R0 = 5. Currently there is uncertainty regarding the true herd immunity threshold.

Mobility

To investigate the impact of mobility on COVID-19 transmission, we analyze time away from home using SafeGraph mobile device tracking data. Figure 10 displays daily hours away from home from January 01, 2020 to February 25, 2021 in the Denver metro area (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, and Jefferson counties) as well as the rest of Colorado. The faint lines display the daily data while the thick lines represent a smoothed average of the data over time. We also include estimates of the mean daily population-weighted temperature over time from gridMET to explore the relationship between weather and mobility. Figure 9 shows that statewide time away from home dramatically decreased in March 2020 when the pandemic began. Time away from home gradually increased as the weather warmed and restrictions were relaxed in the summer. As the weather cooled and cases rose in the state, time away from home fell through December, but is currently increasing, especially in the non-metro areas. To enhance privacy, SafeGraph excludes Census Block Group (CBG) information if fewer than five devices are observed on any day. SafeGraph determines a device's CBG of residence by calculating the most common evening location over the past six weeks.

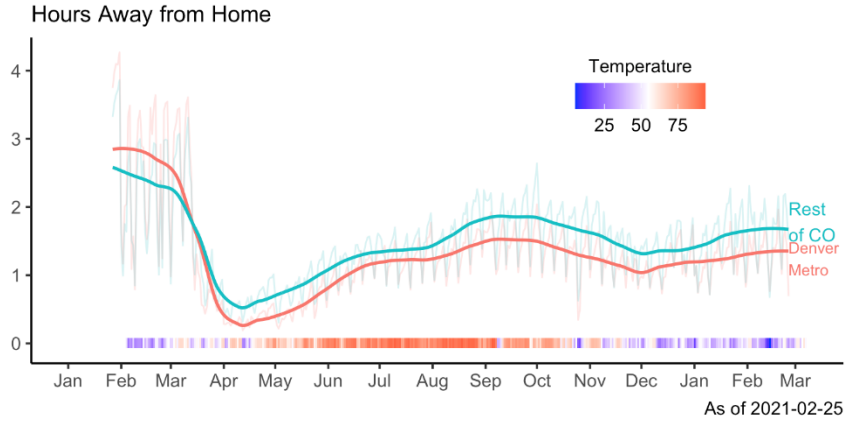


Figure 9 (above). Daily hours away from home (SafeGraph) are averaged across census block groups within the two regions. The faint lines show the daily data, and the thick lines represent a smoothed average over time. The ribbon below the time away from home displays the population-weighted mean daily temperature across the state from gridMET.

Long-Term Projections

We generate projections of future infections, hospital demand and deaths under scenarios given different levels of transmission control, different dates for a drop in transmission control, and growth of B.1.1.7 and other variants of concern. There is considerable uncertainty about how policies and behaviors over the last few weeks will influence the course of the epidemic, how rapidly variants of concern will spread in Colorado, and how rapidly the vaccine will be administered.

Vaccination. This week's projection set explores a single vaccine scenario provided by CDPHE. Under this scenario, approximately 64% of the Colorado population receives at least a first dose of a vaccine by 06/01. This includes increased allocations of the Pfizer and Moderna vaccines and introduction of the Johnson & Johnson single-dose vaccine in late March. We model a maximum of 80% uptake in each age group. Vaccination rates in the projections occur at current age-specific rates which currently prioritizes the oldest age groups. Once 80% of the oldest age groups are vaccinated, vaccine is then allocated to the next oldest age group. We note that there is uncertainty regarding vaccine allocation by age and we will update these assumptions when we have greater clarity. We assume all individuals who receive a first dose of a two-dose vaccine (Pfizer, Moderna) receive a second dose on schedule. Vaccine allocation scenarios run through June 1st. Details of the vaccine scenarios and key assumptions are provided in Appendix Tables A2 and A3.

Changes in Transmission Control now and later. Scenarios were developed to examine the potential impact of decreases in transmission control. Changes in transmission control occur when people have more contacts which can be due to changes in policy and/or behavior. These scenarios investigate drops in transmission control to 70% and 60% on Friday, 03/12, as well as two weeks, four weeks, or eight weeks after that date. In these scenarios, transmission control is held at the current value (82%), at which point transmission control drops to 70% or 60% indefinitely.

