The current state of COVID-19 in Colorado

11/12/2020

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

- Colorado has greatly exceeded the April hospitalization peak. There are more people hospitalized with COVID-19 now than since the virus arrived in Colorado. Infections are rising across the state.
- Hospitalizations are increasing more rapidly than projected last week.
- On the current trajectory Colorado will likely reach estimated ICU surge capacity (N=1800) in December.
- Transmission control needs to be increased to at least 80% from the current value of 61% within the next two weeks to safely avoid limits of medical care.
- Estimated infection prevalence now is higher that it has ever been in Colorado. All age groups and race-ethnic groups are impacted.

Snapshot of current SARS-CoV-2 transmission in Colorado

- Effective reproductive number: 1.70 (95% confidence interval 1.64, 1.77). *Hospitalizations are increasing rapidly.*
- Estimated prevalence of infections: Approximately 912 (95% CI: 893, 935) of every 100,000 Coloradans or 1 in every 110 Coloradans are currently infectious. *The estimated prevalence is higher than last week.*
- Estimated number of infections to date: Approximately 9.7% (95% CI: 9.7, 9.8) of the Colorado population has been infected to date.
- Estimated current level of transmission control: 61% (95% CI: 59%, 62%) for the period of 10/12 to 10/27. *There is an approximate 61% 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 recent weeks for all age groups. Individuals aged 20-39 have the lowest estimated level of transmission control (Transmission control = 49%). Notably, transmission control estimates have continued to decline in the oldest age group (age 65+) suggesting that people in this age group are increasingly becoming infected with the virus (Transmission control = 69%).
- Hospitalizations are increasing across the state. In the Denver Metro Area, hospitalizations are increasing rapidly in all counties.

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

- If we remain on the current trajectory, we could exceed ICU hospital capacity by New Year's Day. Increases in contacts over the holidays will accelerate growth in the number of cases and ICU hospital capacity may be exceeded earlier.
- The longer the state remains on the current trajectory, the greater the change in transmission control needed to keep hospital demand below capacity.

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 11/09/2020. 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.

Model updates

We analyzed Colorado hospitalization records and found a decline in ICU need among hospitalized COVID-19 patients since March (Appendix Figure A1). To account for this change, we updated the probability that symptomatic individuals require ICU care to reflect recent experience. This probability is age-dependent and now changes in the model over the course of the pandemic to reflect the hospitalization data reviewed. This change brings the model into better alignment with current picture in Colorado.

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. Table A1 provides values for model parameters. Our most recent estimate of transmission control, for the period 10/12 to 10/27, is 61% (95% CI = 59%, 62%). 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 10/27.

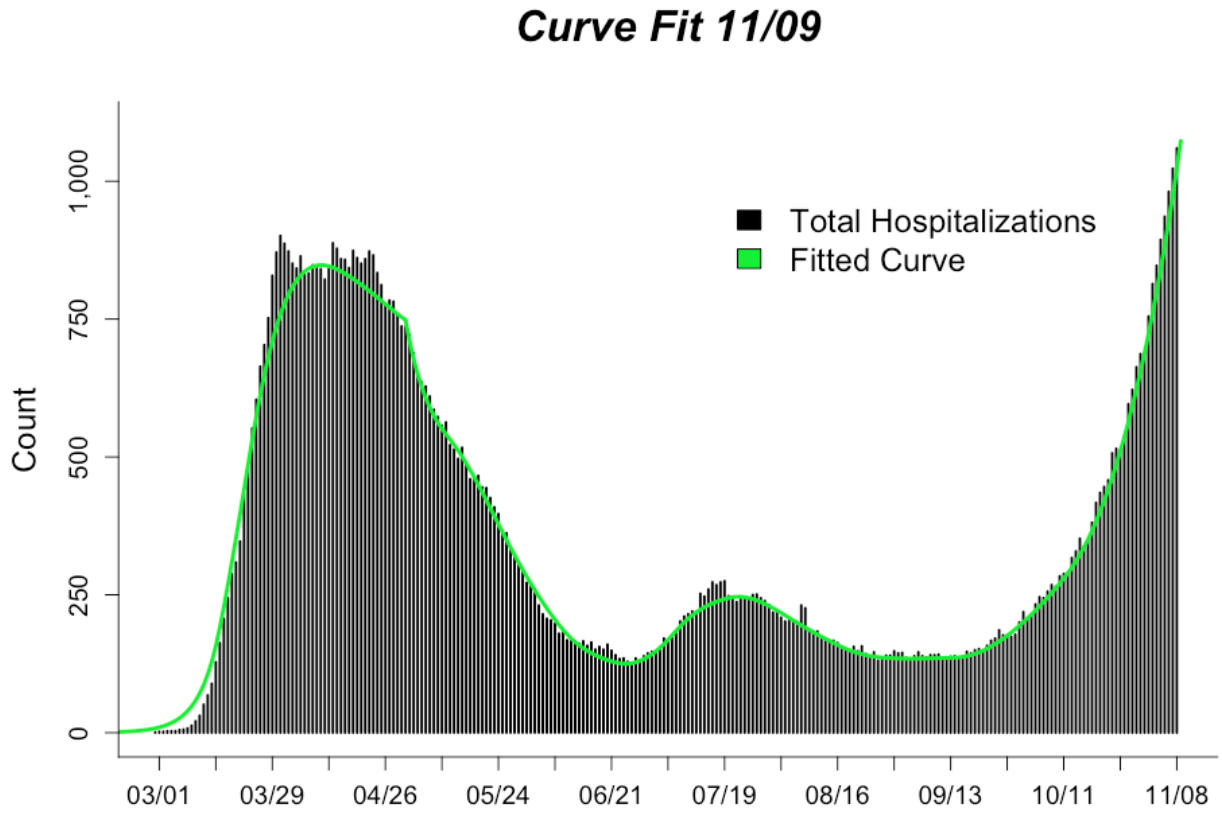


Figure 2. Current model fit (green line) to count of hospitalized COVID-19 cases (black lines) using the age-structured SEIR model. Hospitalized COVID-19 cases are from CDPHE reported COVID-19 hospitalizations and EMResource (EMR) hospital census data provided by CDPHE.

The effective reproductive number

The estimated effective reproductive number (R_E) is shown in Table 1 and Figure 3. Table 1 provides estimates that 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 (11/09)	Estimate one week ago (11/02)	Estimate two weeks ago (10/26)
Estimate of Re, approach 1 *	1.70 (1.64, 1.77)	1.66 (1.24, 1.76)	1.57 (1.47, 1.70)
Estimate of Re, approach 2 *	1.82	1.77	1.66
Estimate from RT-Live	1.20 (0.95, 1.43)	1.23(1.00, 1.50)	1.23 (0.96, 1.45)

*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 October 27th. 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.

