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Curbing the COVID-19 pandemic with facility-based isolation of mild cases: a mathematical modeling study

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Abstract

Background: In many countries, patients with mild coronavirus disease 2019 (COVID-19) are told to self-isolate at home, but imperfect compliance and shared living space with uninfected people limit the effectiveness of home-based isolation. We examine the impact of facility-based isolation compared to self-isolation at home on the continuing epidemic in the USA.

Methods: We developed a compartment model to simulate the dynamic transmission of COVID-19 and calibrated it to key epidemic measures in the USA from March to September 2020. We simulated facility-based isolation strategies with various capacities and starting times under different diagnosis rates. Our primary model outcomes are new infections and deaths over 2 months from October 2020 onwards. In addition to national-level estimations, we explored the effects of facility-based isolation under different epidemic burdens in major US Census Regions. We performed sensitivity analyses by varying key model assumptions and parameters.

Results: We find that facility-based isolation with moderate capacity of 5 beds per 10 000 total population could avert 4.17 (95% credible interval 1.65–7.11) million new infections and 16 000 (8000–23 000) deaths in 2 months compared with home-based isolation. These results are equivalent to relative reductions of 57% (44–61%) in new infections and 37% (27–40%) in deaths. Facility-based isolation with high capacity of 10 beds per 10 000 population could achieve reductions of 76% (62–84%) in new infections and 52% (37–64%) in deaths when supported by expanded testing with an additional 20% daily diagnosis rate. Delays in implementation would substantially reduce the impact of facility-based isolation. The effective capacity and the impact of facility-based isolation varied by epidemic stage across regions.

Conclusion: Timely facility-based isolation for mild COVID-19 cases could substantially reduce the number of new infections and effectively curb the continuing epidemic in the USA. Local epidemic burdens should determine the scale of facility-based isolation strategies.

Introduction

The worldwide death toll from coronavirus disease 2019 (COVID-19) is staggering. One of the most critical decisions in this current phase of the pandemic—as well as for long-term control strategies—is how to isolate and manage patients with asymptomatic, mild, or moderate COVID-19.[1,2] As the majority of COVID-19 cases have a mild clinical course, effective strategies are needed to isolate such cases. Isolation of people with mild COVID-19 is particularly important because they tend to be more active and thus have more contacts with other people compared to patients with severe COVID-19 whose symptoms impede their mobility and often lead to isolation in hospitals. Patients with mild COVID-19 may also have higher viral load and thus could be more infectious per contact than patients with more severe COVID-19.[3]

In most countries, hospital bed capacity is insufficient to isolate all patients as the need for isolation increases during epidemic surges. Indeed, many countries, such as the United States and the United Kingdom, have built field hospitals to ensure that COVID-19 patients in recovery and other patients who do not need intensive or complex treatments receive adequate care.[4,5] Yet, in general, these countries have chosen to isolate patients with mild to moderate COVID-19 in their homes.[6]

Home-based isolation, however, has several important limitations. For one, home-based isolation is not effective in preventing transmissions within households. In China, before the implementation of facility-based isolation, more than half of COVID-19 patients had at least one family member with the disease, and 75–80% of all clustered infections occurred within families.[7,8] In New York City, 66% of COVID-19 cases were people who had stayed in their homes,[9] suggesting high rates of intra-family transmission of COVID-19. Furthermore, it is difficult to achieve high compliance with home-based isolation guidelines.[10] Studies have shown that home-based isolation decreases non-household contacts of patients by only 10 to 50%.[11–13] A rigorous review concluded that 46–66% of transmissions are household-based.[14] Thus, home-based isolation may fail to effectively prevent both household and non-household transmission of COVID-19.

An alternative strategy to home-based isolation is facility-based isolation. Several Asian countries, such as China, Singapore, South Korea and Vietnam, have used facility-based isolation to contain the COVID-19 epidemic.[15–22] One example is the Fangcang shelter hospitals that were a major component of COVID-19 control measures in Wuhan, China, the original epicenter of the epidemic.[15] These hospitals were rapidly converted from existing public facilities and served to simultaneously isolate and care for patients with mild to moderate COVID-19.[15] In Singapore, asymptomatic and mild COVID-19 patients are isolated in community care facilities, which were modeled after the Fangcang shelter hospitals in China.[18] South Korea and Vietnam also adopted this approach. In South Korea, patients with severe COVID-19 were sent to hospitals, while those with mild COVID-19 checked into isolation units at converted community centers and corporate training facilities.[16,17] In Vietnam, all COVID-19 patients, including asymptomatic cases, were hospitalized.[20,21] Recently, Hong Kong converted an exhibition center into a facility for isolating and treating patients with mild COVID-19, as the city experienced surging COVID-19 case numbers and a hospital bed shortage.[19]

As countries were emerging from COVID-19 lockdowns, many gradually reopened their borders and resumed air traffic. To prevent COVID-19 importation, many countries also adopted facility-based centralized quarantine and isolation strategies for travelers. For example, all people entering China were quarantined in centralized facilities.[23] In Singapore, all travelers from high-risk countries were transported directly from the airport to hotels for facility-based quarantine and were not allowed to leave their individual rooms for two weeks. Travelers who tested positive for COVID-19 upon arrival or during quarantine were subsequently isolated in centralized facilities.[24] In general, facility-based quarantine and isolation of travelers, accompanied by expanded testing, can timely identify COVID-19 cases and effectively prevent onward transmission.[25]