New Variants. Currently, two variants of concern have been identified in Colorado: the B.1.1.7 variant in late December, and the B.1.351 variant identified earlier this week. The current scientific evidence indicates that the new B.1.1.7 variant is likely more infectious, more virulent, and more lethal than the currently circulating variants (NERVTAG, Public Health England). Evidence suggests B.1.351 is also more infectious. The spread of the more infectious variant can lead to an increase in infections, hospitalizations, and deaths without changes in policy or behavior.

In the United Kingdom, the variant spread rapidly and is estimated to be causing over 90% of new infections. Recent CDC models as well as genomic surveillance in the US suggest that the variant may rapidly become the dominant strain in the US. In light of this, the variant scenario models rapid growth of a variant of concern in Colorado, akin to the growth in of the variant in the UK. In this scenario, the B.1.1.7 variant accounts for half of SARS-CoV-2 infections by mid-April, and over 90% of infections by June.

Based on recent reports we assume that the variant is 1.5 times more infectious than currently circulating variants; infection with the variant confers a 1.4-fold increased risk of hospitalization and a 1.4-fold increased risk of death among those hospitalized for those age 40+; infection with the variant confers a 1.7-fold increase in the risk of death among cases not hospitalized and age 40+. Under this scenario, the amount of variant in the Colorado population is assumed to be 8% on 3/8 which is in line with recent estimates from CDPHE.

Projections: Current Trajectory. Figure 10 shows estimated hospitalizations and cumulative deaths through June 2021 if Colorado remains on the current trajectory, assuming continued vaccine roll-out. These scenarios assume no further growth of the B.1.1.7 variant or other variants of concern.

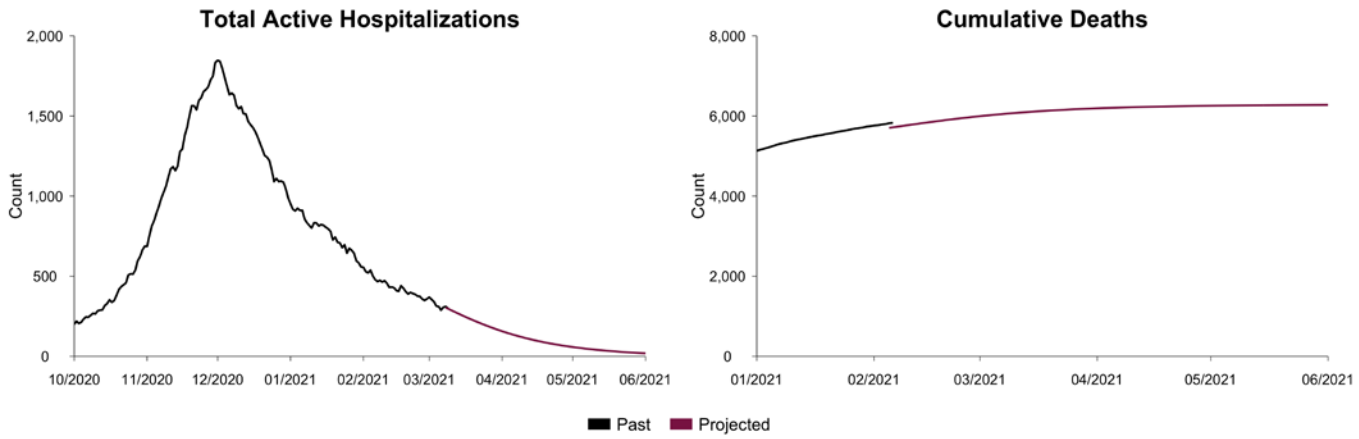


Figure 10 (above). Projected total number of patients actively hospitalized for COVID-19 (left) and projected cumulative deaths through early June 2021, assuming transmission control remains at the current levels (82% TC) indefinitely. This projection assumes the vaccine scenario described above with 80% vaccine uptake. Black lines indicating historical data reflect observed hospitalizations reported in EMR and observed cumulative deaths gathered from the CEDRS line list provided by CDPHE. Observed deaths are shown through 02/06 to account for lags in reporting.