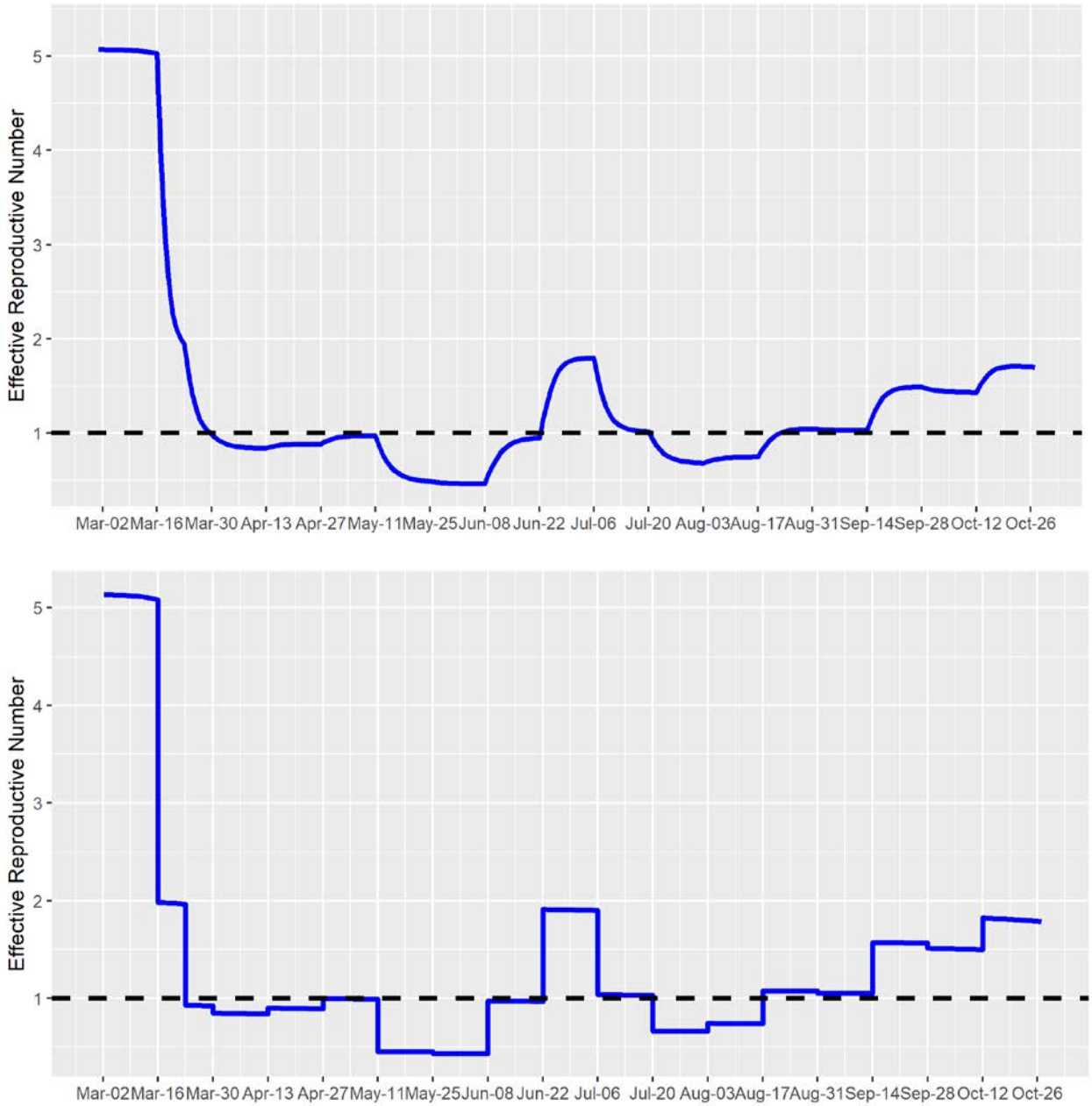


Figure 3. The effective reproductive number using approach 1 (top) and approach 2 (bottom).

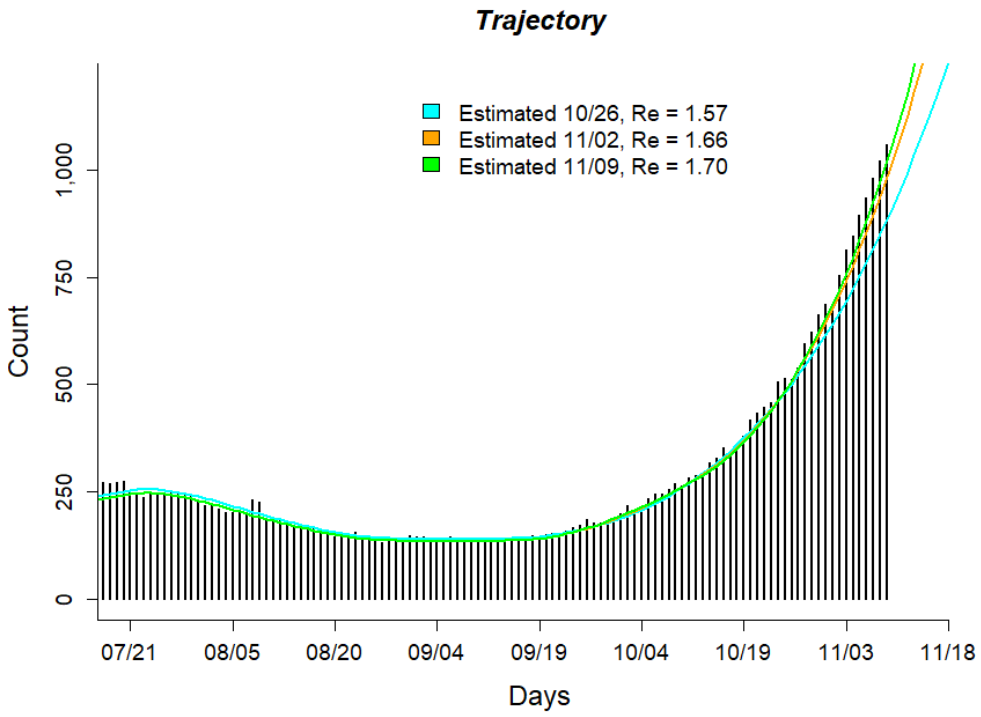


Figure 4. The projected trajectory of COVID-19 hospitalizations if Colorado remains on the current estimated trajectory (green line), the trajectory estimated one week prior (orange line), and the trajectory estimated two weeks prior (cyan line). Each trajectory is generated assuming transmission control levels remain at the estimated levels: current estimate (11/09) 61% based on the period 10/12 to 10/27, one-week prior estimate (11/02) 62% based on the period 10/12 to 10/20, two-week prior estimate (10/26) 65% based on the period 9/28 to 10/13. 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 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 (both symptomatic and asymptomatic), as well as the proportion detected by Colorado's surveillance system. These estimates are sensitive to model assumptions, including assumptions about the probability that an infected individual will be symptomatic and require hospital care, as well as estimates about length of hospital stay, which vary over time; we also make assumptions as to how these variables vary by age.