Several empirical studies have shown that facility-based isolation of asymptomatic, mild and moderate cases is associated with reduced COVID-19 daily reproduction number, infections and mortality.[25–28] A recent study reconstructed the full transmission dynamics of COVID-19 in Wuhan and found that the control efforts based on facility-based isolation and quarantine averted about 70% of infections in total.[29] Another modeling study also showed that facility-based isolation could effectively avert 37% more infections than home-based isolation in the epidemic setting of Singapore.[30]

It remains unclear, however, how epidemic control outcomes would be affected by different implementation designs of facility-based isolation and epidemic factors. In this study, we aimed to examine the potential impact of facility-based isolation at different scales and starting times, compared to home-based isolation. We based our analysis on the continuing COVID-19 epidemic in the United States, which currently has the highest COVID-19 burden in the world.[31] Using a mathematical model calibrated to the recently reported epidemic metrics at national and regional levels in the USA, we estimated the reductions in new infections and deaths that facility-based isolation could achieve compared to home-based isolation.

Methods

Model overview

We used a compartment model, a common modeling approach to project temporal trends in infectious diseases and to estimate the impact of interventions on disease transmission,[32,33] to simulate the epidemic trajectory of the COVID-19 epidemic in the United States. We extended the Susceptible-Exposed-Infectious-Removed model by incorporating pre-symptomatic, asymptomatic, and undiagnosed infections (Figure S1). We further differentiated the diagnosed COVID-19 cases by the severity of disease (mild to moderate versus severe to critical). According to the US Centers for Disease Control and Prevention (CDC), patients with mild to moderate COVID-19 account for 81% of all COVID-19 patients.[34,35] In our status-quo scenario, we assumed that patients diagnosed with mild to moderate COVID-19 and undiagnosed symptomatic patients are isolated in their homes. In line with the extant literature, we assumed that home-based isolation reduces but still permits transmission within households and communities.[7,8,11–13] We also included disease transmission from pre-symptomatic and asymptomatic cases in our model, based on the emerging empirical evidence.[3,36,37]

Considering that community transmission of COVID-19 in the United States was first detected in February 2020,[38] we started our simulation on 1 February 2020, to capture the transmission dynamics in early epidemic stages. We calibrated the model to match the reported key epidemic metrics during the course of the epidemic in the United States since mid-March 2020, using data from *The COVID Tracking Project*.[39] Our model projected the number of infections and deaths in the USA for 2 months since 1 October 2020. Based on these numbers, we evaluated the impact of facility-based isolation of patients with mild to moderate COVID-19 on the current epidemic trend. All data used in this analysis are publicly available and thus this study did not require approval from an institutional review board. All statistical analyses and modelling were performed in R.[40]

Parameter estimation and calibration

To capture various public health control measures that have taken place and the changing social behavior patterns since the start of the COVID-19 epidemic, we allowed the transmission rate in our model to vary over time. We assumed an initial constant transmission rate in early periods before the adoption of stay-at-home orders across multiple US states since mid-March 2020.[41,42] Although the lockdown and social distancing restrictions showed promising effects in slowing down the spread of COVID-19,[43] with the reopening and relaxing of these restrictions, COVID-19 cases began to flare up during June 2020 and surpassed the outbreak's first peak in April.[39] The number of daily cases decreased substantially following the second peak in July, but the decreasing trend slowed down in September. To capture these temporal changes in disease transmission, we used a cubic spline function to approximate the transmission rate function over time, with 13 knots spread over the 6-month time span from mid-March to mid-September 2020 (Supplement Material S1).

We assumed that the incubation period from infection to symptom onset was 5.2 days.[44] We divided the incubation period into a latency period of 2.9 days and a pre-symptomatic infectious period of 2.3 days.[29] Pre-symptomatic and asymptomatic cases of COVID-19 can transmit the virus, but the estimates of their contributions to overall viral spread have remained highly uncertain. We adopted the estimates used by the CDC for their COVID-19 pandemic planning scenarios[45] and assumed that 40% of infections were asymptomatic and that the infectiousness of pre-symptomatic and asymptomatic cases was 75% that of symptomatic cases. We further assumed a mean time interval from symptom onset to self-isolation at home of 2.6 days[46] and a duration of infectiousness since symptom onset of 7 days.[47,48]

In the status-quo scenario, patients with mild to moderate COVID-19 were assumed to be in home-based isolation following diagnosis. We assumed that during home-based isolation, the social contact rate was reduced by 50%, based on existing evidence showing reductions of the social contact rate between 10% and 50%[11,13] and in line with the assumption about the effectiveness of home-based isolation made in a previous mathematical modelling study.[12]

