The current state of COVID-19 in Colorado

11/20/2020

Prepared by the Colorado COVID-19 Modeling Group
Colorado School of Public Health: Andrea Buchwald, Elizabeth Carlton, Debashis Ghosh, Jonathan Samet, Laura Timm, Emily Wu; University of Colorado School of Medicine: Kathryn Colborn; University of Colorado-Boulder Department of Applied Mathematics: David Bortz; University of Colorado-Denver: jimi adams; Colorado State University: Jude Bayham

For Contact: Jon.Samet@CUAnschutz.edu

Summary

- The effective reproductive number is approximately 1.4, a drop from 1.7 and transmission control has increased from 61% to 65% since last week.
- Colorado has greatly exceeded the April hospitalization peak
- An estimated 1 of 49 Coloradans are infectious, by far the highest prevalence to date. Prevalence is as high as 1 in 39 in some regions.
- Over the next two weeks, COVID-19 hospital demand will likely rise well above 2000 beds and ICU needs will exceed 600 beds, both figures below max capacity.
- There is great uncertainty about December as interventions are being implemented and the holidays take place.
- On the current trajectory, COVID-19 hospital and ICU demand may be within surge capacity estimates, but contacts will remain risky for months to come and incomplete understanding of immunity and asymptomatic infections limit confidence in the long-run projection.

Snapshot of current SARS-CoV-2 transmission in Colorado

- Effective reproductive number: 1.44 (95% confidence interval 1.64, 1.77). *Hospitalizations are increasing rapidly.*
- Estimated prevalence of infections: Approximately 2040 (95% CI: 1965, 2174) of every 100,000 Coloradoans or 1 in every 49 Coloradans are currently infectious. *The estimated prevalence is higher than last week.*
- Estimated number of infections to date: Approximately 12.95% (95% CI: 12.9, 13.0) of the Colorado population has been infected to date.
- Estimated current level of transmission control: 65% (95% CI: 62%, 67%) for the period of 10/25 to 11/04. *There is an approximate 65% reduction in total transmission-relevant contacts, inclusive of reductions due to contact tracing, self-isolation, mask wearing, and all other policy and behavioral changes compared to a situation with transmission uncontrolled, as in the very early days of the pandemic.*
- Using an extended modeling approach that includes case data, we estimate transmission control has declined in comparison to last week in individuals aged 20-39 (transmission control = 40%). Notably, transmission control estimates have begun to increase in the oldest age group (age 65+) suggesting that people in this age group are taking fewer risks of exposure to the virus (Transmission control = 76%).

Snapshot of the potential future trajectory of SARS-CoV-2 in Colorado

- If we remain on the current trajectory, we could just reach ICU surge capacity in mid-January. Increases in contacts over the holidays will accelerate growth in cases and ICU hospital capacity may be exceeded earlier. Reductions in contacts due to polices and/or behaviors can reduce demand in the weeks ahead.

Introduction

We used our age-structured SEIR model and COVID-19 hospital census data to characterize the current status of the COVID-19 epidemic in Colorado and the collective impact of efforts to date to reduce the spread of the SARS-CoV-2 virus. These estimates are based on hospitalization data through 11/16/2020. We use these estimates to generate projections of the potential future course of SARS-CoV-2 in Colorado under different scenarios of transmission control measures. These include estimates of hospital needs over the next two weeks based on the current estimated trajectory, and long-term projections that consider the impact of increases in transmission control as well as increased contact rates over period from Thanksgiving to the New Year holidays.

These estimates are based on a transmission control model. We use this model to generate estimates of the effective reproductive number, to show the current trajectory of hospitalizations, to project the potential trajectory of hospitalizations under different scenarios, and to estimate the variability in transmission control by age group, using both hospitalization and case data for parameter estimation.

We also note that this report incorporates updated figures for the number of beds available in Colorado for caring for COVID-19 patients: intensive care unit beds—1325; non-ICU beds—5135; and total: 6460. These were provided by CDPHE based on information provided under the recent executive order.

Current COVID-19 hospitalizations and model fit

Figure 2 shows COVID-19 hospitalizations (black bars) and the green line shows the current model fit to the data using the TC method. Table A1 provides values for model parameters for the TC approach. Our most recent estimate of transmission control, for the period 10/25 to 11/04, is 65% (95% CI = 62%, 67%). We note that due to the approximately 13-day lag between infection and hospitalization, we are currently only able to estimate social distancing and transmission control through 11/04.

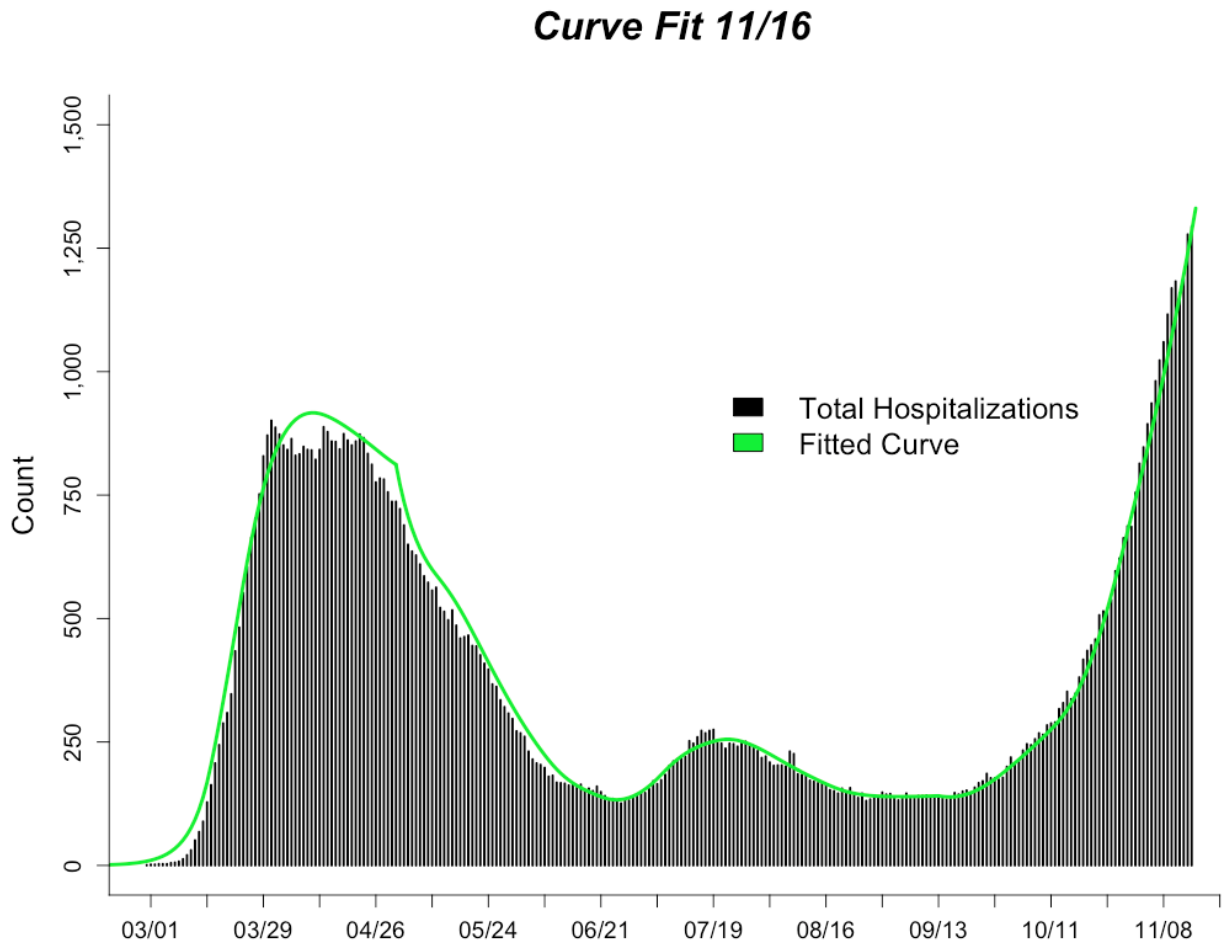


Figure 2. Current model fit (green line) to count of hospitalized COVID-19 cases (black lines) using the age-structured SEIR model. Hospitalized COVID-19 cases are from CDPHE reported COVID-19 hospitalizations and EMResource (EMR) hospital census data provided by CDPHE.

The effective reproductive number

The estimated effective reproductive number (R_E) is shown in Table 1 and Figure 3. Table 1 provides estimates we generated using two distinct but conceptually similar methods. We also provide values from RT-Live, which uses SARS-Cov-2 case. Trends in these external estimates reflect our estimates.

Table 1. Current and prior estimates of the effective reproductive number (Re) in Colorado.