We estimate that approximately 568,000 (95% CI: 564,000, 572,000) people in Colorado, or 9.7% (95% CI: 9.7, 9.8) of the population, have been infected to date.

We estimate that there are approximately 53,000 (95%CI: 52,000, 55,000) infectious individuals in Colorado at present: approximately 912 (95% CI: 893, 935) of every 100,000 Coloradans or 1 in every

110 people (95% CI: 107, 112). 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 more likely to encounter infectious individuals in the population than they were this spring and summer.

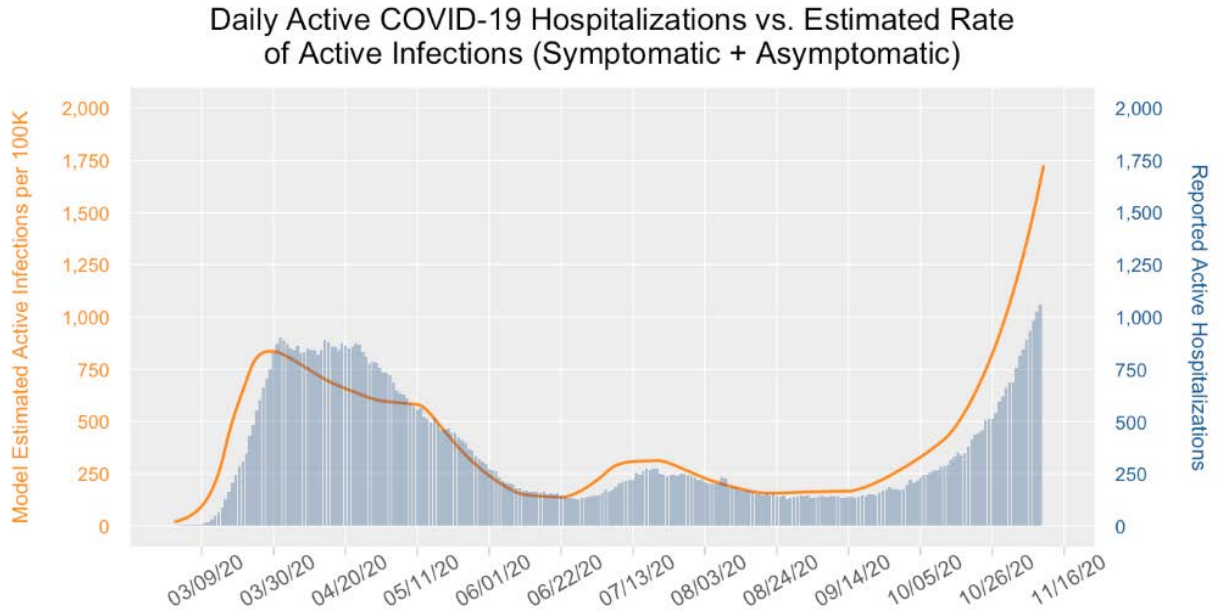


Figure 5. Estimated daily number of people (per 100,000 population) who are infectious and infected with SARS-CoV-2 (point prevalence), as shown on the orange line, and the number of actual COVID-19 hospitalizations (blue bars). The number of infectious individuals is inferred using the model and based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

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

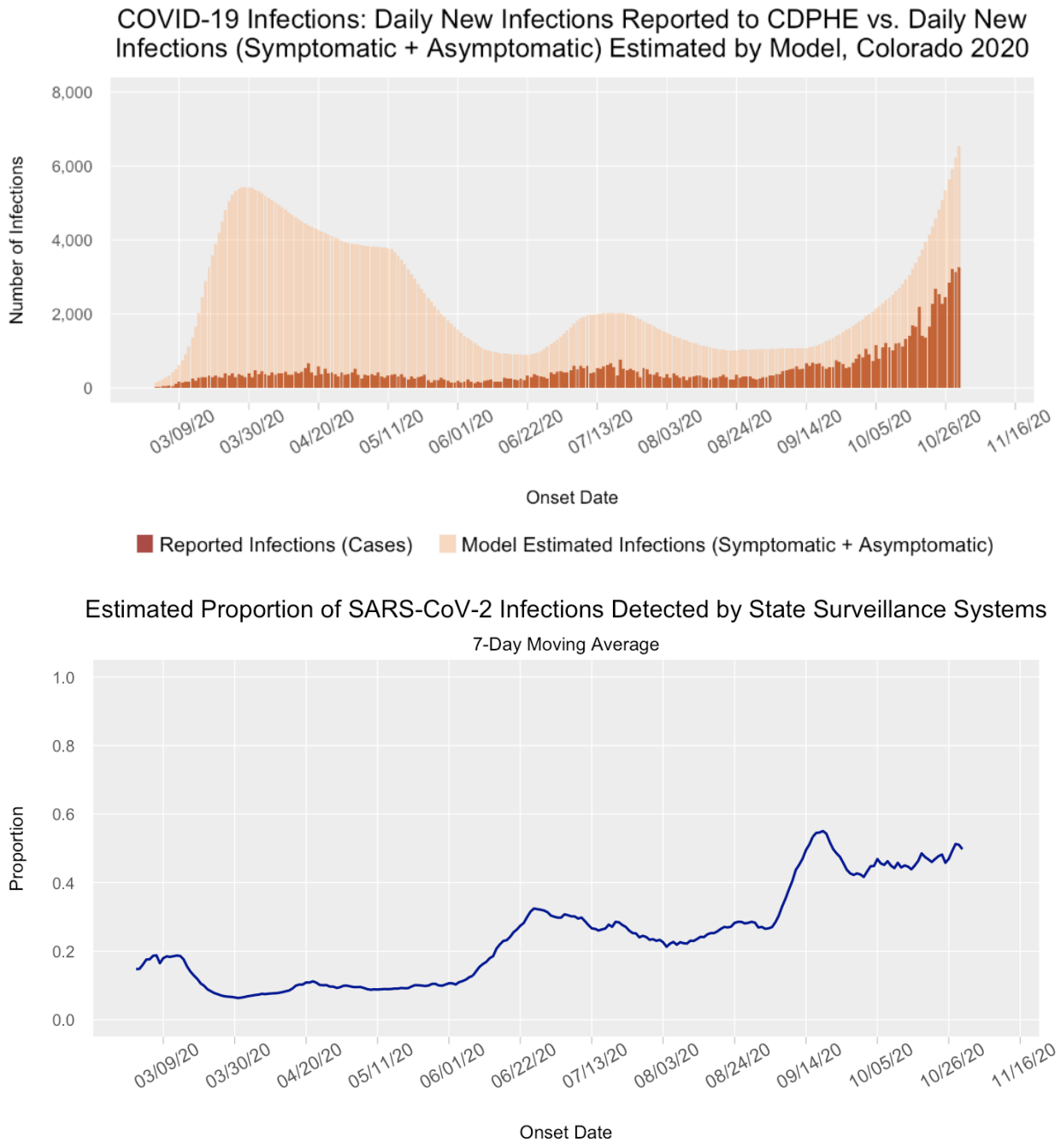


Figure 6. Estimated daily number of new (incident) SARS-CoV-2 infections based on the SEIR model (light orange graph) and reported cases (dark orange graph) over time shown in the top panel. Lower panel shows the 7-day moving average of the estimated proportion of SARS-COV2 infections that are being 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 10/31 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 56%.