Early evidence during the epidemic showed that 19% of patients had severe to critical COVID-19 upon diagnosis.[34,49] As increasing proportions of young and healthy people become infected and receive COVID-19 tests, the case-severity ratio is likely to decline over time.[50–52] The mortality rate of patients with severe COVID-19 may also decrease over time, as treatment protocols become more effective. We therefore allowed the case-severity ratio and mortality rate to decrease in our model, with rates of decrease determined by our model calibration. For severe cases, we assumed that the average time from hospitalization to recovery was 13 days based on the empirical evidence.[34,53,54]

Our data sources for model calibration included the daily new confirmed cases, COVID-19 related deaths, and current hospitalizations in the USA from *The COVID Tracking Project*.[39] The values of the knots for the transmission rate spline function, and the rates of decrease of the case-severity ratio and the mortality rate were calibrated to the above key epidemic metrics using the Metropolis–Hastings Markov chain Monte Carlo algorithm.[55] We used the Delayed-Rejection Adaptive Metropolis (DRAM) sampler from the BayesianTools R package. Calibration targets included the three epidemic outcome measures, number of daily new cases, daily new deaths, and current hospitalizations, which we extracted from *The COVID Tracking Project*[56] from 16 March 2020 (the first day *The COVID Tracking Project* collected full data from all 56 states and territories in the USA) to 1 October 2020, when our final analyses were conducted. Further details on the model calibration are included in Supplement Material S1.

Isolation strategies and model outcomes

Our objective was to estimate the impact of facility-based isolation of patients with mild to moderate COVID-19 compared to the status-quo policy of home-based isolation. Our primary outcomes were the numbers of new infections and deaths over 2 months (60 days) since 1 October 2020 for each isolation strategy. We examined two critical design factors in facility-based isolation: the capacity and the starting time of facility-based

isolation. In particular, we considered three different levels of capacity for facility-based isolation relative to the size of the total population: (i) a moderate capacity of 5 beds per 10 000 population (i.e., facilities can isolate at most 5 patients with mild to moderate COVID-19 per 10 000 population, while mild to moderate cases in excess to this population ratio remain in home-based isolation); (ii) a high capacity of 10 beds per 10 000 population, which represents a scenario comparable to the scale of Fangcang shelter hospitals in the city of Wuhan during February and March 2020,[15] where facility-based isolation for patients with mild to moderate COVID-19 was first proposed and implemented; and (iii) a low capacity of 2.5 beds per 10 000 population. Furthermore, we projected the outcomes of implementing facility-based isolation with a moderate capacity (i.e., 5 beds per 10 000 population) at different starting times relative to the epidemic outbreak: (i) immediately, (ii) after 14 days and (iii) after 28 days since the start of our model projections.

Other critical factors that could influence disease transmission and thus the impact of isolation strategies are whether infected individuals can be effectively identified and diagnosed in a timely manner. Case identification and diagnosis could be improved through expanded testing, using such public health measures as contact tracing and frequent screening of close contacts of confirmed COVID-19 cases and other individuals at high risk of COVID-19. To examine the potential benefits of expanded testing, we further evaluated each isolation strategy with additional testing and diagnosis of asymptomatic individuals, pre-symptomatic individuals, and undiagnosed symptomatic individuals who self-isolate at home (Figure S1). We do so in two scenarios, with rates of additional daily diagnosis of 10% and 20%, respectively.

Regional analyses

The spread of COVID-19 has been geographically heterogeneous within the United States. With different epidemic control efforts, compliance with stipulations to reduce social contacts, and timelines of reopening the economy after an initial lockdown,[57–59] the different regions of the United States have exhibited widely varied courses of the epidemic and are currently in different epidemic stages.[38,39,57] To further explore the differential impact of facility-based isolation in different epidemic stages, we performed regional analyses for each of the 4 US Census Regions: West, Midwest, South and Northeast.[60] We recalibrated the model for each region and projected the epidemic under the same isolation strategies and assumptions as in the base-case national analysis.

Sensitivity analyses and model uncertainty

We conducted several sensitivity analyses to test the robustness of our results under different parameter assumptions. In particular, we recalibrated our model with the more optimistic assumption that home-based isolation reduced social contacts and transmission rates by 70% and 90%, respectively, compared to no isolation. We also performed analyses using a longer period of infectiousness (10 days),[45] and different transmission rates during the projection period (50% lower or 50% higher) than the calibrated values to reflect the variability of future transmission rates.

To account for model uncertainty, we sampled the parameter values from the posterior distributions of the calibrated parameters and performed model projection for each sampled parameter value. Model outcomes are presented as the mean value and the 95% equal-tailed credible interval (CrI).

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The funders of the study had no role in study design, data collection, data analysis, data interpretation or writing of the article.

Results

Epidemic impact of facility-based isolation with different capacities

Our model projected that in the status-quo scenario, where all patients with mild to moderate COVID-19 self-isolated at home, the cumulative number of confirmed COVID-19 cases would increase from 7.27 (95% CrI 7.06–7.44) million to 10.84 (95% CrI 9.07–13.73) million within two months from the beginning of October (Figure 1). The model projected a total of 7.29 (95% CrI 3.33–14.99) million new infections (including all infected individuals with or without diagnosis) and 42 000 (95% CrI 26 000-68 000) deaths during the two-month period.