	Current Estimate (11/16)	Estimate one week ago (11/09)	Estimate two weeks ago (11/02)
Estimate of Re, approach 1, TC model*	1.44 (1.38, 1.55)	1.70 (1.64, 1.77)	1.66 (1.24, 1.76)
Estimate of Re, approach 2, TC model*	1.55	1.82	1.77
Estimate from RT-Live	1.15 (0.89, 1.32)	1.20 (0.95, 1.43)	1.23(1.00, 1.50)

*Our estimates are based on hospitalization data through the date listed. Estimates from the external sites are extracted on the day listed. Because of the 13-day lag between infection and hospitalization, on average, our current estimate reflects transmission up to approximately November 4th. Approach 1 uses model output to estimate the average number of new cases generated by existing cases, accounting for the latent period and

duration of infectiousness. The second method uses the model structure to estimate the dominant eigenvalue for a matrix describing population flows across the model compartments.

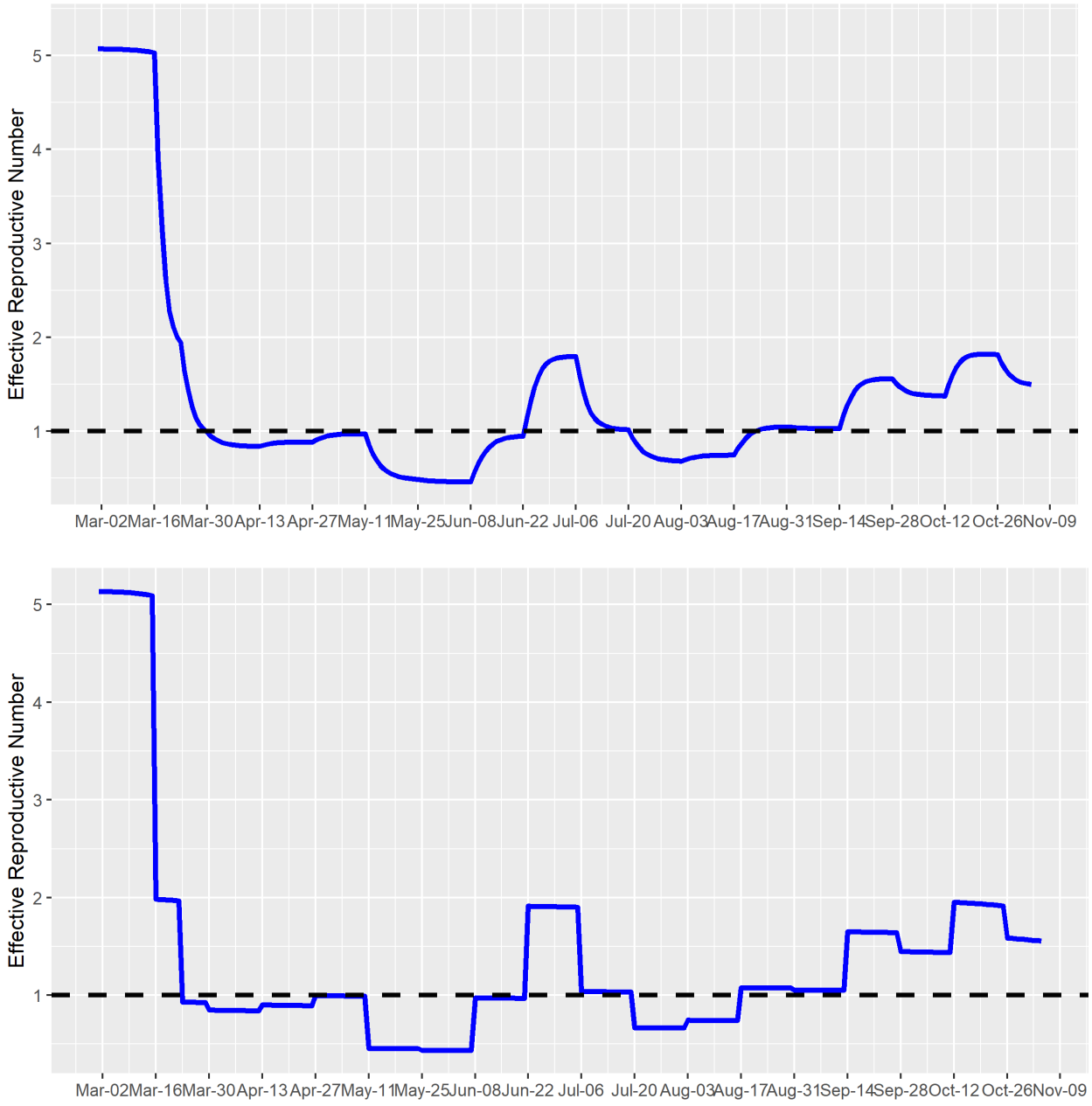


Figure 3. The effective reproductive number using approach 1 (top) and approach 2 (bottom) based on the TC model.

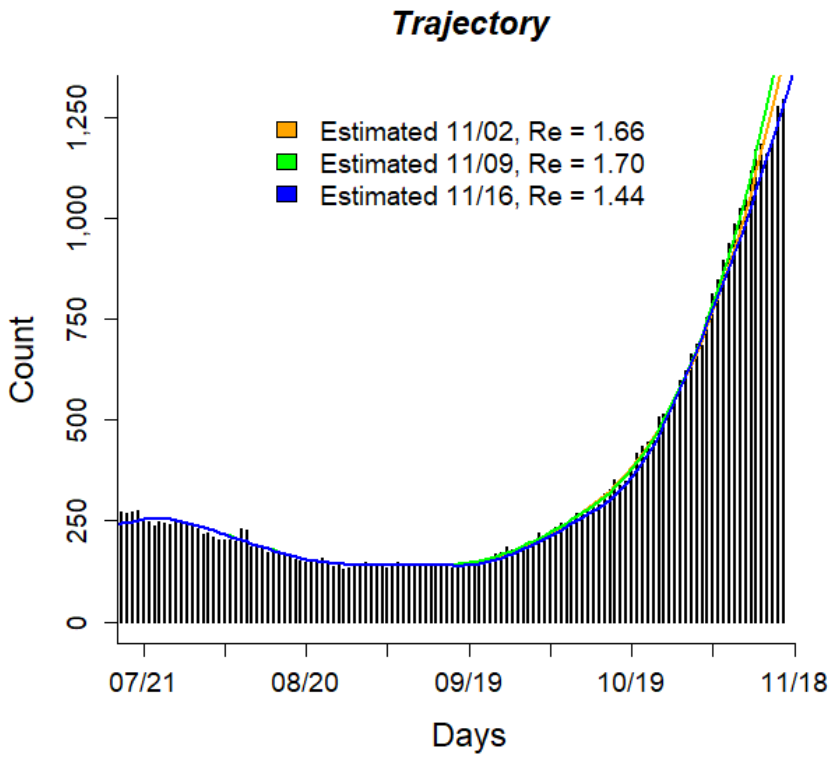


Figure 4. The projected trajectory of COVID-19 hospitalizations if Colorado remains on the current estimated trajectory (blue line), the trajectory estimated one week prior (green line), and the trajectory estimated two weeks prior (orange line). Each trajectory is generated assuming transmission control levels remain at the estimated levels: current estimate (11/16) 65% based on the period 10/25 to 11/04, one-week prior estimate (11/09) 61% based on the period 10/12 to 10/27, two-week prior estimate (11/02) 62% based on the period 10/12 to 10/20. Note that the estimation periods overlap as we re-estimate parameters each week and use the past approximately 10 days to estimate the most recent transmission control parameter.

The estimated cumulative and current number of infections in the population

We use the TC model to estimate the cumulative number of infections to date and the approximate number of infectious individuals in the population. Given the characteristics of SARS-CoV-2 and of COVID-19, many infections are not detected by surveillance systems – the estimates provided here are intended to provide an approximation of the total number of infections, as well as the proportion detected by Colorado's surveillance system. These estimates are sensitive to model assumptions, including assumptions about the probability an infected individual will be symptomatic and require hospital care, as well as estimates about length of hospital stay, which vary over time, all variables of which we assume varies by age.

We estimate that approximately 757,000 (95% CI: 751,000, 762,000) people in Colorado, or 12.95% (95% CI: 12.9, 13.0) of the population, have been infected to date.

We estimate that there are approximately 119,000 (95%CI: 115,000, 127,000) infectious individuals in Colorado at present: approximately 2040 (95% CI: 1965, 2173) of every 100,000 Coloradoans or 1 in every 49 people (95% CI: 46, 51). Figure 5 illustrates the relationship between COVID-19 hospitalizations and the estimated number of infectious individuals at any given point in time. The number of infectious individuals is approaching the March/April peak. This implies that individuals are far more likely to encounter infectious individuals in the population than they were this spring and summer.