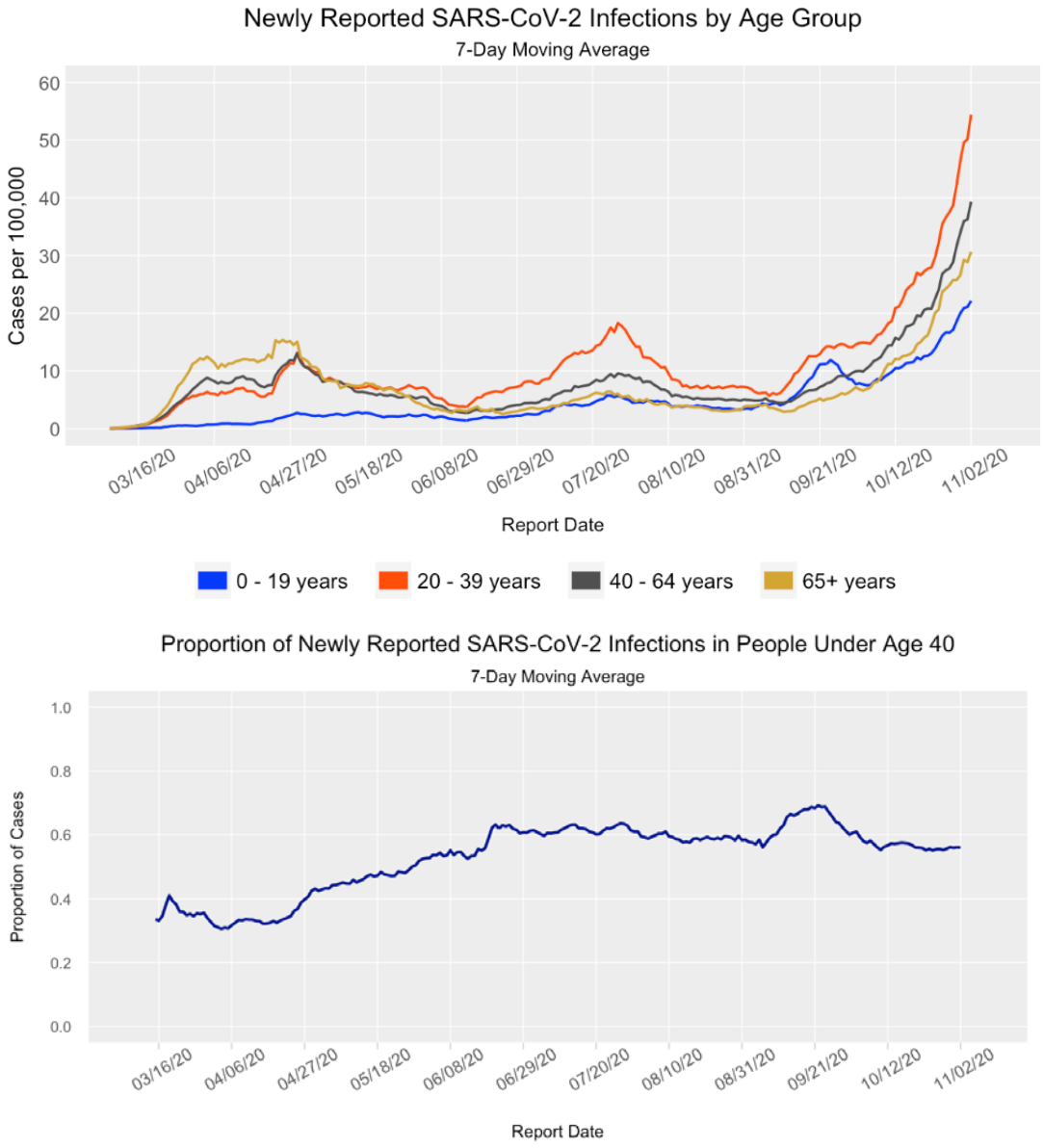
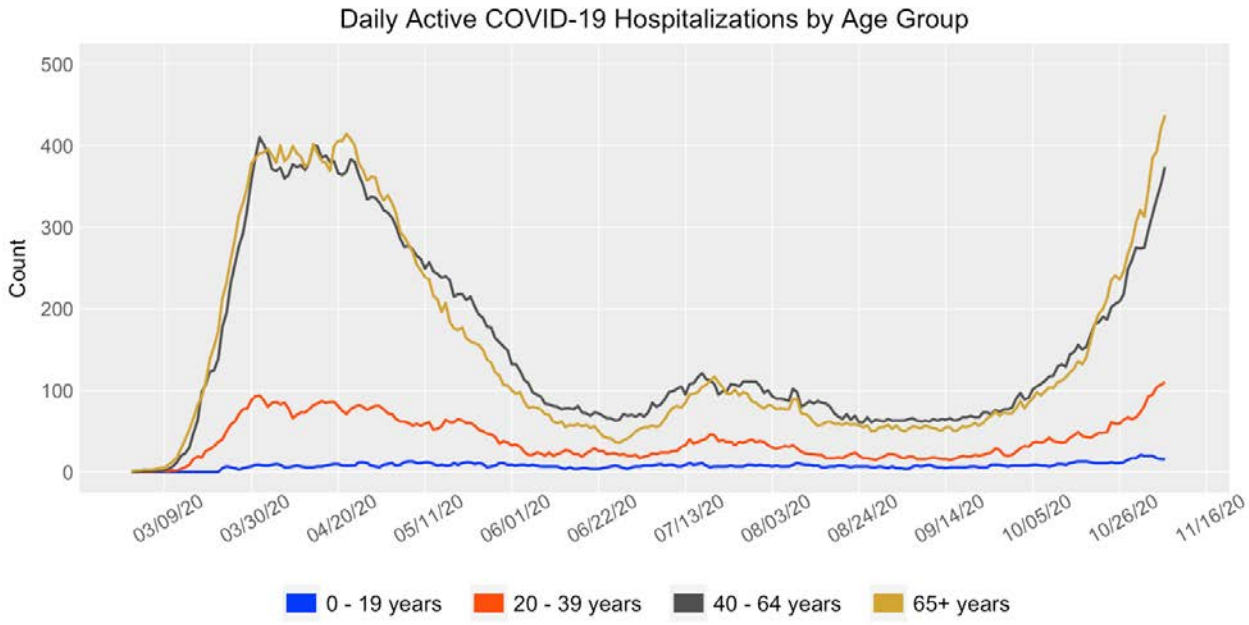


Figure 7. Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by age group (top) and the proportion of all cases among individuals under 40 (bottom). Reported cases are based on CDPHE data and shown by report date. Incident cases per 100,000 were obtained by standardizing weekly 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.