For the facility-based isolation scenario with moderate capacity, the number of new infections over the next 2 months would decrease to 3.12 (95% CrI 1.71–8.19) million, with a total number of 4.17 (95% CrI 1.65–7.11) million new infections averted. This decrease is equivalent to a relative reduction of 57% (95% CrI 44–61%) compared to the home-based isolation scenario (Figure 2, Table S2). Facility-based isolation at this capacity level reduced the number of deaths within two months to 26 000 (95% CrI 19 000–44 000), resulting in 16 000 (95% CrI 8000–23 000) deaths averted, which is equivalent to a 37% (95% CrI 27–40%) relative reduction.

Reducing facility-based isolation capacity to 2.5 beds per 10 000 population resulted in a smaller reduction in new infections (32%, 95% CrI 22–42%) and deaths (20%, 95% CrI 16–23%) within 2 months. These relative reductions are equivalent to 2.35 (95% CrI 1.40–3.50) million averted infections and 8000 (95% CrI 6000–11 000) averted deaths (Figure 2, Table S2).

We found that expanded testing could further boost the impact of facility-based isolation strategies. Under the expanded testing with an additional diagnosis rate of 20% per day, facility-based isolation of moderate capacity achieved higher epidemic impact, averting 69% (95% CrI 56–72%) of new infections and 45% (95% CrI 36–48%) of deaths. These reductions are equivalent to 5.01 (95% CrI 2.11–8.81) million averted infections and 19 000 (95% CrI 10 000–29 000) averted deaths, respectively (Figure 2, Table S2). Facility-based isolation with high capacity (10 beds per 10 000 population) would lead to even larger reductions of 76% (95% CrI 62–84%) of new infections and 52% (95% CrI 37–64%) of deaths, under expanded testing with a rate of additional diagnoses of 20% per day.