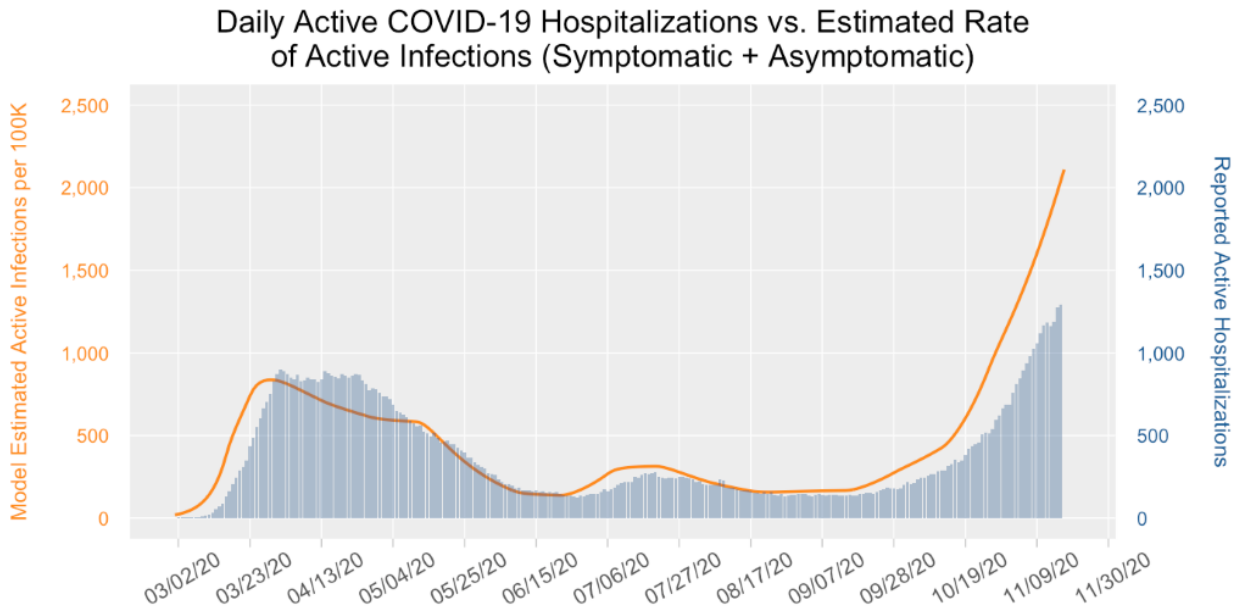


Figure 5. Estimated daily number of people (per 100,000 population) who are infectious and infected with SARS-CoV-2 (point prevalence), as shown on the orange line, and the number of actual COVID-19 hospitalizations (blue bars). The number of infectious individuals is inferred using the model and based on hospitalizations.

Comparing observed to model-estimated infections, we estimate that approximately 49% of infections in the past two weeks were detected by state surveillance systems, including both asymptomatic and symptomatic infections (Figure 6).

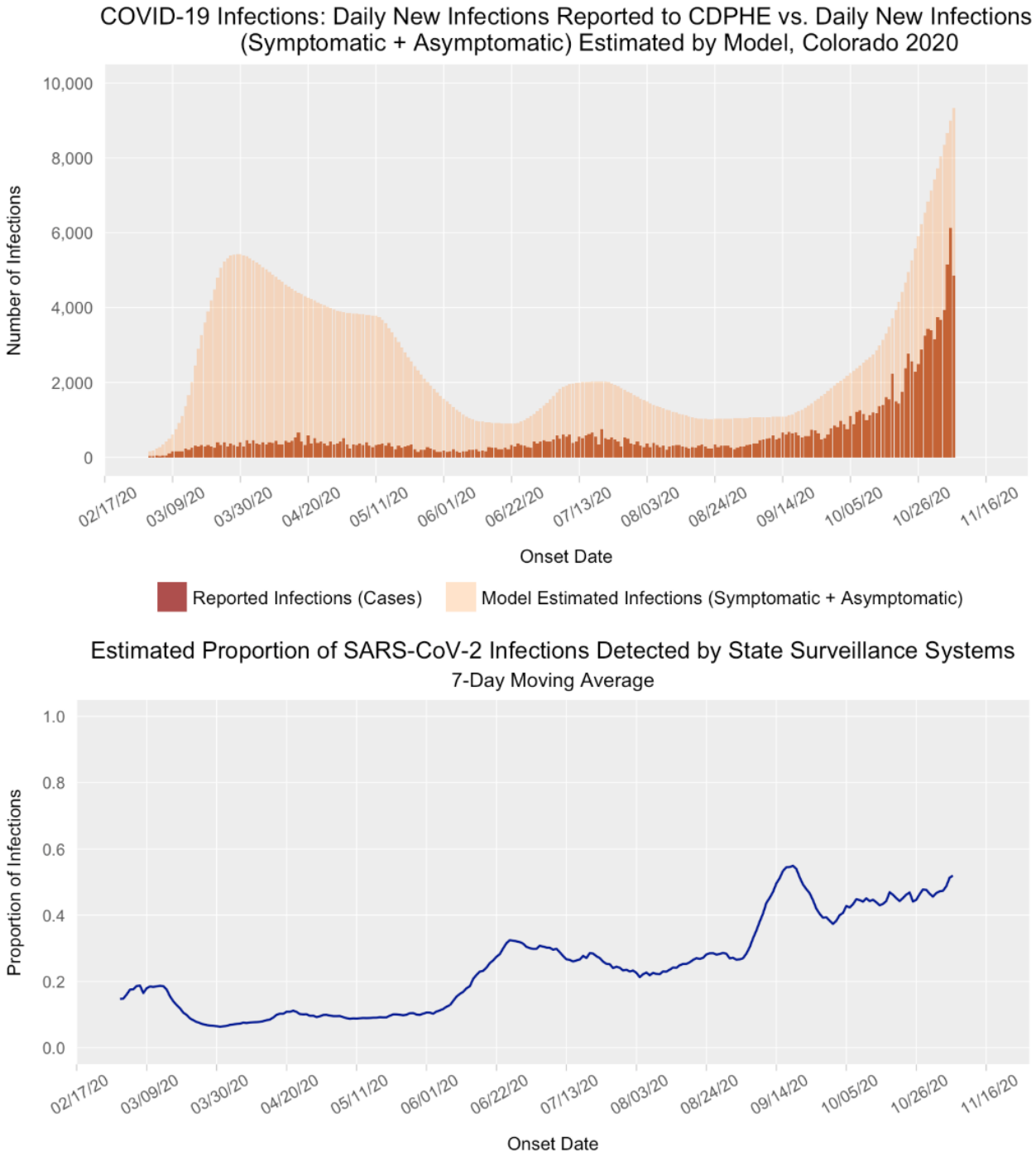


Figure 6. Estimated daily number of new (incident) SARS-CoV-2 infections based on the SEIR model (light orange graph) and reported cases (dark orange graph) over time shown in the top panel. Lower panel shows the 7-day moving average of the estimated proportion of SARS-COV2 infections that are being 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 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 11/07 to account for typical lags between symptom onset and case report.

The distribution of reported infections and hospitalizations by age, race and ethnicity

Reported SARS-CoV-2 Cases by age group. Figure 7 shows the 7-day moving average of reported new SARS-CoV-2 infections by age group. Recent reports of new cases are highest for those aged 20 - 39. The average proportion of COVID-19 cases in people under age 40 over the last two weeks is approximately 58%.

