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Association Between Prison Crowding and COVID-19 Incidence Rates in Massachusetts Prisons, April 2020-January 2021

Abigail I. Leibowitz, BA; Mark J. Siedner, MD, MPH; Alexander C. Tsai, MD, PhD; Amir M. Mohareb, MD

Invited Commentary

IMPORTANCE COVID-19 incidence and mortality are higher among incarcerated persons than in the general US population, but the extent to which prison crowding contributes to their COVID-19 risk is unknown.

OBJECTIVE To estimate the associations between prison crowding, community COVID-19 transmission, and prison incidence rates of COVID-19.

DESIGN, SETTING, AND PARTICIPANTS This was a longitudinal ecological study among all incarcerated persons in 14 Massachusetts state prisons between April 21, 2020, and January 11, 2021.

EXPOSURES The primary exposure of interest was prison crowding, measured by (1) the size of the incarcerated population as a percentage of the prison's design capacity and (2) the percentage of incarcerated persons housed in single-cell units. The analysis included the weekly COVID-19 incidence in the county where each prison is located as a covariate.

MAIN OUTCOMES AND MEASURES The primary outcome was the weekly COVID-19 incidence rate as determined by positive SARS-CoV-2 tests among incarcerated persons at each prison over discrete 1-week increments.

RESULTS There was on average 6876 people incarcerated in 14 prisons during the study period. The median level of crowding during the observation period ranged from 25% to 155% of design capacity. COVID-19 incidence was significantly higher in prisons where the incarcerated population was a larger percentage of the prison's design capacity (incidence rate ratio [IRR] per 10-percentage-point difference, 1.14; 95% CI, 1.03-1.27). COVID-19 incidence was lower in prisons where a higher proportion of incarcerated people were housed in single-cell units (IRR for each 10-percentage-point increase in single-cell units, 0.82; 95% CI, 0.73-0.93). COVID-19 transmission in the surrounding county was consistently associated with COVID-19 incidence in prisons (IRR [for each increase of 10 cases per 100 000 person-weeks in the community], 1.06; 95% CI, 1.05-1.08).

CONCLUSIONS AND RELEVANCE This longitudinal ecological study found that within 14 Massachusetts state prisons, increased crowding was associated with increased incidence rates of COVID-19. Researchers and policy makers should explore strategies that reduce prison crowding, such as decarceration, as potential ways to mitigate COVID-19 morbidity and mortality among incarcerated persons.

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Author Affiliations: Harvard T.H. Chan School of Public Health, Boston, Massachusetts (Leibowitz); University of Colorado School of Medicine, Denver (Leibowitz); Medical Practice Evaluation Center, Massachusetts General Hospital, Boston (Siedner, Mohareb); Division of Infectious Diseases, Massachusetts General Hospital, Boston (Siedner, Mohareb); Harvard Medical School, Boston, Massachusetts (Siedner, Tsai, Mohareb); Center for Global Health, Massachusetts General Hospital, Boston (Siedner, Tsai, Mohareb); Mongan Institute, Massachusetts General Hospital, Boston (Siedner, Tsai).

Corresponding Author: Amir M. Mohareb, MD, Medical Practice Evaluation Center, Massachusetts General Hospital, 100 Cambridge St, 16th Floor, Boston, MA 02114 (amohareb@mgh.harvard.edu).

COVID-19 has presented unique clinical and public health challenges for carceral settings, including jails, prisons, and immigration detention centers. The US has the largest carceral system in the world in terms of both total number of incarcerated persons and per capita incarceration.[1] COVID-19 incidence in state and federal prisons is estimated to be more than 5 times higher than that in the general population.[2] Similarly, age- and sex-adjusted COVID-19 mortality rates have been reported to be 2 to 3 times higher among incarcerated persons than in the general US population.[3]

There are many possible reasons for higher COVID-19 incidence in carceral settings, such as crowded living conditions; reduced access to testing and medical care; inconsistent implementation of risk mitigation techniques, such as hand hygiene and mask wearing; frequent passage of correctional staff, vendors, and visitors between the community and correctional facilities and frequent transfer of incarcerated individuals between housing units and from local jails to state prisons; and environmental factors, such as poor ventilation and cell structure.[4,5] In the US, correctional facilities also regularly exceed their design capacity, and several physicians and public health experts have suggested that there is an association between the level of crowding in prisons and the COVID-19 risk among incarcerated persons.[6,7] However, both state policy makers and state court decisions have noted a lack of epidemiologic evidence supporting this proposed association.[8]

Our study aims to address this lack of empirical evidence and determine the extent to which prison crowding is associated with COVID-19 risk. Our primary objective was to estimate the association between prison crowding and the incidence of COVID-19 among incarcerated persons in Massachusetts state prisons.

Key Points

Question Is prison crowding associated with the risk of COVID-19 among incarcerated persons?