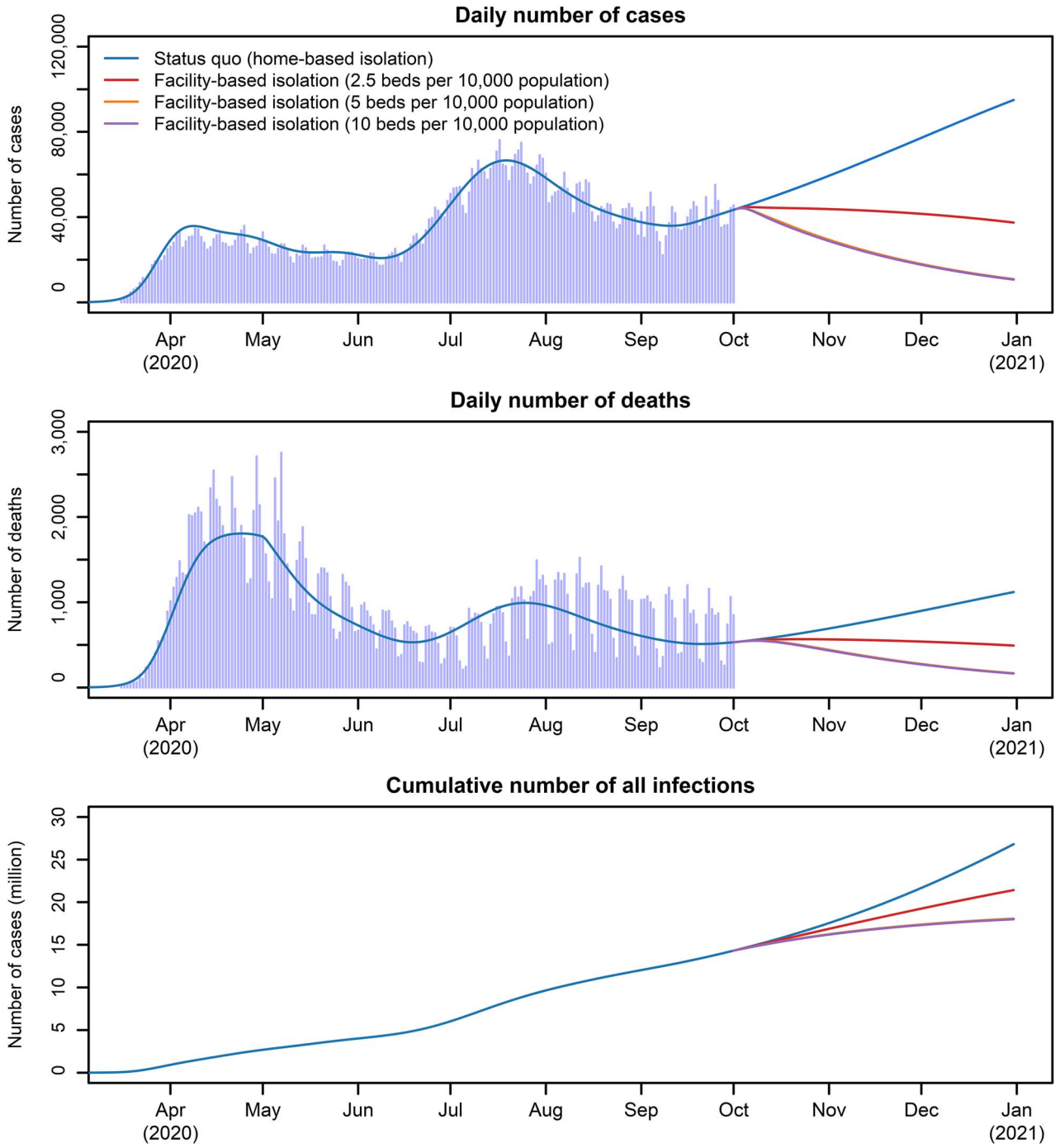

Figure 1. The impact of facility-based isolation with different capacities on the COVID-19 epidemic in the USA from 1 October 2020 onward. Note: Our compartment model was calibrated based on the number of confirmed cases, deaths, and hospitalized patients from mid-March to the end of September 2020 in the USA. The model projects the number of new confirmed cases and deaths, and the cumulative number of all new infections since October 2020 with facility-based isolation capacities of 2.5, 5, and 10 beds per 10 000 total population, respectively.

Epidemic impact of facility-based isolation with different starting times of implementation

We next examined how the starting time of facility-based isolation would affect its impact on new infections and deaths. We found that delays in starting isolating patients with mild to moderate COVID-19 in facilities would reduce the impact of facility-based isolation (Figure 3). If facility-based isolation were implemented 2 weeks after the beginning of the model projection, the number of new infections in the next 2 months would decrease to 4.57 (95% CrI 2.93–11.39) million, which is equivalent to a 37% (95% CrI 24–40%) relative reduction compared to the status-quo scenario (Table S3). This relative reduction is substantially lower than that for the immediate implementation scenario (which led to a 57% reduction). With the longer implementation delay of 4 weeks, the impact of

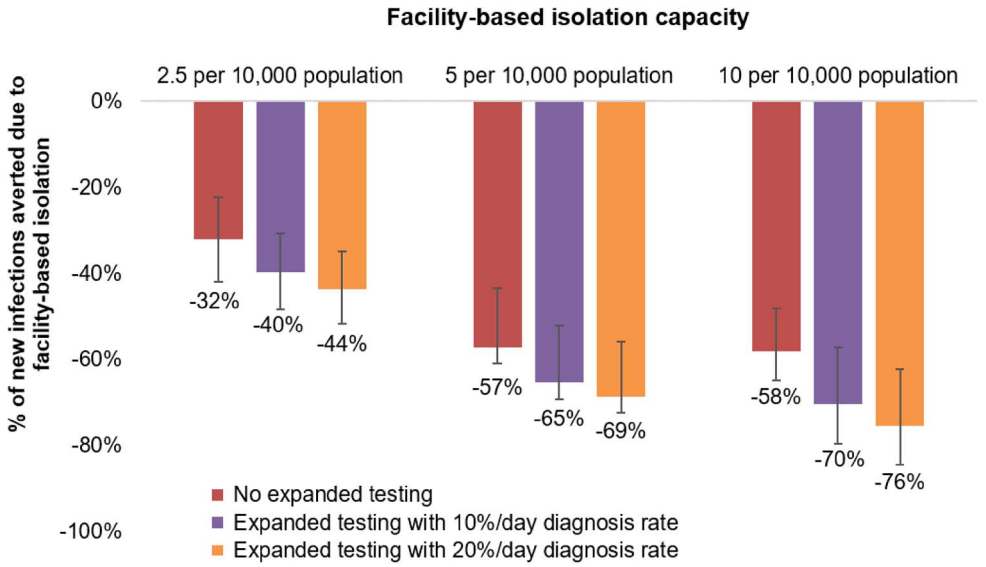

Figure 2. Relative reductions in new COVID-19 infections within 2 months in the USA (comparing facility-based isolation with different capacities to home-based isolation). Note: In this figure, we compare results at different levels of facility-based isolation (2.5, 5, and 10 beds per 10 000 total population). The percentage of new infections averted was estimated by comparing the projected number of new infections (including both diagnosed and undiagnosed cases) during October and November 2020, using facility-based isolation versus home-based isolation strategies. In the expanded testing scenarios, we assumed that, respectively, an additional 10% and 20% of infected people in three groups (asymptomatic individuals, pre-symptomatic individuals, and undiagnosed symptomatic individuals who self-isolate at home) are newly diagnosed each day.

facility-based isolation would be even lower: a 19% (95% CrI 11–23%) relative reduction in new infections. Delay in implementing facility-based isolation would also reduce the impact on averting deaths: a two-week delay would result in a relative reduction of deaths of 20% (95% CrI 14–21%) and a 4-week delay would result in a relative reduction of deaths of 7% (95% CrI 5–9%). Within each stratum of implementation time, facility-based isolation was increasingly effective in reducing new infections and deaths when the diagnosis rate was increased through expanded testing (Figures 2 and 4).