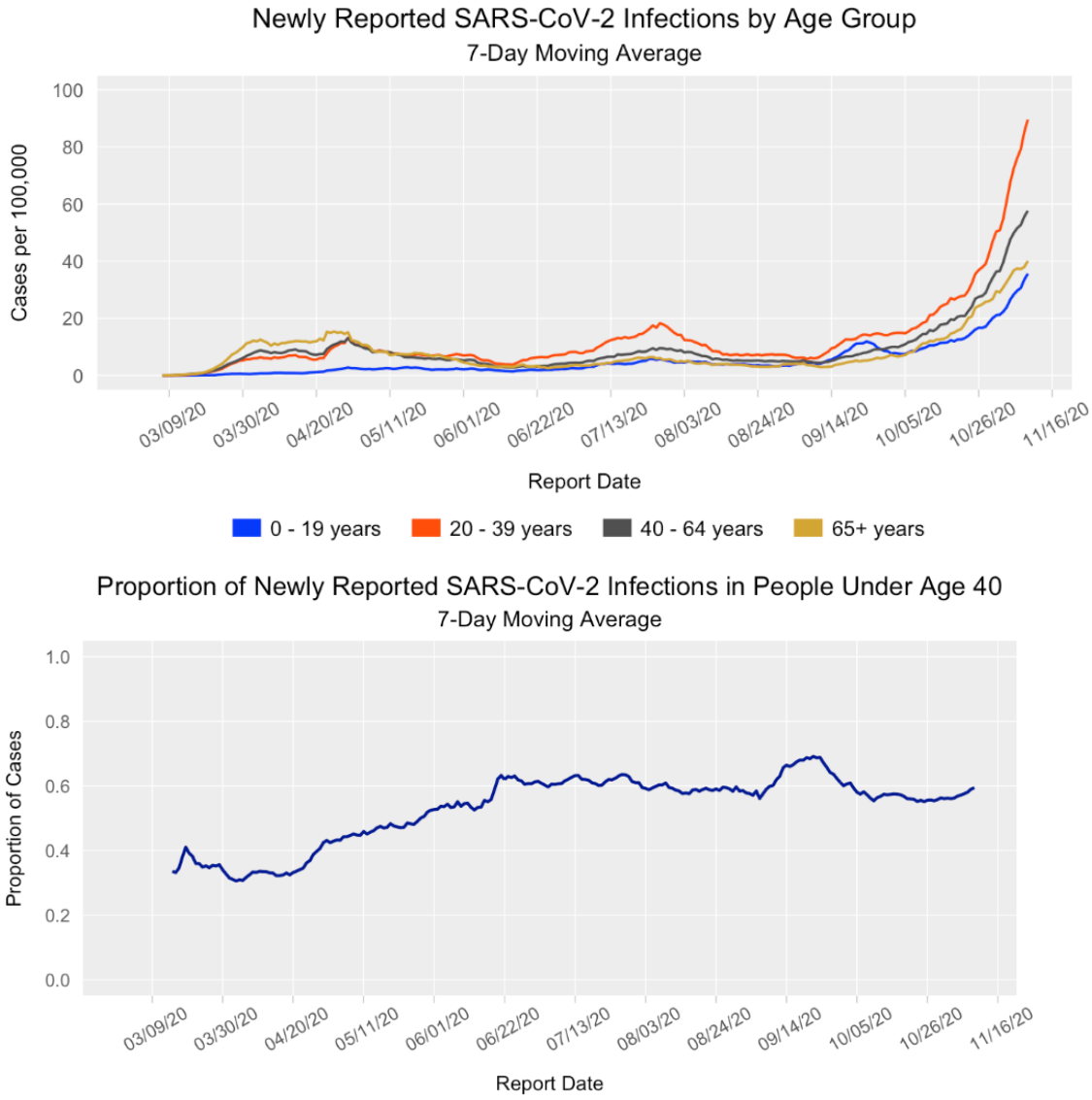


Figure 7. Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by age group (top) and the proportion of all cases among individuals under 40 (bottom). Reported cases are based on CDPHE data and shown by report date. Incident cases per 100,000 were obtained by standardizing weekly reported age-specific case and hospitalization counts to the Colorado population distribution by age, gathered from the Colorado Census 2020 estimates. Data are shown through 11/02/2020, to account for typical lags between case report and data updates.

COVID-19 hospitalizations by age group. Figure 8 shows the number of individuals hospitalized with COVID-19 by age group from March through the present, based on COPHS hospital census records.

Currently, individuals age 65+ account for the greatest COVID-19 hospital use. People under 40 account for approximately 14% of COVID-19 hospital use, on average, over the last two weeks.

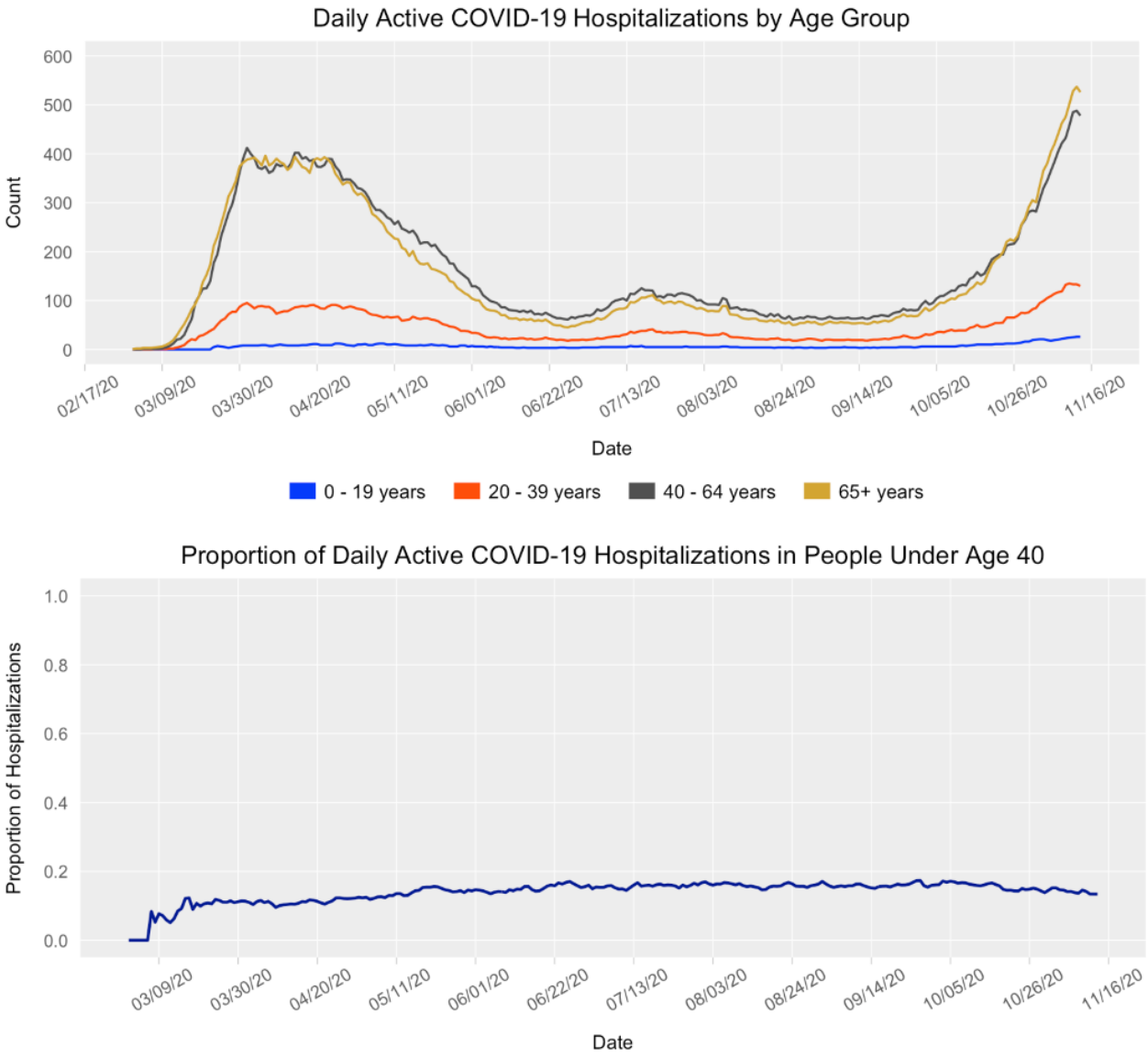


Figure 8. The number of individuals hospitalized with COVID-19 by age group from March through the present (top) and the proportion of COVID-19 hospital beds occupied by individuals under age 40. Data based on COvid Patient Hospitalization Surveillance (COPHS). Data shown through 11/13.

COVID-19 reported cases by race/ethnicity. Figure 9 shows the number of reported cases by race/ethnicity from March through the present. Hispanic populations continue to be disproportionately impacted.

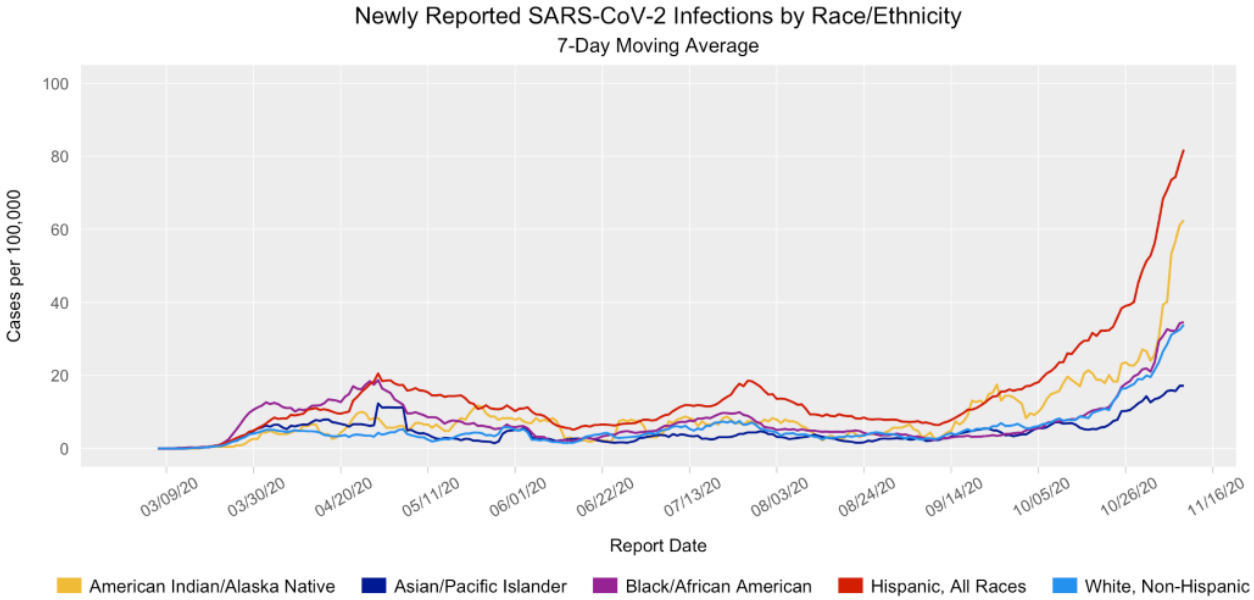


Figure 9. Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by race and ethnicity in Colorado. Reported cases are based on CDPHE data and shown by report date. Cases per 100,000 were obtained by standardizing weekly reported race-specific case counts to the race/ethnicity distribution of the state of Colorado gathered from the CDPHE COVID-19 Case Summary Dashboard. These standardized estimates combine Asian and Native Hawaiian/Pacific Islander races and exclude Other/Unknown races (which account for 34% of observations over the last two weeks). Data is shown through 11/09 to account for lags in case reporting.