Projections: Changes to Transmission Control. Figure 11 shows the projected active hospitalizations and cumulative deaths through early June 2021, if Colorado remains on its current trajectory (82% TC) or switches to 70% or 60% indefinitely on Friday, 03/12 under the specified vaccine scenario. Figure 12 shows the projected active hospitalizations through early June 2021, if these drops in transmission control are delayed by 2, 4, or 8 weeks. Table 1 show the projected deaths and infections from 3/08 to 6/01 under these scenarios. These projections do not account for a potential increase in the B.1.1.7 variant.

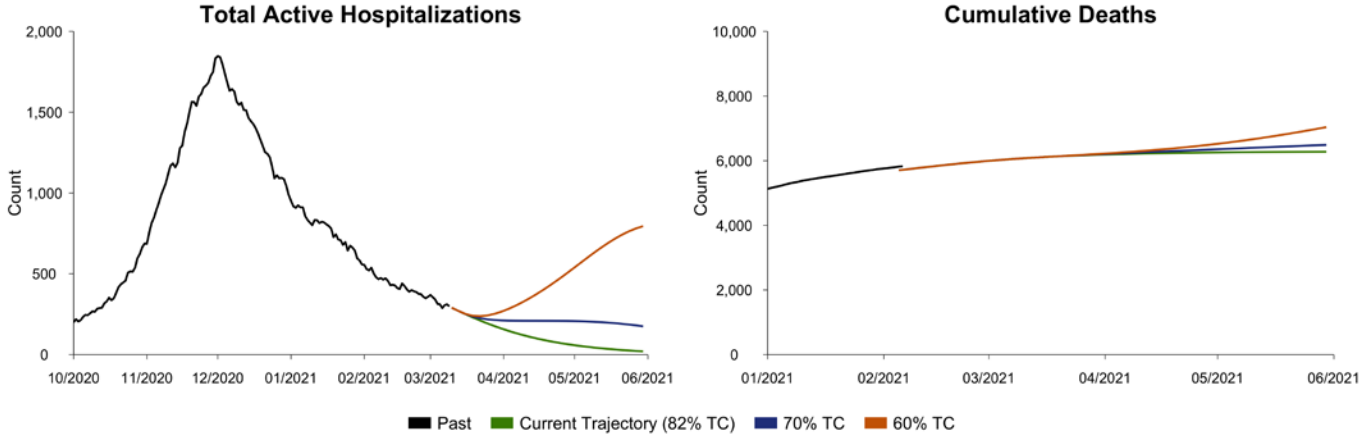


Figure 11 (above). Projected active hospitalizations and cumulative deaths through early June 2021, assuming Colorado remains on its current trajectory (82% TC) as indicated by the green lines, or switches to 70% TC (blue lines) or 60% TC (orange lines) beginning Friday, 03/12. This projection assumes continued vaccine roll-out and no further growth in B.1.1.7 or other variants of concern. Black lines indicating historical data reflect observed hospitalizations reported in EMR and observed cumulative deaths gathered from the CEDRS line list provided by CDPHE. Observed deaths are shown through 02/06 to account for lags in reporting.