Impact of facility-based isolation by region

In our regional analysis, we found that the effects of facility-based isolation differed substantially by region, depending on the stages and trends of regional epidemics (Table S4, Figure S4). In the Northeast of the United States, where epidemic spread initially remained low but has been rising slowly, even facility-based isolation with low capacity could avert 60% of new infections—an impact that is sufficient to effectively contain the epidemic. In the Midwest of the USA, where the number of daily cases is growing rapidly, facility-based isolation strategies could reduce new infections in 2 months by 37% (95% CrI 24–50%) with moderate capacity, substantially slowing the increasing trend. With high facility-based isolation capacity, the increasing trend could be reversed. In the West and South of the USA, where the numbers of daily cases are rising following a decreasing trend since the peak in mid-July, facility-based isolation with moderate capacity could reduce new infections up to 59% (95% CrI 48–65%) and 54% (95% CrI 42–57%), respectively. These comparisons across regions indicate that the impact of facility-based isolation is likely to vary substantially by epidemic stage and recent trends.

Sensitivity analyses

To examine the robustness of our results, we performed additional sensitivity analyses on those model parameters that were based on assumptions or partial data. Our results show that if home-based isolation were highly effective, facility-based isolation would result in lower relative reductions in new infections (Table S5). On the other hand, the impact of facility-based isolation became much less sensitive to the effectiveness of home-based isolation with expanded testing. Other factors showed only modest effects on our results compared to the base case.

Discussion

Compared to home-based isolation, facility-based isolation with moderate capacity was projected to avert 4.2 million new infections and 16 000 new deaths from COVID-19 within 2 months for the current epidemic situation in the United States, equivalent to reducing new infections by more than half and the number of new deaths by more than a third within 2 months. When supported by expanded testing, facility-based isolation at the high capacity level similar to that in Wuhan, China, during February and March 2020 (i.e., 10 beds per 10 000 population) would achieve even greater impact, reducing the number of new infections by more than three quarters and halving the number of new deaths. The timing of implementation of facility-based isolation relative to the start of the COVID-19 epidemic is an important determinant of impact on new infections and deaths: speedier implementation disproportionately boosts impact.

The overall impact of facility-based isolation in the United States hides substantial regional differences. For regions with low epidemic burdens, such as the Northeast of the USA, facility-based isolation with low capacity is adequate to effectively