Using age-specific case data to estimate transmission control behaviors by age

Due to the variation in behavior by age and the increase in cases seen among younger age groups, we estimate how transmission control varies by age group. We use CEDRS case data presented in Figure 7 to fit age-group specific levels of transmission control. We make the following assumptions about detection rate: We take the probability of detection from the overall model (calculated by comparing daily model estimated infections to reported infections (Figure 6)) as a time series (daily time-step) and fit observed CEDRS case data to age-specific estimated infections over time. To account for age-specific differences in detection rate, we fit parameters for age-differences in detection rate to hospitalization data and then refit the TC parameters to case data. Transmission control levels continue to decrease among most age groups. Individuals aged 20-39 have the highest contact rates currently (TC= 40%). In other individuals, cases have increased recently, leading to a decreased estimate of transmission control (TC = 64% and 60% for individuals under 20 and 40-64, respectively). TC has increased among individuals aged 65+ to 76%, nearing the threshold value for decrease (78%).

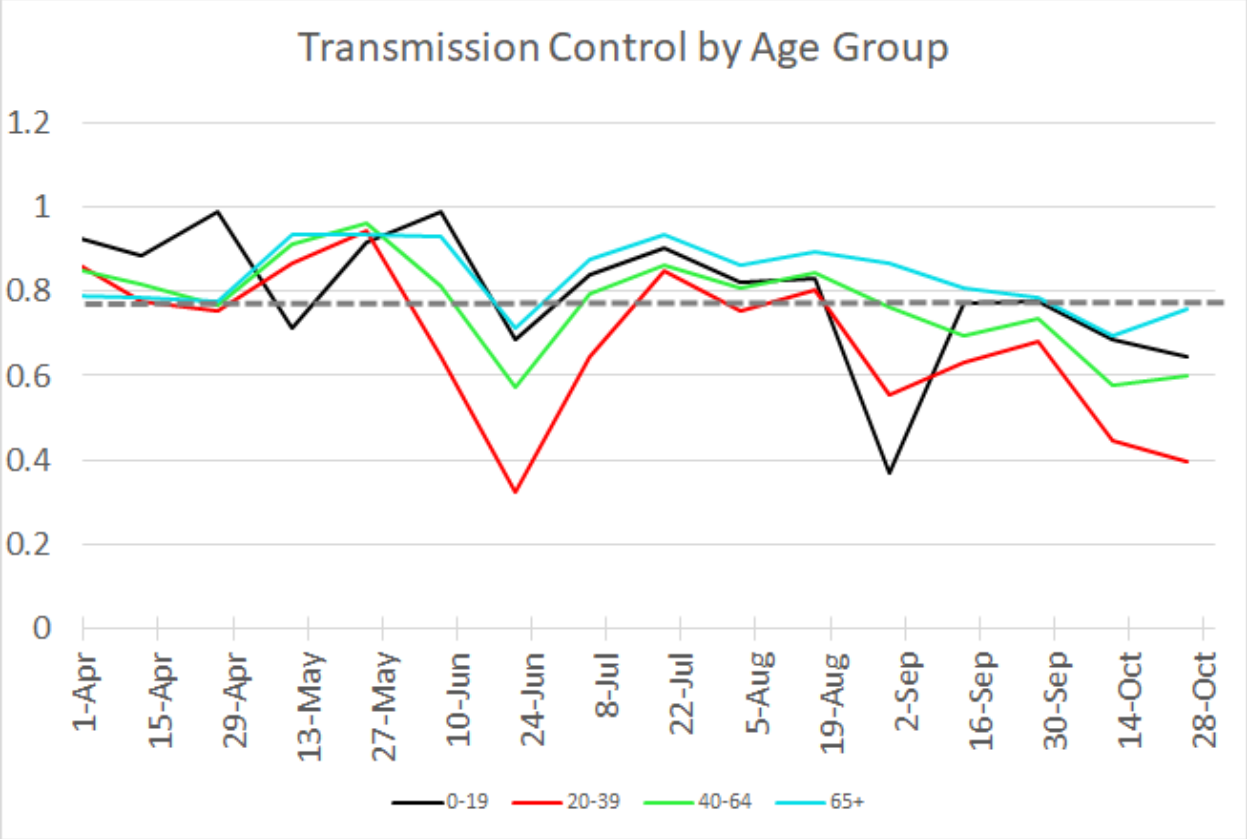


Figure 10. Estimates of transmission control by age plotted over time. Transmission control values are plotted at the time period for which they begin, as the last period for which transmission control is estimated is 10/26 – 11/07, the point on the graph is plotted at 10/26. Grey dashed line indicates threshold value of transmission control = 78%.

Near-term forecast

We generated estimated hospitalizations over the next two weeks and on Christmas assuming Colorado remains on the current trajectory and accounting for uncertainty in our current estimated trajectory (Figure 11, bottom). These estimates are based on 10,000 simulated runs of the model, with 1,000 of those runs randomly selected for visualization.

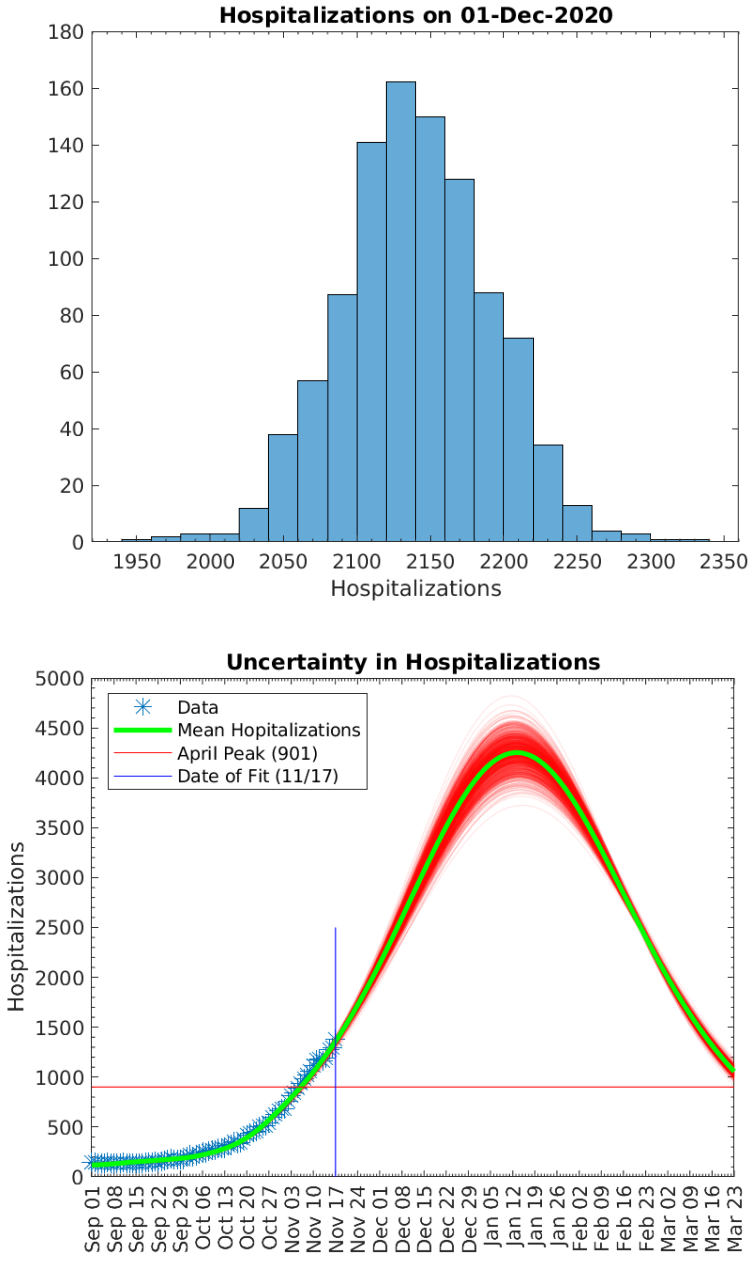


Figure 11. Distribution of hospitalizations in two weeks (top) and estimated daily count of total hospital demand (bottom) if we remain on the current trajectory (transmission control at 65%). Additional lines show the range of uncertainty in the projection.