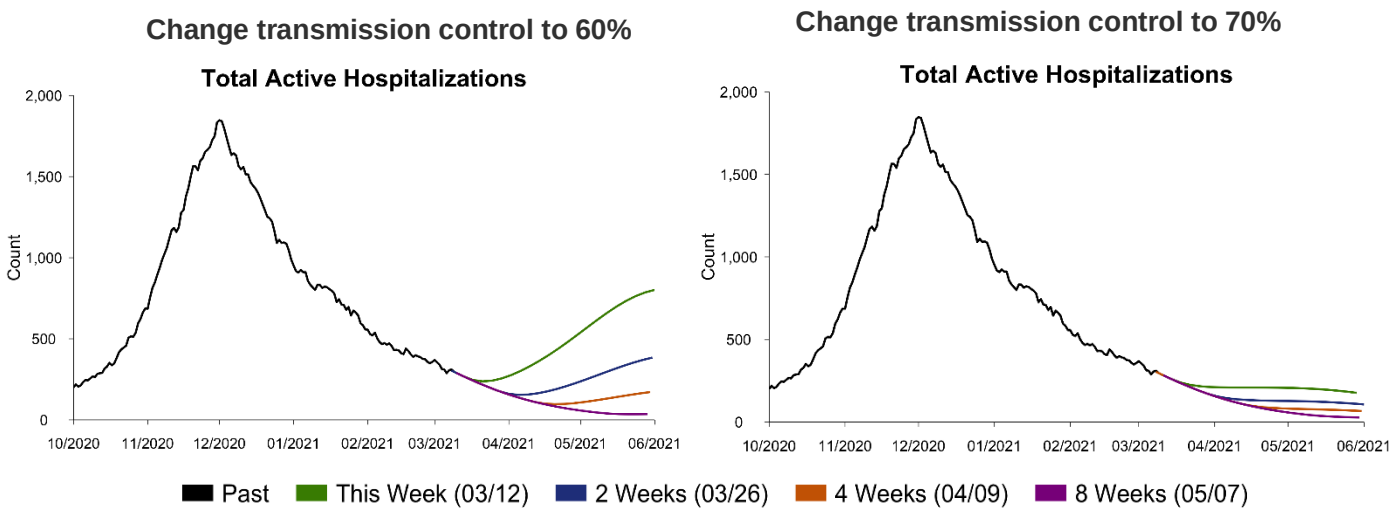


Figure 12 (above). Projected active hospitalizations through early June 2021, assuming Colorado drops transmission control to 60% (left panel) or 70% (right panel) on Friday, 03/12 (green lines), as well as two weeks (blue lines), four weeks (orange lines), or eight weeks (purple lines) after that date. This projection assumes continued vaccine roll-out and no further growth in B.1.1.7 or other variants of concern. Black lines indicating historical data reflect observed hospitalizations reported in EMR.

Table 1 (below). Projected deaths and SARS-CoV-2 infections from 03/08 to 06/01 if Colorado remains on the current trajectory, or if transmission control drops to 70% or 60% on Friday (3/12) as well as two, four and eight weeks after this date. These estimates assume continued vaccine distribution and no further growth of the B.1.1.7 variant.

	Change TC on 3/12	Wait 2 weeks (3/26)	Wait 4 weeks (4/09)	Wait 8 weeks (5/07)
Deaths from 3/08 to 6/01				
Current trajectory (82%)	220	--	--	--
Switch to 70% TC	441	318	259	223
Switch to 60% TC	1,024	531	328	227
Infections from 3/08 to 6/01				
Current trajectory (82%)	46,000	--	--	--
Switch to 70% TC	154,000	97,000	68,000	48,500
Switch to 60% TC	471,000	221,000	110,000	51,400

Projections: Rapid Spread of the B.1.1.7 Variant. Figure 13 shows the projected active hospitalizations and cumulative deaths through early June 2021, if Colorado remains on its current trajectory (82% TC) or switches to 70% or 60% indefinitely on Friday, 03/12 under a rapid increase in the B.1.1.7 variant. This projection assumes continued vaccine allocation.