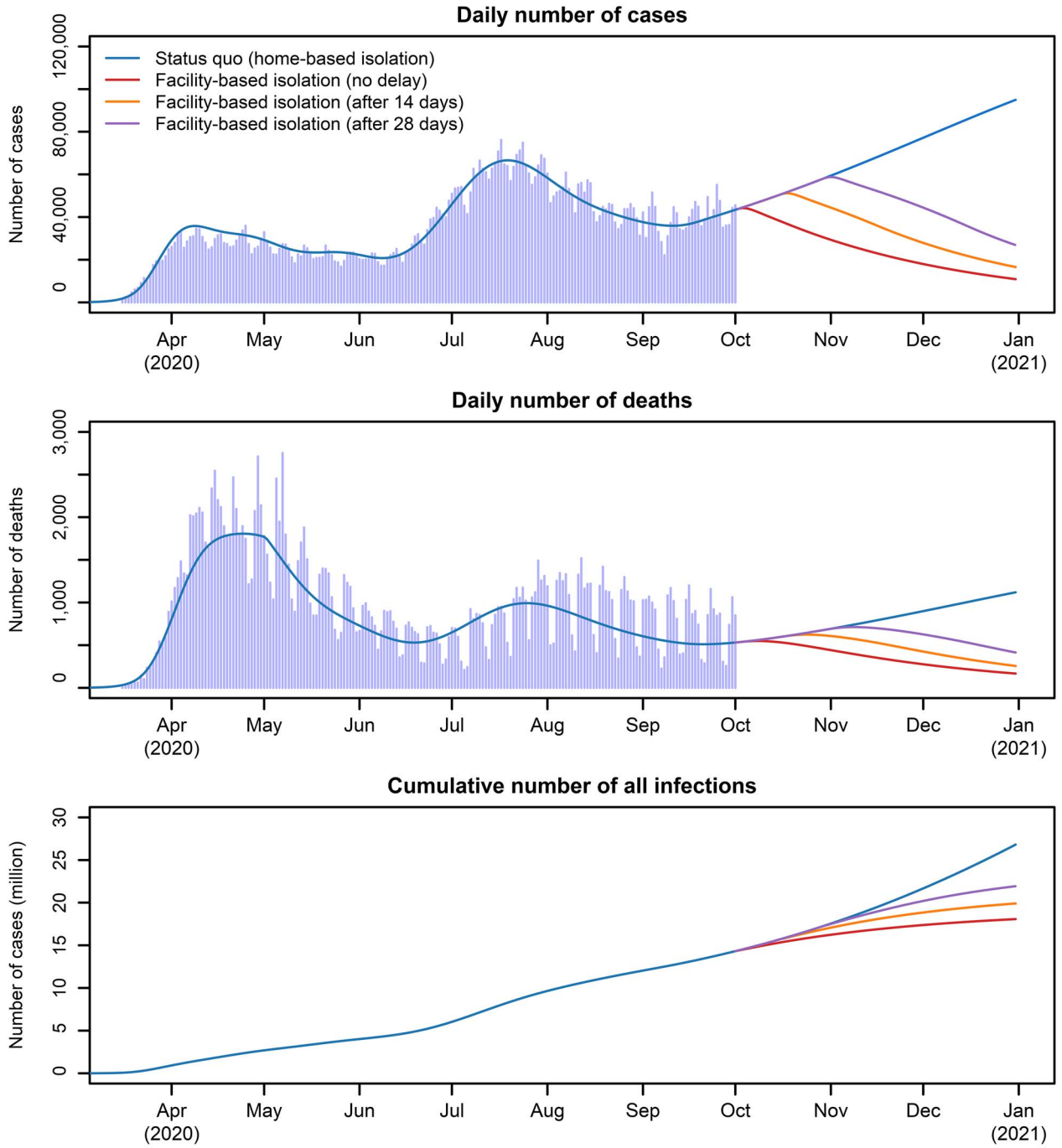

Figure 3. The impact of facility-based isolation with a moderate capacity of 5 beds per 10 000 population implemented at different starting times on the COVID-19 epidemic in the USA from 1 October 2020 onward. Note: Our compartment model was calibrated based on the number of confirmed cases and deaths, and hospitalized patients from mid-March to the end of September 2020. The model projects the number of new confirmed cases and deaths, and the cumulative number of all new infections, when facility-based isolation is implemented immediately, with a 2-week delay, and with a 4-week delay, respectively. We use facility-based isolation capacity of 5 beds per 10 000 total population.

control the epidemic even in the context of rising cases. In contrast, for regions with high epidemic burdens and continuing epidemic growth, such as the Midwest of the USA, facility-based isolation with high capacity would be needed to effectively reverse the increasing trends. The capacity for facility-based isolation thus needs to be adapted to local epidemic burdens to ensure that the potential benefits of this strategy are reaped.

Our findings that facility-based isolation could substantially reduce the number of infections in the United States compared to home-based isolation is consistent with a recent study estimating the impact of facility-based isolation for Singapore.[30] Recent evidence show that countries without facility-based isolation for mild COVID-19 patients such as Germany, Israel, Australia, and Japan did not contain the outbreak to the extent that

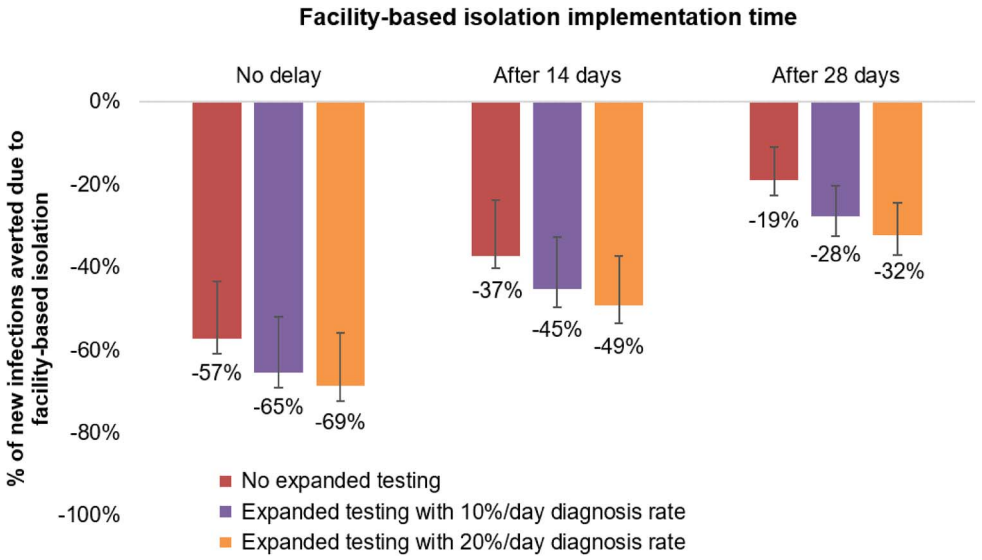

Figure 4. Relative reductions in new COVID-19 infections within 2 months in the USA (comparing facility-based isolation with different starting times to home-based isolation). Note: In this figure, we compare results for different implementation starting times (no delay, a delay of 14 days, and a delay of 28 days). The percentage of new infections averted was estimated by comparing the projected number of new infections (including both diagnosed and undiagnosed cases) during October and November 2020, using facility-based isolation versus home-based isolation strategies. In the expanded testing scenarios, we assumed that, respectively, an additional 10% and 20% of infected people in three groups (asymptomatic individuals, pre-symptomatic individuals, and undiagnosed symptomatic individuals who self-isolate at home) are newly diagnosed each day. In these models, we assumed facility-based isolation capacity of 5 beds per 10 000 total population.

those countries with facility-based isolation did. Germany and Israel have announced a second lockdown.[61] Both Australia and Japan saw flare-ups during August, due to low compliance with isolation policies and high rates of intra-family transmissions.[25,62] Without facility-based isolation of all COVID-19 patients and other supportive public health interventions (such as massive testing, contact tracing and quarantine), social distancing and lock-down measures alone are unlikely to completely suppress the epidemic—once lockdown and closure periods end and the economy reopens, second-waves are likely to occur.[63] One implication of these results is that the United States should consider re-purposing the emergency field hospitals that have been built in several cities—to offer facility-based isolation to people with mild to moderate COVID-19.[64] These existing field hospitals in the United States and other high-income countries have primarily served other functions, in particular providing overflow bed capacity, which hospitals could use to transfer COVID-19 patients who had needed intensive and complex care but had sufficiently recovered to be treated at lower levels of care.[65] Some of the existing field hospitals have also provided care for people needing hospitalization for COVID-19-unrelated healthcare needs, who could not be offered beds in traditional hospitals because these beds were needed to treat COVID-19 patients.[65]