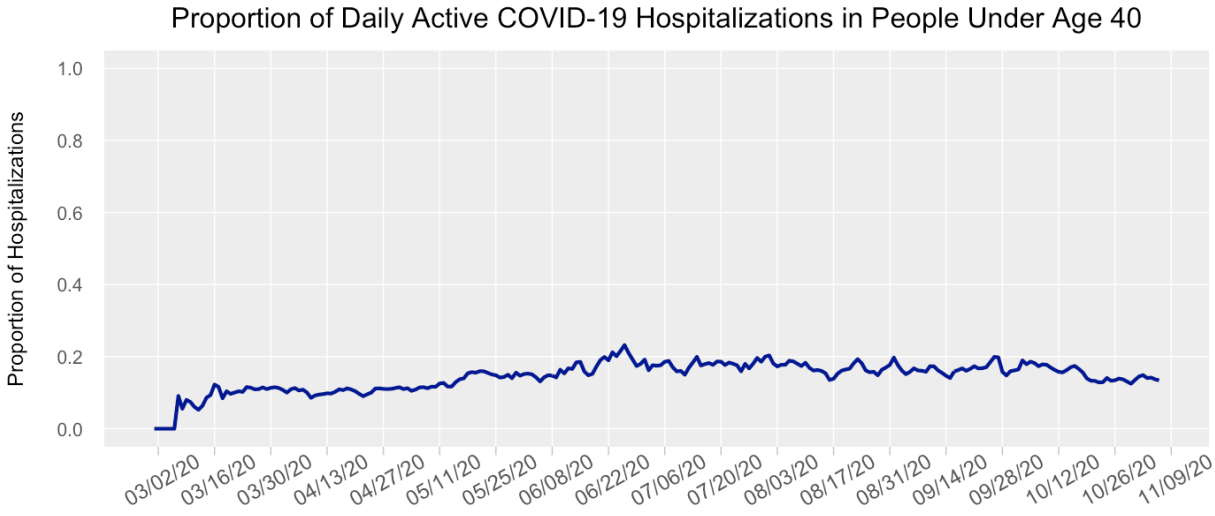


Figure 8. The number of individuals hospitalized with COVID-19 by age group from March through the present (top) and the proportion of COVID-19 hospital beds occupied by individuals under age 40. Data based on COVID Patient Hospitalization Surveillance (COPHS). Data shown through 11/06.

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.

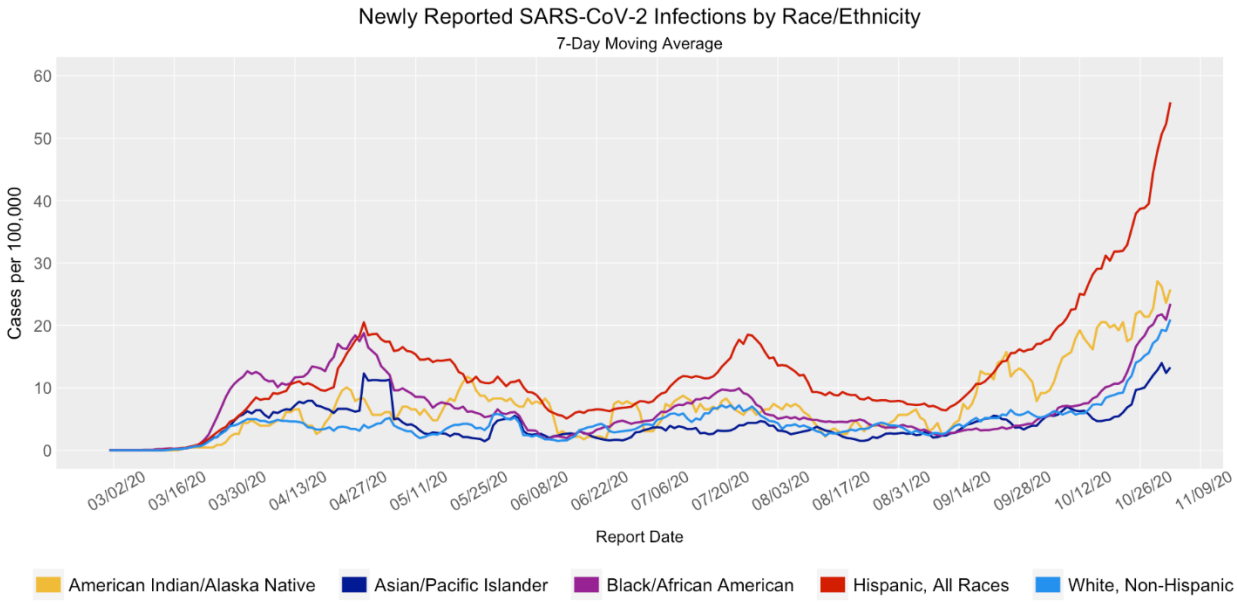


Figure 9. Distribution of 7-day moving average of newly reported SARS-CoV-2 infections by race and ethnicity in Colorado. Reported cases are based on CDPHE data and shown by report date. Cases per 100,000 were obtained by standardizing weekly reported race-specific case counts to the race/ethnicity distribution 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 32% of observations over the last two weeks). Data is shown through 11/02 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 transmission control parameters to case data. Transmission control levels continue to decrease among all age groups. Individuals aged 20-39 have the highest contact rates currently (TC= 49%). In all other individuals, cases have increased recently, leading to a decreased estimate of transmission control (TC = 69%, 60%, and 69% for individuals under 20, 40-64, and 65+ respectively).