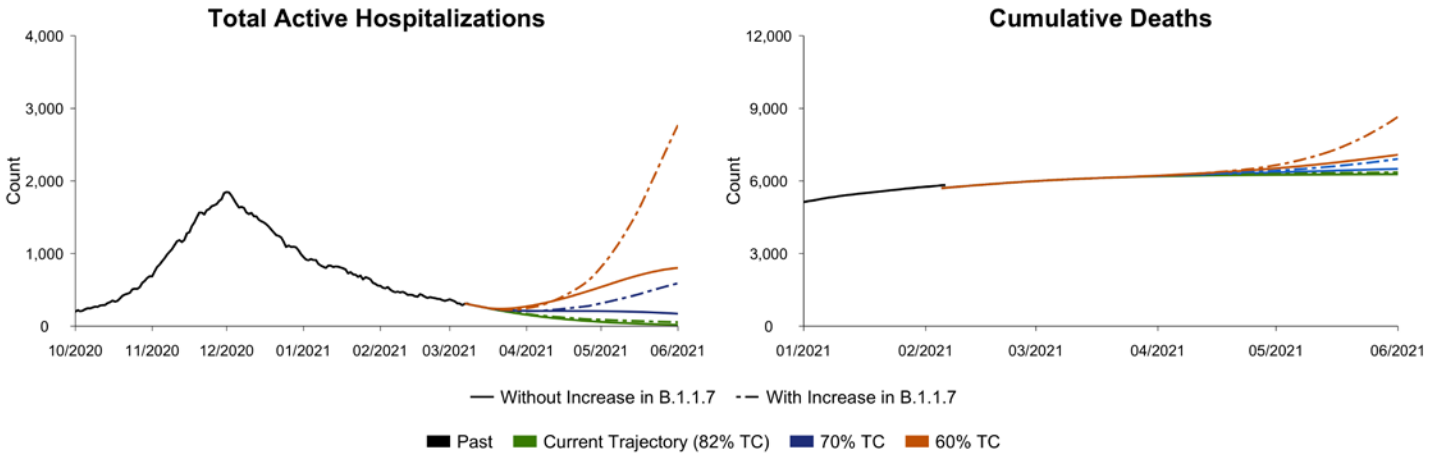


Figure 13 (above). Projected active hospitalizations and cumulative deaths through early June 2021 assuming Colorado remains on its current trajectory (82% TC) as indicated by the green lines, or switches to 70% TC (blue lines) or 60% TC (orange lines) beginning Friday, 03/12, assuming no further growth in the B.1.1.7 variant (solid lines) vs. rapid growth of B.1.1.7 infections (dashed lines). Black lines indicating historical data reflect observed hospitalizations reported in EMR and observed cumulative deaths gathered from the CEDRS line list provided by CDPHE. Observed deaths are shown through 02/06 to account for lags in reporting.

Table 2 (below). Projected deaths and SARS-CoV-2 infections from 03/08 to 06/01 if Colorado remains on the current trajectory or if transmission control drops to 70% or 60% on Friday (3/12), assuming no further growth in the B.1.1.7 variant (solid lines) vs. rapid growth of B.1.1.7 infections (dashed lines). These estimates assume continued vaccine distribution.

	No Further B.1.1.7 spread	Rapid B.1.1.7 spread
Deaths from 3/08 to 6/01		
Current trajectory (82%)	220	299
Switch to 70% TC on 3/12	441	853
Switch to 60% TC on 3/12	1,024	2,592
Infections from 3/08 to 6/01		
Current trajectory (82%)	46,000	59,800
Switch to 70% TC on 3/12	154,000	259,000
Switch to 60% TC on 3/12	471,000	927,000

When Will Infection Prevalence Return to Prior Low Levels?

In order to facilitate decision-making around policy changes such as the reopening of businesses to full occupancy, we estimated the projected prevalence of active COVID-19 infections through July 2021, assuming we remain on the current trajectory. Figure 14 shows that if we remain on the current trajectory, infection prevalence will reach the summer low prevalence (85 per 100,000) on approximately 04/23/2021. These estimates assume continued vaccine distribution and no further growth of the B.1.1.7 variant.