The focus on these two functions resulted in under-utilization of the existing field hospitals, which in the USA are estimated to have cost around $660 million to build for a total capacity of nearly 15 000 beds.[66] Large field hospitals were closed soon after opening, because they remained heavily under-utilized and often cared for only a few patients at any time. Examples of field hospital closures include large facilities in Denver, Miami Beach, Detroit and suburban Milwaukee in the United States, as well as seven so-called National Health Service (NHS) Nightingale hospitals in the United Kingdom.[65,67,68] While these emergency field hospitals have remained largely empty, higher-level hospitals have been under severe pressure.[4,69,70] Repurposing field hospitals to isolate patients with mild to moderate COVID-19 could improve this situation through two mechanisms: first, facility-based isolation with accompanying high-quality basic medical care for mild to moderate cases of COVID-19 can relieve pressures from traditional hospitals during epidemic surges[15,71,72]; and, second, facility-based isolation will avert new infections and thus fundamentally reduce the need for hospital capacity.

In this context, we note that we have only modeled the isolation and triage functions of facility-based isolation and its overall epidemic impact in the community, as illustrated by the Fangcang shelter hospitals in China,[15] but have not captured other functions that facility-based isolation can fulfill. These other functions—including frequent disease monitoring and rapid referral to higher level facilities through pre-organized referral processes[6,15,73,74]—likely provide additional health benefits compared to home-based isolation. Taking all benefits into consideration and given the relatively low costs of both setting up and running field hospitals, facility-based isolation is also likely to be highly cost-effective.[15] On the other hand, in facility-based isolation, patients are cut off from their families and social support networks and may find it harder to work than at home. Further empirical research is needed to identify those patients who might find facility-based isolation desirable or at least acceptable—for instance, those who fear they might infect their family or community members in home-based isolation.[75,76] Countries and communities will likely need to carefully tailor facility-based isolation policies to local cultures and public sentiment. Clear and coherent communication and public engagement strategies may further facilitate understanding and appreciation

of facility-based isolation as an option for curbing the COVID-19 epidemic. Finally, the physical design of facilities for isolating patients with mild to moderate COVID-19 can ensure that they are desirable places for care and recovery—for instance, by maximizing patients' privacy and providing amenities and access to work space within the physical constraints of the facilities.[15,16] WHO's recently published recommendations on 'Repurposing facilities for isolation and management of mild COVID-19 cases' provide valuable initial guidance for constructing, governing and managing facilities for isolation.[64]

Our study has several limitations. First, we only estimated the epidemic impact of facility-based isolation, but did not quantify impacts on social and economic outcomes. Future research should measure the cost-effectiveness of different approaches to facility-based isolation in reducing COVID-19 epidemic spread, as well as empirically establish the impact on patients' economic activity and social functioning. Second, we did not model the operational processes of facility-based isolation, such as admission, transfer and discharge. We assumed that infected individuals could be isolated immediately as long as facility-based isolation capacity was not fully utilized and that individuals would leave the facility as soon as they had recovered and stopped being infectious, implying that our model may have overestimated the throughput rate of actual facility-based isolation. Possible reasons for substantially lower throughput rates include administrative delays in admitting patients and longer than required length of stay in the isolating facility because of delays in confirming recovery. Therefore, the capacity parameter in our model can be interpreted as the size of the population in complete and effective isolation, i.e., the minimum physical capacity needed for isolation facilities. Third, although we performed regional analyses to evaluate the impact of facility-based isolation in US census regions, substantial heterogeneity in epidemic stages and trends exists at smaller geographic scales in the USA. Our regional analyses are thus not intended to provide facility-based isolation policy recommendations by census region, but to demonstrate the different values of facility-based isolation in different epidemic contexts. The most effective scale of facility-based isolation should be determined based on the epidemic burden at the local level. Lastly, our model projection was based on transmission patterns that were calibrated to the data prior to October 2020, when this analysis was performed, and thus underestimates the most recent epidemic trends in the USA. This does not undermine the value of our results, because our analysis focused on evaluating the impact of facility-based isolation on the epidemic, rather than forecasting future epidemic trajectories; the number of infections that facility-based isolation averts will be even higher when the epidemic grows faster.

In summary, taking the United States as an example we show that facility-based isolation can effectively curb the COVID-19 pandemic. By completely isolating patients with mild to moderate COVID-19 in facilities—rather than incompletely isolating patients in their homes—over half of new infections within 2 months could be averted given the current epidemic burden in the USA. Expanded testing could further boost the effectiveness of facility-based isolation. Local epidemic burdens need to be considered in determining the optimal capacity of facility-based isolation in particular communities.

Supplementary data

Supplementary data are available at *JTM* online.

Declaration of Interests

All authors declare no competing interests.

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