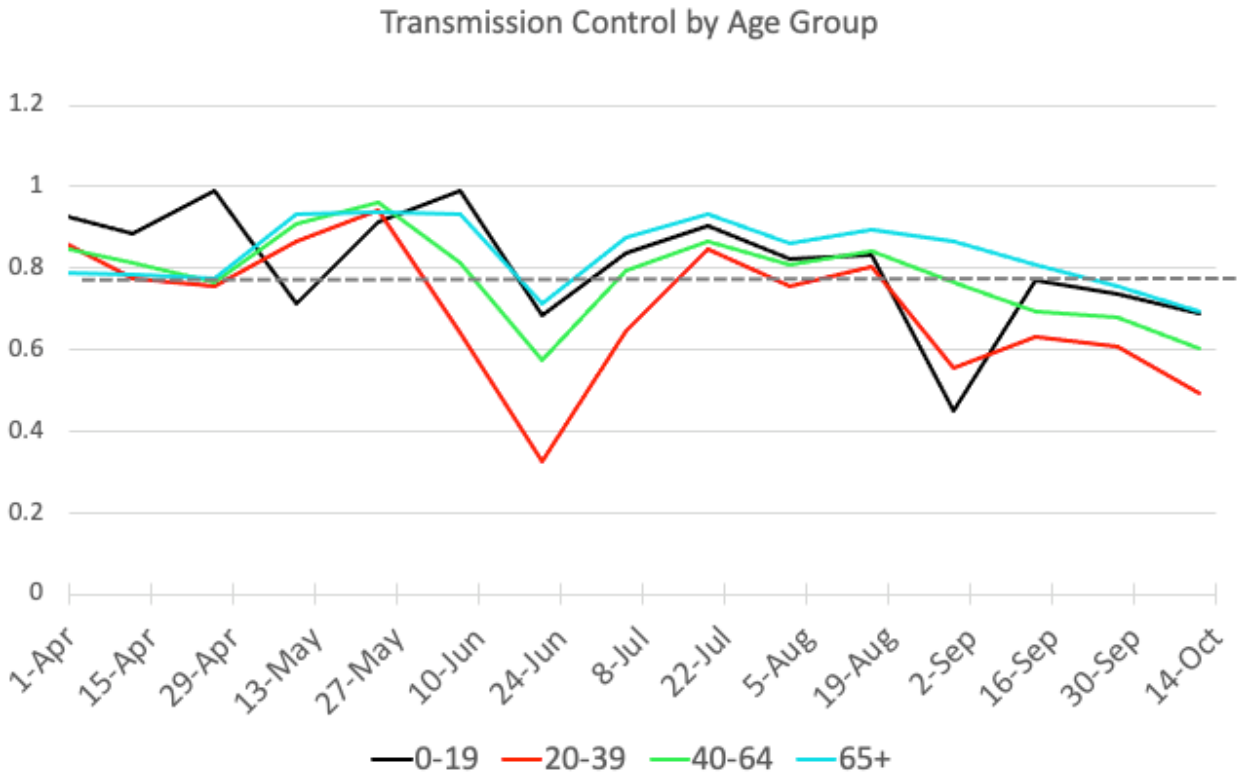


Figure 10. Estimates of transmission control by age plotted over time. Transmission control values are plotted at the time period for which they begin, as the last period for which transmission control is estimated is 10/12 – 10/27, the point on the graph is plotted at 10/12. Grey dashed line indicates threshold value of transmission control = 78%.

Near-term forecast

We generated estimated hospitalizations over the next two weeks and at 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, with 1,000 of those runs randomly selected for visualization in the figure below.

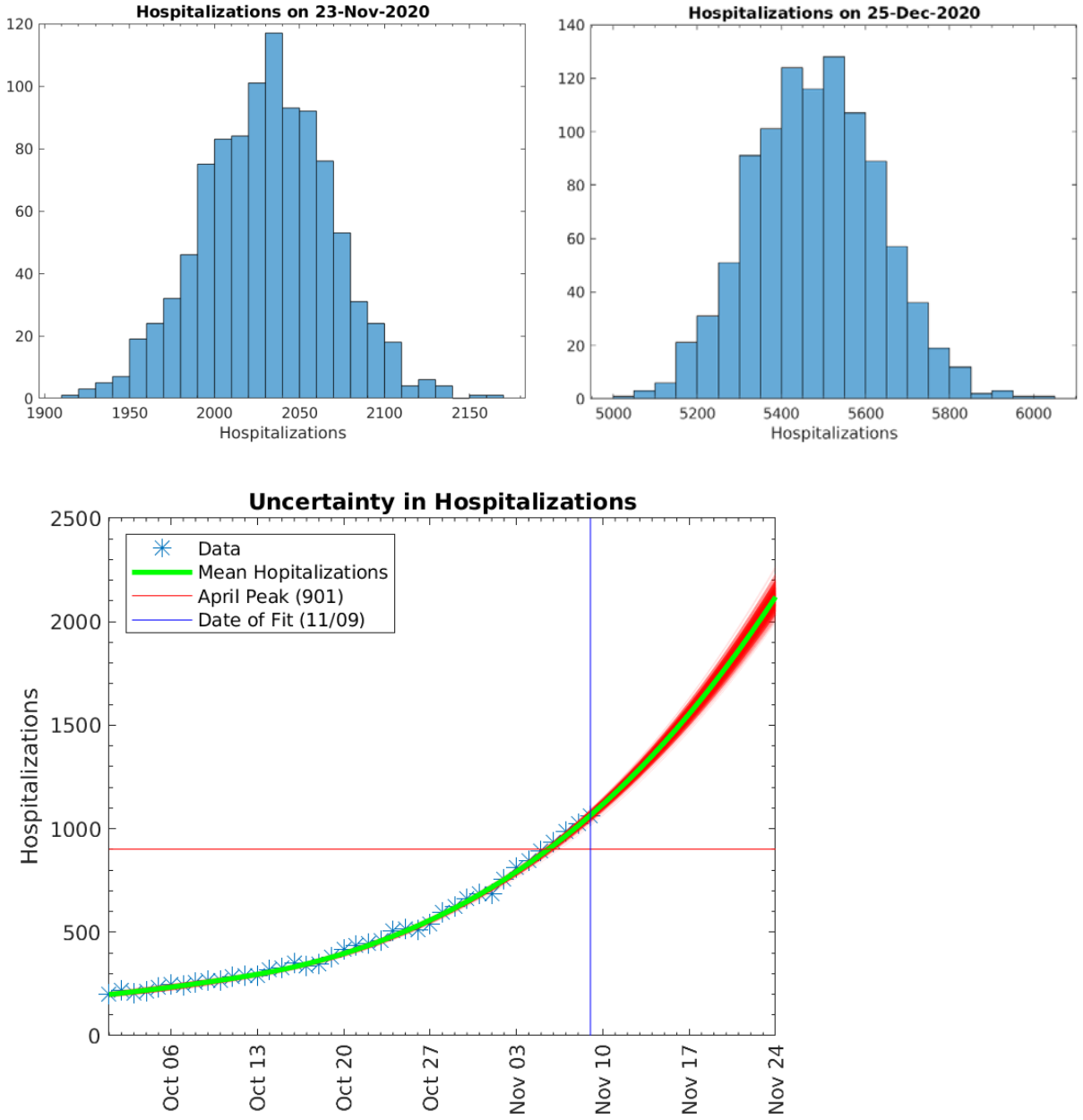


Figure 11. Distribution of hospitalizations over the two weeks (top left) and on Christmas day (top right) and estimated daily count of total hospital demand (bottom) if we remain on the current trajectory (solid line, 61% for the period 10/12 – 10/27). The lower portion of Figure 11 shows the range of uncertainty of hospitalizations over the next two weeks if the current trajectory persists.