Scenario-based projections

Projections were generated to evaluate future case numbers, and hospital and ICU need under two sets of scenarios.

- In the first set of scenarios, we estimate hospital demand and fatalities if Colorado remains on the current trajectory or if Colorado shifts to an 80% transmission control trajectory.
- In the second set of scenarios, we examine the impact of timing of intervention implementation on peak ICU and hospital need as well as the date when reported cases would decrease below contact tracing capacity.

These estimates are based on assumptions about policies and behaviors in the weeks ahead as well as static assumptions about immunity and the distribution of asymptomatic infections. There are two key issues create uncertainty about the weeks ahead:

1. Changes in policy and behavior can alter this trajectory. Increased mixing over the holidays can increase infections. Non-pharmaceutical interventions can slow the spread of infections.

2. The timing of the next peak. The April and July peaks were followed by a decline in infections due to changes in behavior and policy that reduced the spread of infection. In the TC=70% or lower scenarios below, infections and hospital demand begin to decline when the population susceptible to infection is reduced to the point that it becomes less and less likely that an infected person encounters a susceptible person. The timing and the magnitude of the peak is sensitive to assumptions about the persistence and timing of immunity and asymptomatic infections.

It is possible that care demand peaks sooner, or **later and with greater magnitude**, depending on policy/behaviors, immunity and the frequency of asymptomatic infections.
The course in 2021 is highly uncertain at present

Projection set 1. Current trajectory and alternative trajectories

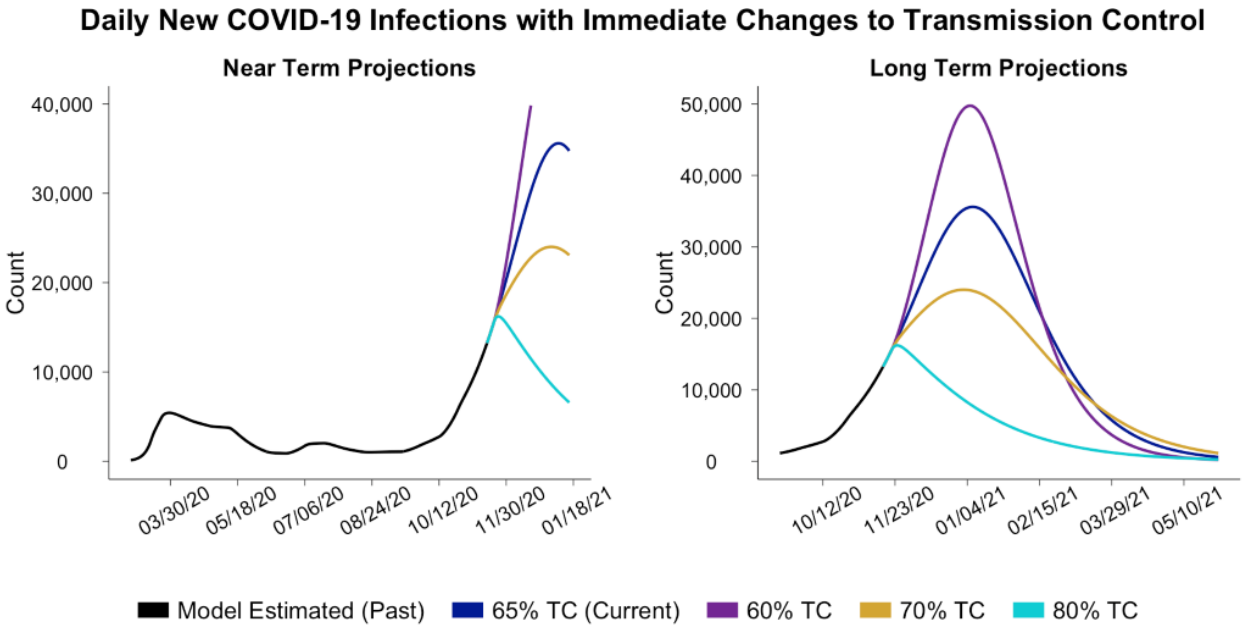
In these scenarios, projections are generated assuming transmission control is maintained at the current trajectory (TC=65%). Projections are also generated assuming transmission control decreases to 60% or increases to 70% or 80% on 11/20 (Figure 12). We do not model specific scenarios of changes in transmission with the holidays, given the immediate proximity of the Thanksgiving Holiday. Additionally, policy measures are being implemented for counties that have moved to the Red Level on the COVID dial dashboard.

Projections show that on the current trajectory, at the current level of transmission control, Colorado could see substantial growth in cases in the weeks ahead, and ICU capacity would be expected to be exceeded by January 15th. If Colorado remains on the current estimated trajectory, and contacts increase over the holidays, ICU capacity could be exceeded in mid-December.

Table 2. Comparison of the projected date that ICU surge capacity is reached, the date that ICU demand peaks, the estimated number of ICU beds needed at the peak, and the cumulative COVID-19 deaths at different levels of transmission control.

	Date ICU Capacity Reached*	Date of ICU Peak	ICU Need at Peak¥	Cumulative cases through 12/31/2020¥	Cumulative deaths through 12/31/2020¥
Current trajectory (10/25 – 11/04, TC = 65%)	1/15/2021	1/15/2021	1,326	2,370,000	6,560
TC = 70% starting 11/20	N/A	1/10/2021	903	2,000,000	5,900
TC = 80% starting 11/20	N/A	12/02/2020	566	1,470,000	4,900
Steady increase in TC (start at 65% and increase 5% every week starting 11/20, to 80% max)	N/A	12/15/2020	686	1,730,000	5,500
Steady decrease TC (start at 65% and decrease 5% every week starting 11/20, to 50% min)	12/17/2020	1/14/2021	2,405	3,250,000	8,580

*ICU bed capacity for COVID-19 patients is estimated to be 1,325 in Colorado, a figure provided by CDPHE.
¥Estimates are rounded to three or two significant figures.