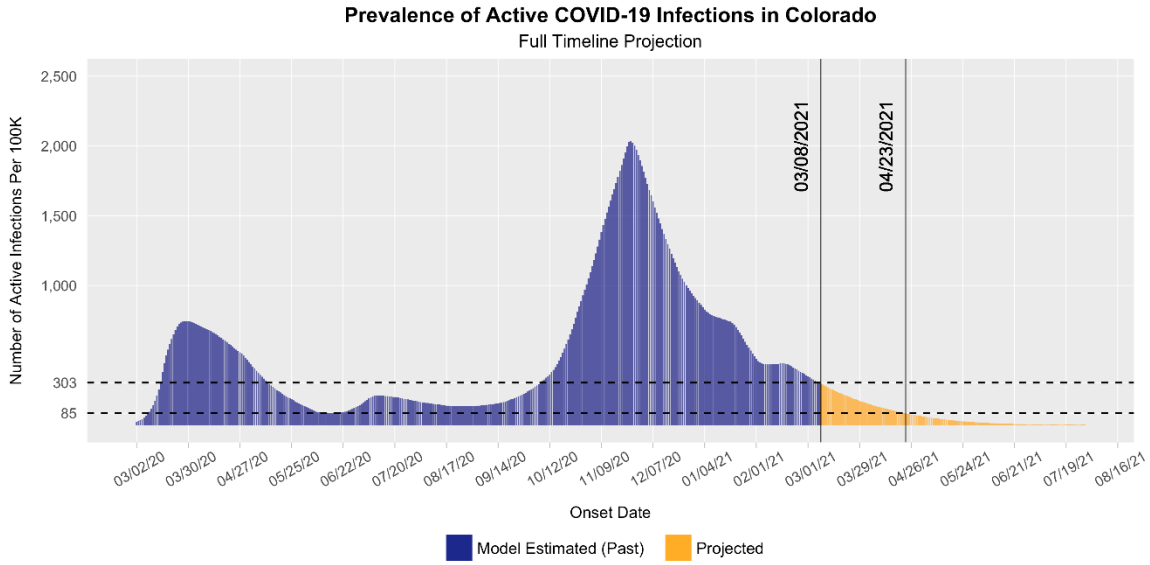


Figure 19 (above). Estimated daily number of people who are infectious and infected with SARS-CoV-2 (point prevalence). The number of infectious individuals is inferred using the model and estimates and based on hospitalizations. Horizontal dashed lines indicate the current estimated prevalence of detected and undetected infections, both symptomatic and asymptomatic, as of 03/08, and projections of the date we reach the summer low prevalence (85 per 100K).

Appendix

Code, Documentation, and Prior Reports

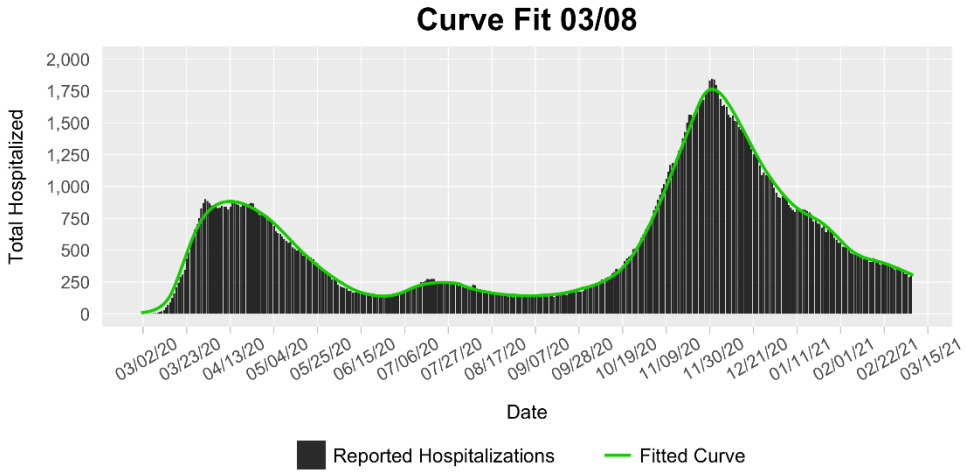
Code for our model is available on GitHub: https://github.com/agb85/covid-19

Documentation for the model can be found at: https://agb85.github.io/covid-19/SEIR%20Documentation.pdf

Prior modeling reports and documentation can be found at: https://agb85.github.io/covid-19/

Regional modeling results can be found at: https://www.colorado-data.org/regional-epidemic-models

Model Fit



Appendix Figure A1 (above). Current model fit (green line) to the count of hospitalized COVID-19 cases (black lines) through 03/08 using the age-structured SEIR model. Hospitalized COVID-19 cases are from CDPHE reported COVID-19 hospitalizations and EMResource (EMR) hospital census data provided by CDPHE.

Data Sources

Appendix Table A1 (below). Data used for this model is collected from a variety of sources. Potential lags in reporting can often result in an artificial decline during the most recent days in a dataset, such as with reported cases. To reconcile this, we have cleaved the source data by a set number of days depending on the degree of lag and the metric used. For example, data measured by onset date is cleaved more aggressively than data measured by report date because reported cases tend to be more up to date than the former.