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. These scenarios also consider the potential impact of increased population mixing and more social contacts over the holidays
- 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.

Projection set 1. Current trajectory and an 80% trajectory with and without a holiday increase in contacts.

In these scenarios, projections are generated assuming the transmission control is maintained at the current trajectory (TC=61%). Projections are also generated assuming transmission control increases to 70% or 80% on 11/13 (Figure 12).

In these scenarios we additionally consider the potential impact of increased population mixing over the holidays (Figure 13 and Table 2). Given the past increases in cases around the Independence Day (TC = 60%) and Labor Day holidays, we generated preliminary scenarios to evaluate the impact if infectious contacts were to increase over the upcoming holidays. These scenarios assume contact rates increase starting the Friday before Thanksgiving, 11/20/2020, and that the increase in contacts lasts until 1/03/2021. We do not know what the true increase in infectious contacts will be over the holiday season – we modeled 10% and 20% relative decreases in transmission control levels as preliminary and plausible scenarios. With these assumptions, we examine the extent to which the level of infections entering the holiday season affects the impact of increasing mixing during the holidays.

Projections show that on the current trajectory and 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 New Year's Day. If Colorado remains on the current estimated trajectory, and contacts increase over the holidays, ICU capacity could be exceeded by mid-December. If Colorado shifted to an 80% transmission control scenario on 11/13, critical care demand will remain well below ICU surge capacity but large increases in contacts over the holidays could lead to further growth in infections.

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[¥]
Projection set 1: Changes to the current trajectory[¶]					
Current trajectory (10/12 – 10/27, TC = 61%)	1/01/2021	1/8/2021	1,850	2,969,500	9,000
TC = 80%	N/A	11/28/2020	560	1,391,399	4,500
Projection set 2. Increased contacts over the holidays Holiday scenarios (10% decrease over holidays)**					
Baseline TC = 61% (current)	12/18/2020	1/5/2021	2,400	3,545,588	11,500
Baseline TC = 80%	N/A	1/4/2021	720	1,519,586	5,100
Projection set 3. Increased contacts over the holidays Holiday scenarios (20% decrease over holidays)**					
Baseline TC = 61% (current)	12/14/2020	1/3/2021	2,900	4,088,354	14,100
Baseline TC = 80%	N/A	1/8/2021	1,300	2,012,930	6,100

*ICU surge capacity for COVID-19 patients is estimated to be 1800 in Colorado, a figure provided by CDPHE.
[¥]Estimates are rounded to three or two significant figures.
[¶] The 80% TC scenario is modeled assuming transmission control increase to 80% on 11/13.

** Holiday scenarios assume transmission control values remain at indicated value until 11/20, at which point they decrease by a relative 10% reduction. The decreased value remains until January 3rd, when the TC level switches back to the indicated baseline TC value.

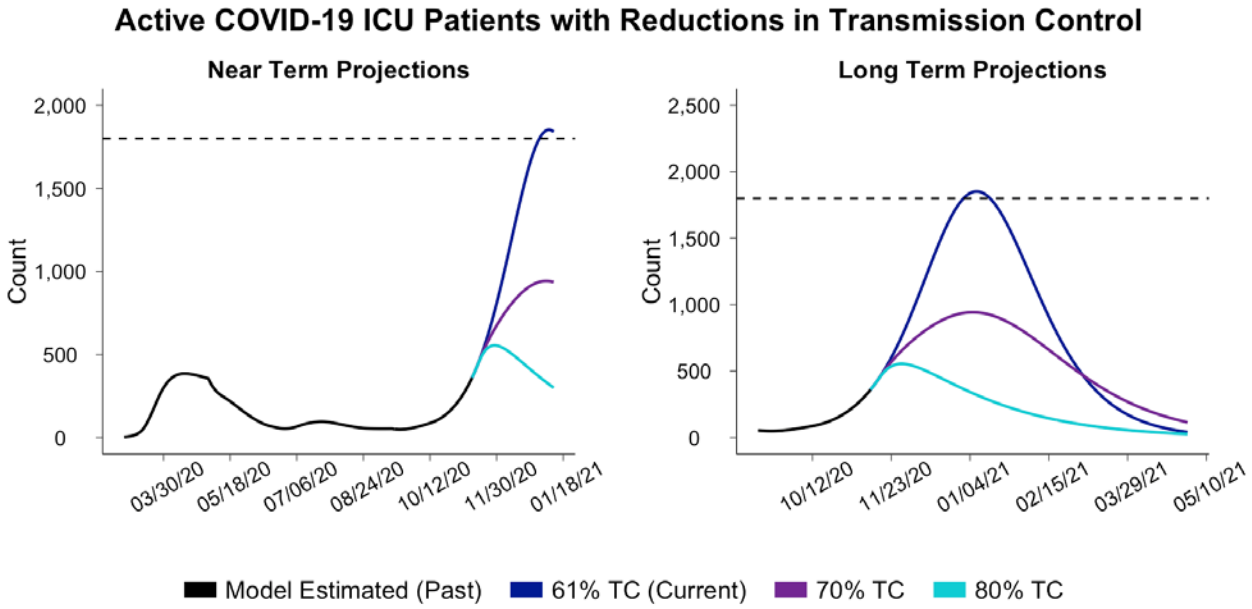


Figure 12. Projected daily count of COVID-19 ICU patients varying levels of transmission control, assuming transmission control remains at current levels (61%), or switches to 80% or 70% 11/13. Near-term projections are shown on the left and long-term trajectories are shown on the right. Dotted lines indicate estimated ICU surge capacity = 1,800.