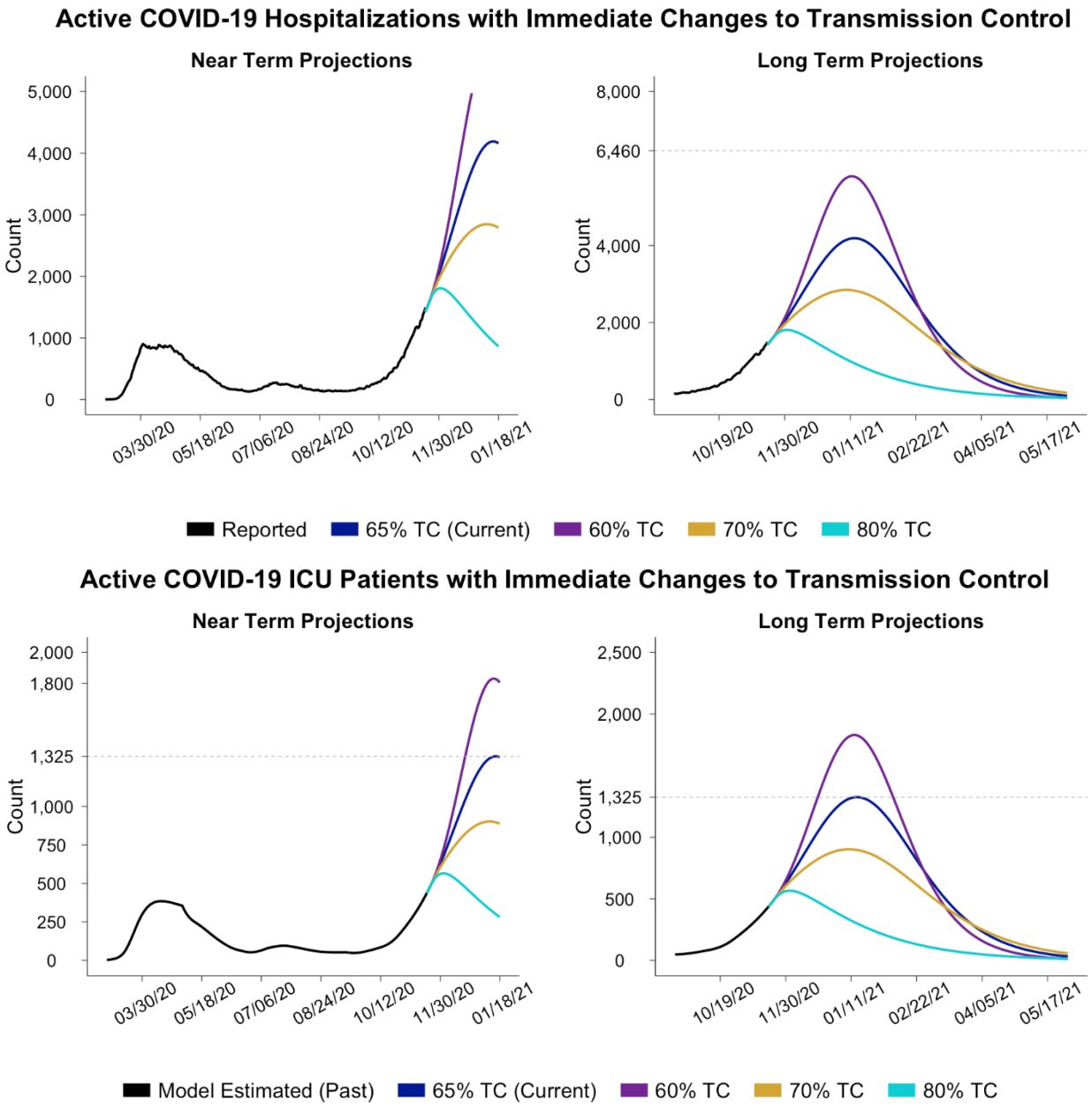
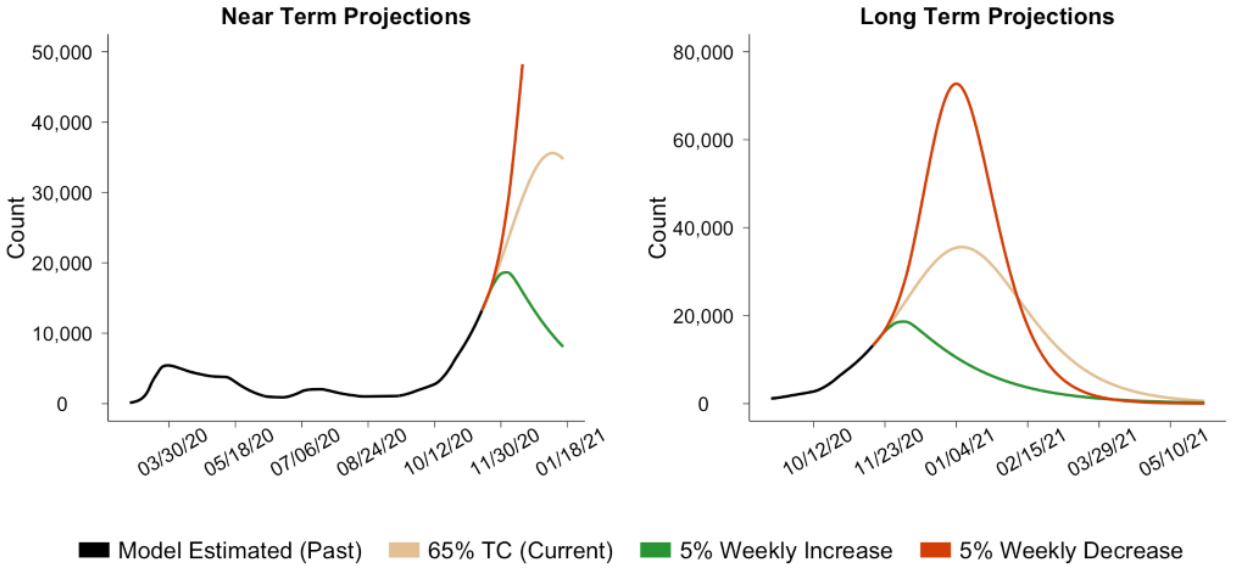
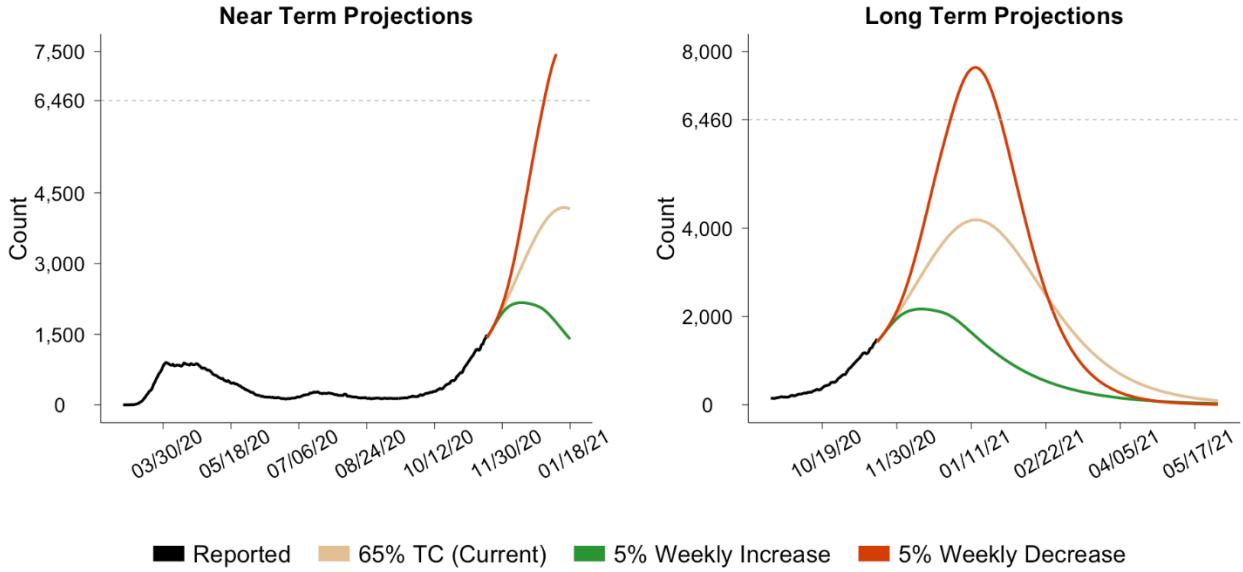


Figure 12. Projected daily count of COVID-19 incident infections, active hospitalizations, and active ICU patients under varying levels of transmission control, assuming transmission control remains at current levels (65%), or switches to 80%, 70%, or 60% on 11/20. Near-term projections are shown on the left and long-term trajectories are shown on the right. Dashed lines indicate capacity limits for all hospitalizations (6,460 med/surg beds available for COVID-19 patients) and critical care (1,325 ICU beds available for COVID-19 patients). Figures on hospital capacity limits are provided by CDPHE.

Daily New COVID-19 Infections with Incremental Changes to Transmission Control



Active COVID-19 Hospitalizations with Incremental Changes to Transmission Control



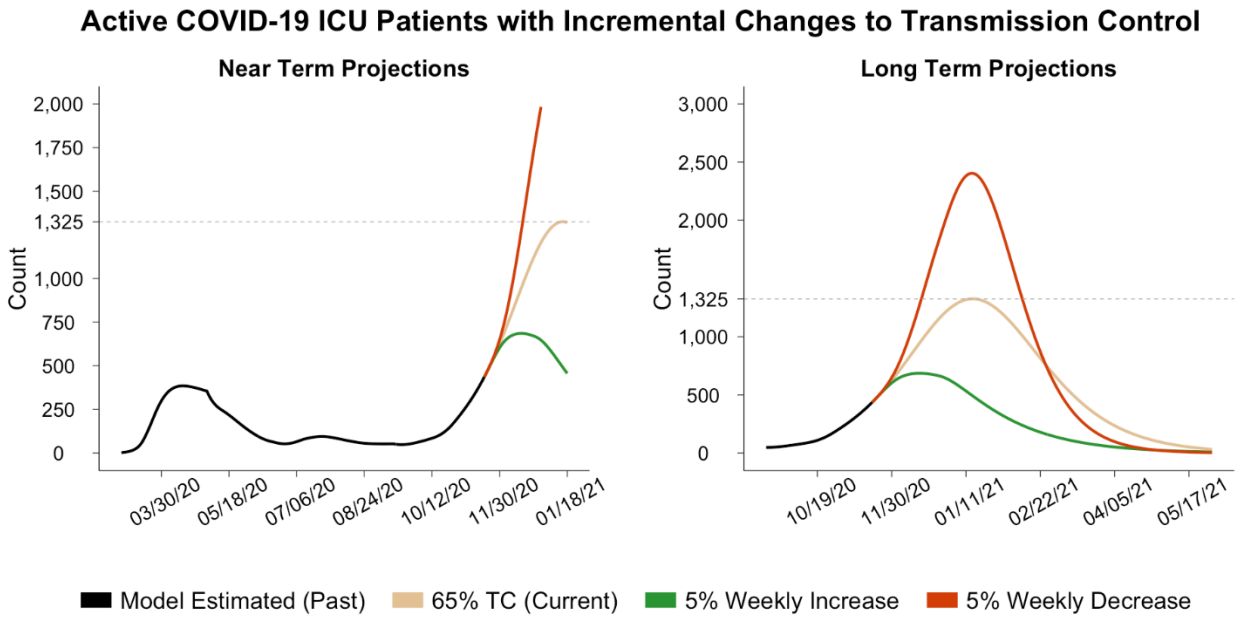
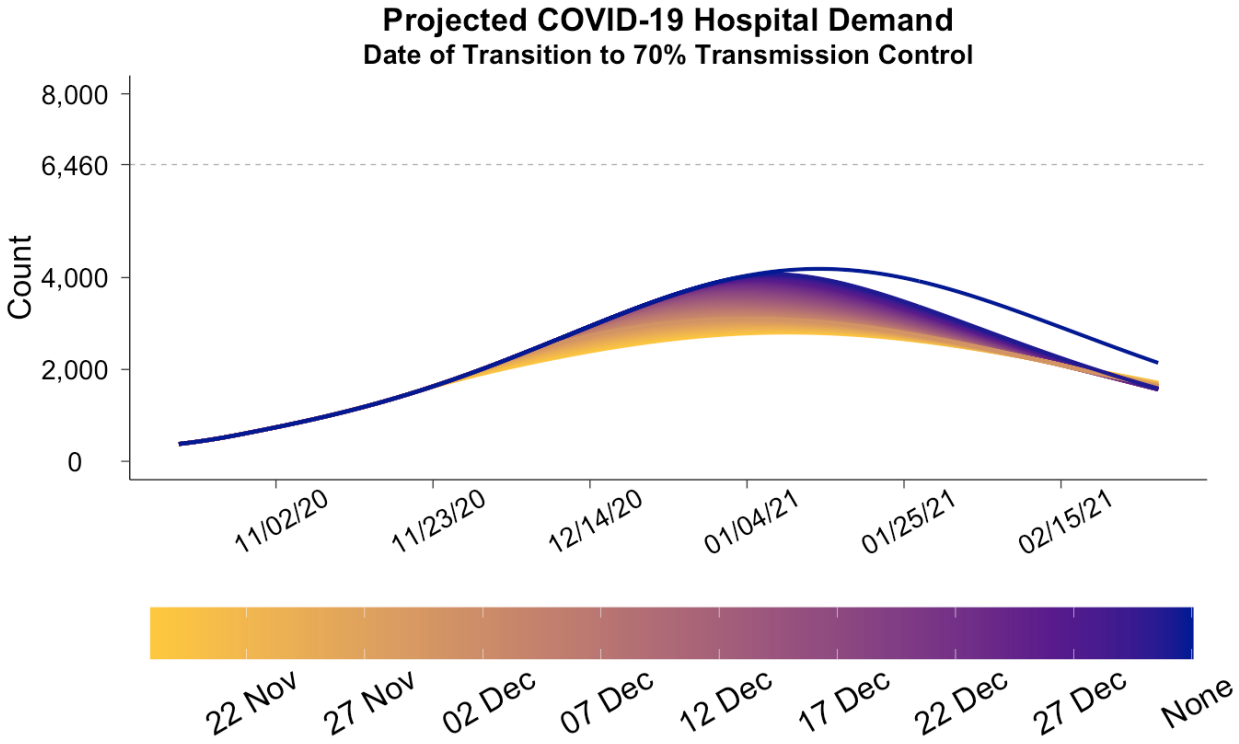