Data	Description	Source	Download Date	Cleave Date	Additional Notes
Hospitalizations (whole state)	Daily COVID-19 hospitalization census (i.e. snapshot of number of patients in the state currently hospitalized with COVID-19 on a given day)	EMR (CDPHE Emergency Management Resource) Dashboard	03/08	03/08	Data is collected in real time (updated 10am MST daily) and is not cleaved.
Cases detected by state surveillance systems	Daily count of new COVID-19 cases (using onset date)	CEDRS (Colorado Electronic Disease Reporting	03/08	02/26	If onset date is missing, an imputed onset date is provided by CDPHE, which is based on true onset dates for the

Data	Description	Source	Download Date	Cleave Date	Additional Notes
		System) Line List			previous two weeks, compiled into a proxy distribution and recalculated weekly.
Cumulative deaths	Total deaths among COVID-19 cases to date	CEDRS (Colorado Electronic Disease Reporting System) Line List	03/08	02/06	Used for generating historical and projected estimates of cumulative mortality.

Vaccination

Vaccines became available in Colorado on December 15th, 2020. We use data provided by CDPHE to estimate the number of people vaccinated by age group over time, and to project the allocation of future vaccinations. The allocation of vaccines by age group are described in Table A3.

We use these vaccine scenarios along with assumptions about the level of transmission control moving forward, to generate projections of the percent of the population immune due to vaccination and/or prior infection.

In regards to vaccination, we take into consideration the following:

- We assume all individuals who receive a first dose of a two-dose vaccine (Pfizer, Moderna, or AstraZeneca) receive a second dose on schedule.
- In the model, we represent the efficacy of single and double doses by assuming that among individuals who receive any two-dose vaccine (Pfizer, Moderna, or AstraZeneca), a collective 52% of individuals enter the vaccinated compartment (indicating complete immunity) 14 days after the first dose, and an additional 38% of individuals enter the vaccinated compartment (indicating complete immunity) 32 days after the first dose for a total of 90% of individuals achieving complete immunity through vaccination.
- In the model, we represent the efficacy of the Johnson & Johnson vaccine by assuming that a collective 72% of individuals receiving this vaccine will enter the vaccinated compartment (indicating complete immunity) 28 days after dosing.
- We assume that individuals will be vaccinated regardless of prior infection history. Any individual can receive a vaccine, although vaccination is assumed to have no effect on individuals currently infected.

Appendix Table A2 (below). Vaccination rates by age to date included in the model. These are based on data from CDPHE on vaccinations to date by age.

Dates of First Vaccine Dose Administration	Date Moved to Vaccinated Compartment in Model	0-19 Daily Vaccination Rate*	20-39 Daily Vaccination Rate*	40-64 Daily Vaccination Rate*	65+ Daily Vaccination Rate*
12/15 - 02/01	01/16 - 03/05	43	2,089	2,576	4,976
02/01 - 03/01	03/05 - 04/02	70	2,446	3,823	9,318

*First doses administered per day (assuming all people receiving first doses receive second doses on schedule).

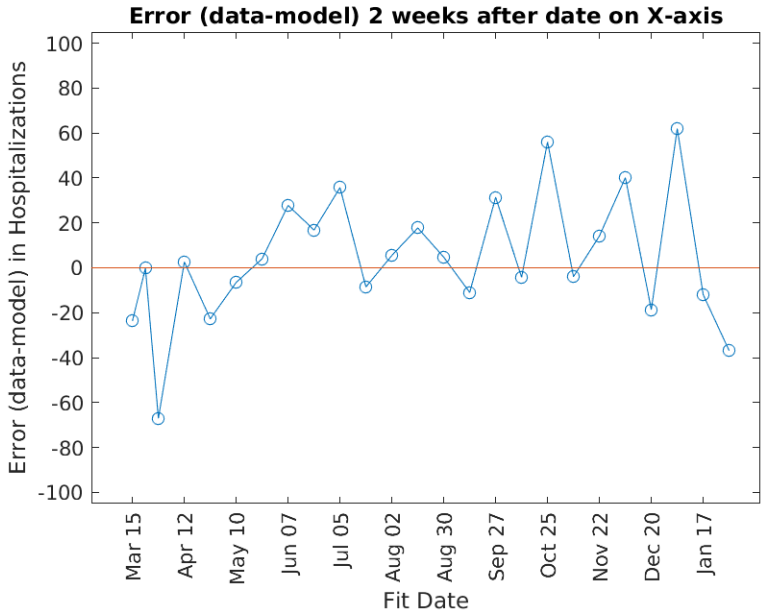
Appendix Table A3 (below). Weekly vaccinations through June 1, based on scenarios provided by CDPHE.