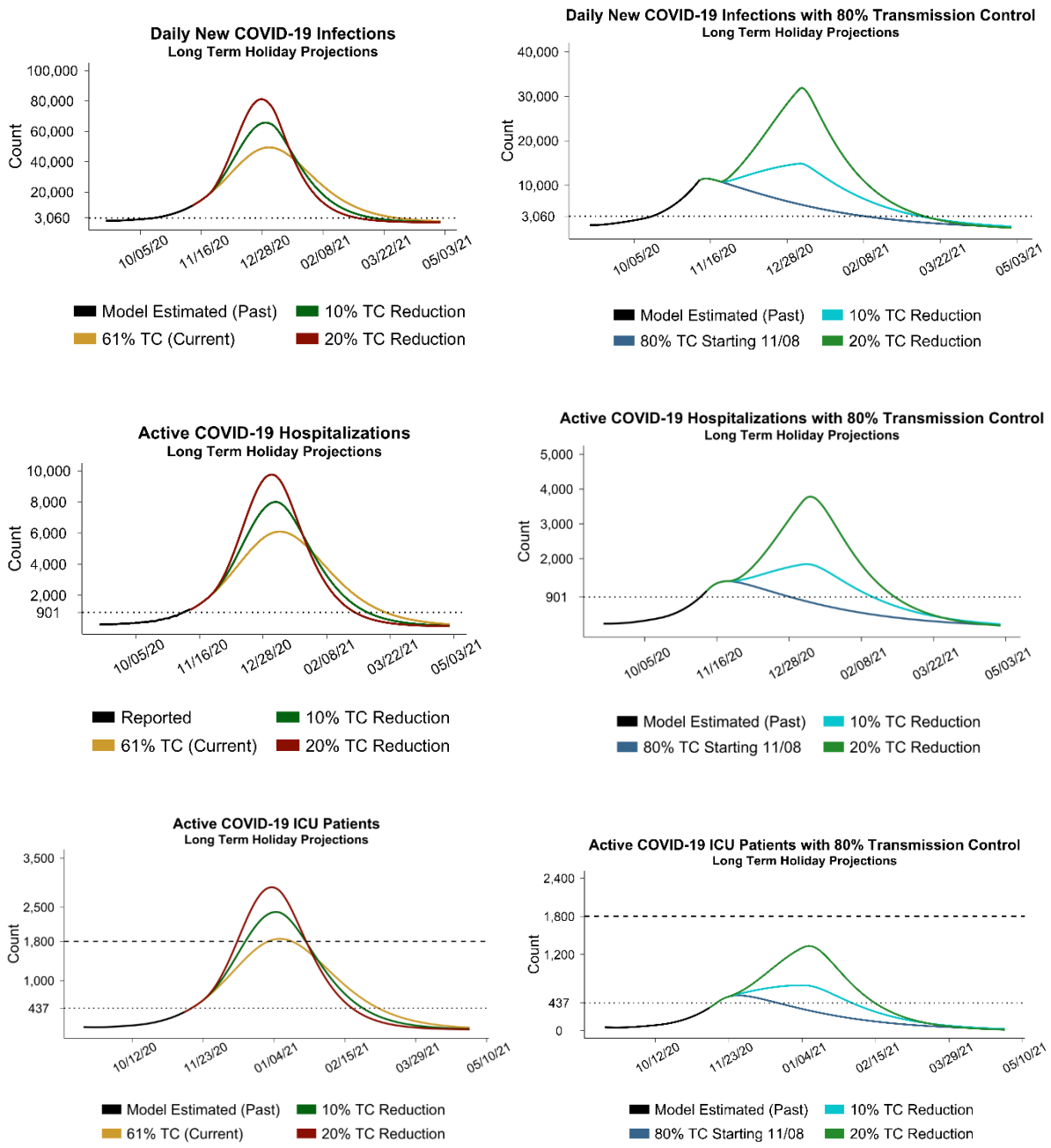


Figure 13. Projected daily count of new infections (top), hospital demand (middle), and intensive care (ICU) demand (bottom) assuming we remain at our current trajectory (61%) until 11/20 (left) or switch to 80% TC on 11/13/2020 (right), with a 10% or 20% relative decrease in transmission control levels over the winter holidays shown. Decrease in transmission control around the winter holidays is assumed to begin 11/20/2020 and last until 1/03/2021. Dotted lines on the infections, hospitalizations, and ICU graphs represent the contact tracing capacity (1500 detected cases), the peak number of hospitalizations in April (901), and the ICU surge capacity for COVID-19 patients (1800), as specified previously by CDPHE, and the April peak (437), respectively. Note that the y-axis scales on the figures on the right are different from those on the left due to the large differences in the projected number of infections and hospitalizations.

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 at which contact tracing capacity would not be exceeded. These scenarios are based on the assumption that Colorado remains on the current estimated trajectory (transmission control 61%) until the indicated date at which time transmission control increases to 80%.

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 80%	Estimated date when hospital demand should start to decline	Estimated peak hospital demand	Estimated date when ICU demand should start to decline	Estimated Peak ICU demand	Estimated date when reported cases are below 1500*
11/8	11/22/2020	1,400	11/24/2020	420	2/8/2021
11/13	11/26/2020	1,700	11/28/2020	530	2/14/2021
11/27	12/8/2020	2,950	12/9/2020	920	2/23/2021
12/11	12/19/2020	4,500	12/20/2020	1,430	2/25/2021

*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 61%) until the indicated date at which point it is increased to 80%.

Appendix

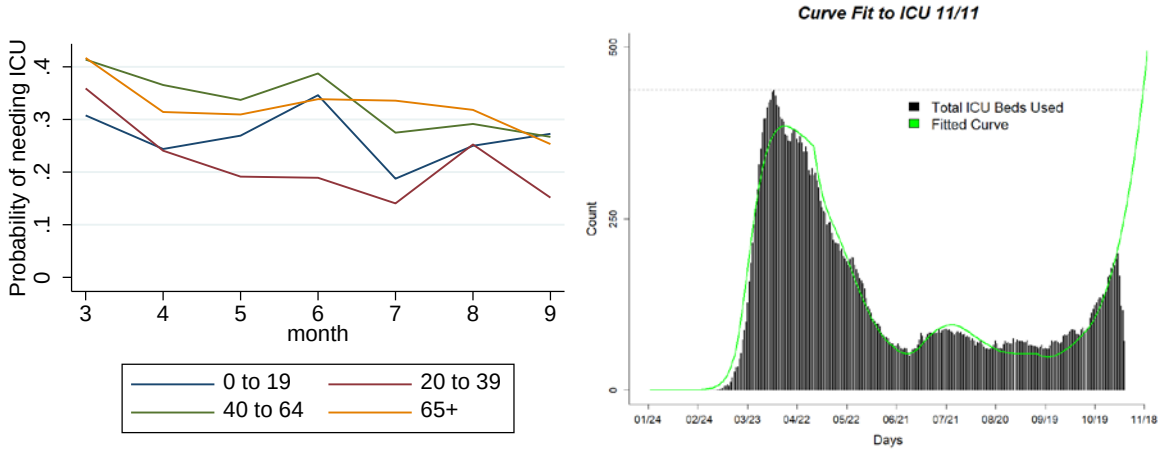
Code for our model is available on GitHub: https://github.com/agb85/covid-19

Documentation for the model can be found at:
https://jbayham.github.io/CO_COVID_Modeling/SEIR_Documentation.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	Fit using data through
Transmission control†			
Estimated transmission control level over past three weeks, 09/28 – 10/20	0-99%	64%	11/09
Estimated current transmission control level, 10/12 – 10/20	0-99%	61% (95% CI: 59%, 62%)	11/09
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].



Appendix Figure A1. The change in the percent of hospitalized patients with COVID-19 that require ICU care, by age and month of admission (left) and updated model fit to observed ICU data (right). Data from Colorado COvid Patient Hospitalization Surveillance (COPHS).

References

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