Figure 13. Projected daily count of COVID-19 incident infections, active hospitalizations, and active ICU patients under varying incremental changes to transmission control, assuming transmission control remains at current levels (65%), increases by 5% weekly starting 11/20 to a maximum of 80%, or decreases by 5% weekly starting 11/20 to a minimum of 50%. Near-term projections are shown on the left and long-term trajectories are shown on the right. Dashed lines indicate capacity limits for hospitalizations (6,460 med/surg beds available for COVID-19 patients) and critical care (1,325 ICU beds available for COVID-19 patients). Figures on hospital capacity limits are provided by CDPHE.

Projection set 2. Impact of timing of transmission control change

These scenarios examine the impact of timing of intervention implementation on peak ICU and Hospital need as well as the point when reported SARS-CoV-2 cases would decrease to a level that can be met by contact tracing capacity. These scenarios are based on the assumption that Colorado remains on the current estimated trajectory (transmission control 65%) until the indicated date at which point transmission control is increased to 70%.



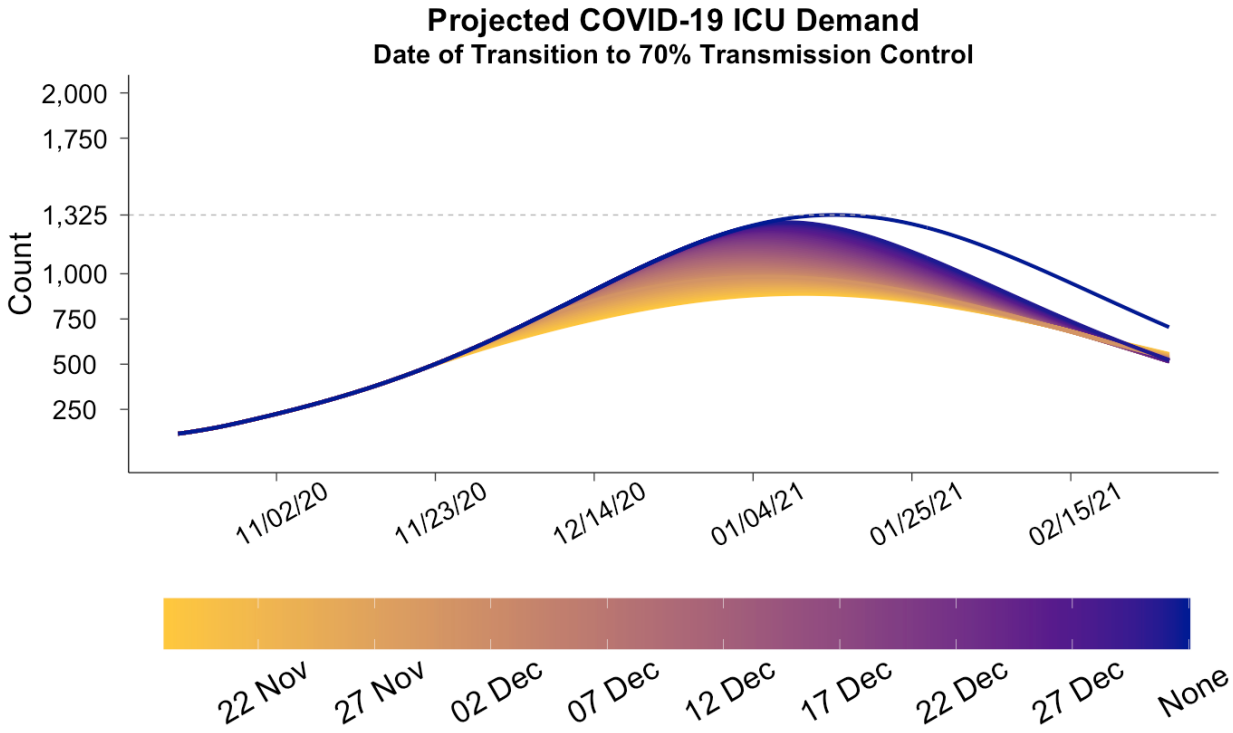


Figure 14. Projected daily count of active hospitalizations (top) and intensive care (ICU) demand (bottom) assuming we remain at our current trajectory (65%) or switch to 70% TC on any given day within the range that falls between 11/18/2020 and 12/31/2020. Dashed lines indicate capacity limits for hospitalizations (6,460 med/surg beds available for COVID-19 patients) and critical care (1,325 ICU beds available for COVID-19 patients). Figures on hospital capacity limits are provided by CDPHE.

Table 3. Estimate dates of decline and peak values of hospital demand and ICU need and timing when cases would decline below contact tracing threshold given different dates of intervention.

Date of Intervention to increase Transmission Control to 70%	Estimated date hospital demand should start to decline	Estimated peak hospital demand	Estimated date ICU demand should start to decline	Estimated Peak ICU demand	Estimated date reported cases are below 1500*
11/20	1/8/2021	2,847	01/10/2021	903	05/21/2021
11/27	1/5/2021	3,020	01/07/2021	957	05/16/2021
12/4	1/3/2021	3,229	01/04/2021	1,023	05/12/2021
12/11	1/2/2021	3,466	01/03/2021	1,096	05/07/2021

*Assuming we continue to detect the same proportion of cases, 49%, based on the model-estimate for the past two weeks.

Model simulations assume the current trajectory (transmission control 65%) until the indicated date at which point it is increased to 70%.

Appendix

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

Appendix Table A1. Estimated model parameters based on fitting our model output of total hospitalizations to reported hospitalizations in Colorado. The new "TR" model includes a single transmission control parameter that accounts for all reduction in effective contacts as a result of all policy and behavior changes to reduce transmission.

	Range of possible values	Fitted value, TC model	Fit using data through
Transmission control†			
Estimated current transmission control level, 10/25 – 11/14	0-99%	65% (95% CI: 62%, 67%)	11/16
Transmission parameters			
The rate of infection (beta)	0.2 - 0.6††	0.48	06/24
Ratio of infectiousness for symptomatic vs. asymptomatic individuals (lambda)	1.0 - 4.0††	1.39	06/24

†Two-week Transmission control parameters are estimated weekly and averaged over time period of interest.
††The range of potential parameter values for the rate of infectiousness for symptomatic vs. asymptomatic individuals [1, 2] are based on the literature, and for the rate of infection, were obtained from the MIDAS Online COVID-19 compilation of parameter estimates [3].

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.