Dates of First Vaccine Dose Administration	Pfizer/Moderna First Doses per Week	Johnson & Johnson First Doses per Week
Week ending March 14	256,880	0
Week ending March 21	270,400	0
Week ending March 28	287,300	67,600
Week ending April 4	304,200	84,500
Week ending April 11*	304,200	101,400

*This allocation is assumed to continue through June 1st.

Retrospective Accuracy of Projected Estimated Hospitalizations

To assess the accuracy of near-term forecast estimates of COVID-19 hospitalizations, we calculated absolute deviation from the number of hospitalizations reported two weeks after the date of forecast, dating back to the fit conducted on March 15th, 2020.



Appendix Figure A2 (above). Graph showing retrospective accuracy of forecasted hospitalizations with respect to reported hospitalizations 14 days after the forecast date, as denoted on the x-axis. The y-axis represents the absolute difference in the estimated number of hospitalizations on the current trajectory 14 days out minus the observed hospitalizations 14 days out.

References

1. Li R, Pei S, Chen B, Song Y, Zhang T, Yang W, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). Science. 2020;368(6490):489-93. Epub 2020/03/18. doi: 10.1126/science.abb3221. PubMed PMID: 32179701; PubMed Central PMCID: PMCPMC7164387.
2. Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, et al. SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients. The New England journal of medicine. 2020;382(12):1177-9. Epub 2020/02/20. doi: 10.1056/NEJMc2001737. PubMed PMID: 32074444; PubMed Central PMCID: PMCPMC7121626.
3. MIDAS. MIDAS Online COVID-19 Portal 2020. Available from: https://github.com/midas-network/COVID-19/tree/master/parameter_estimates/2019_novel_coronavirus.
4. Wu J, Liang B, Chen C, Wang H, Fang Y, Shen S, et al. SARS-CoV-2 infection induces sustained humoral immune responses in convalescent patients following symptomatic COVID-19. MedRxiv. 2020.
5. Wajnberg A, Amanat F, Firpo A, Altman DR, Bailey MJ, Mansour M, et al. Robust neutralizing antibodies to SARS-CoV-2 infection persist for months. Science. 2020.
6. Dan JM, Mateus J, Kato Y, Hastie KM, Faliti C, Ramirez SI, et al. Immunological memory to SARS-CoV-2 assessed for greater than six months after infection. bioRxiv. 2020.
7. Seow J, Graham C, Merrick B, Acors S, Pickering S, Steel KJ, et al. Longitudinal observation and decline of neutralizing antibody responses in the three months following SARS-CoV-2 infection in humans. Nature Microbiology. 2020:1-10.
8. Self WH. Decline in SARS-CoV-2 Antibodies After Mild Infection Among Frontline Health Care Personnel in a Multistate Hospital Network—12 States, April–August 2020. MMWR Morbidity and Mortality Weekly Report. 2020;69.
9. Ibarrondo FJ, Fulcher JA, Goodman-Meza D, Elliott J, Hofmann C, Hausner MA, et al. Rapid decay of anti–SARS-CoV-2 antibodies in persons with mild Covid-19. New England Journal of Medicine. 2020;383(11):1085-7.
10. Poland GA, Ovsyannikova IG, Kennedy RB. SARS-CoV-2 immunity: review and applications to phase 3 vaccine candidates. The Lancet. 2020.
11. Huang AT, Garcia-Carreras B, Hitchings MDT, Yang B, Katzelnick L, Rattigan SM, et al. A systematic review of antibody mediated immunity to coronaviruses: antibody kinetics, correlates of protection, and association of antibody responses with severity of disease. medRxiv. 2020:2020.04.14.20065771. doi: 10.1101/2020.04.14.20065771.