Findings In this longitudinal ecological study including all incarcerated persons in 14 Massachusetts state prisons from April 2020 to January 2021, on average 6876 persons, COVID-19 incidence was significantly higher in prisons operating at a higher percentage of their design capacity and was significantly lower in prisons where a higher proportion of incarcerated people were housed in single-cell units.

Meaning Prison crowding was associated with increased COVID-19 incidence rates; strategies that reduce crowding and increase single-cell occupancy should be explored to mitigate COVID-19 risk in prisons.

Methods

Study Design

We conducted a longitudinal ecological study of COVID-19 incidence in Massachusetts state prisons between April 21, 2020, and January 11, 2021. Prisons are distinct from jails, houses of correction, and juvenile detention facilities because they have a lower rate of turnover within their incarcerated populations. Our analysis included 14 of the 16 state prisons operated by Massachusetts Department of Correction with a total of 38 weeks of data. We excluded 2 facilities that are unique in their level of turnover and availability of on-site medical personnel: the Lemuel Shattuck Hospital Correctional Unit, which provides medical care to incarcerated persons within a public hospital, and the Massachusetts Alcohol and Substance Abuse Center, which houses individuals in short-term substance use rehabilitation. All 14 prisons uniformly implemented the same COVID-19 mitigation policies: mask wearing, hand hygiene, cessation of in-person visitation during periods of high community transmission, quarantine for newly incarcerated persons, symptom screening by correctional staff, and isolation and testing for anyone with symptoms suggestive of COVID-19.[8] This analysis was conducted using deidentified, publicly available data sets and thus was exempt from human subjects review and informed consent processes based on the Common Rule (45 CFR § 46.104(d)(4)).

Data Sources

Data were derived from 5 publicly available sources. First, we used COVID-19 reports from the Massachusetts Department of Correction, which state the number of positive SARS-CoV-2 tests in each prison and the number of people incarcerated in each prison. These reports have been published on a weekly or daily basis since April 13, 2020, pursuant to *Committee for Public Counsel Services v Chief Justice of the Trial Court* (SJC-12926), and the data can be downloaded from ACLU of Massachusetts.[9] When there was daily reporting, we calculated an average population for each prison across each 1-week increment. Second, we used the Massachusetts Department of Correction weekly Institution Cell Housing Reports, which state the number of people within each prison housed in single cells and the total number of people incarcerated in each prison. These data have been available since June 15, 2020.[10] Third, we used the Massachusetts Department of Correction Quarterly Report on the Status of Prison Capacity to determine the design capacity, security level, and sex of individuals in each prison.[11] Fourth, we used the data repository from the 2019 Novel Coronavirus Visual Dashboard, operated by the Johns Hopkins University Center for Systems Science and Engineering, to obtain the number of COVID-19 cases in each Massachusetts county.[12] Fifth, we used 2019 US Census Bureau estimates for the population of Massachusetts state and counties.

Outcome and Exposure Measures

Our primary outcome measure was the weekly COVID-19 incidence rate as determined by positive SARS-CoV-2 tests among incarcerated persons at each prison per week. Our primary exposure of interest was the weekly level of crowding in each prison, which we estimated using 2 definitions. First, we calculated each prison's average population in a given week as a percentage of its design capacity. The design capacity of a prison refers to "the number of inmates that planners intended for a facility"[13] and is available from the Massachusetts Department of Correction Quarterly Report on the Status of Prison Capacity.[11] Second, we calculated the percentage of incarcerated persons in each prison housed in single cells during each week. In this second definition, we used prison population estimates from the Institution Cell Housing Reports to match the source of single-cell housing data.[10]

Covariates

We included the weekly COVID-19 incidence in the county where each prison is located as a covariate. These estimates were calculated by dividing the number of new cases per week in relevant counties by Census Bureau population data and then scaling to generate cases per 10 000 person-weeks. We did not have access to individual-level demographic data for incarcerated persons, such as age, comorbidities, socioeconomic status, prior zip code, or race/experiences of discrimination.

Primary Analysis

We used generalized estimating equations Poisson regression with robust SEs to account for the repeated-measures structure of our data. Our unit of observation was each 1-week increment for each prison. The outcome of interest for the model was the case count in each prison per week, and we included an offset term with each prison's weekly average population size. We evaluated 3 models of COVID-19 incidence, all of which adjusted for the county-level COVID-19 incidence covariate. In model 1, we considered prison crowding as a continuous variable: incarcerated population as a percentage of the prison's design capacity, which was determined by the Massachusetts Department of Correction Quarterly Report on the Status of Prison Capacity.[11] In model 2, to consider a nonlinear association between crowding and incidence, we categorized prison crowding into 3 levels: those with incarcerated populations below 70%, between 70% and 100%, and greater than 100% of the prison's design capacity. We chose these thresholds because they have been considered feasible policy goals for moderate and aggressive decarceration strategies.[8] In model 3, we defined prison crowding as a continuous percentage of incarcerated persons housed in single-cell units. We used 2-tailed *P* values and considered $P < .05$ to be statistically significant.

Sensitivity Analyses

We conducted a number of sensitivity analyses to assess the robustness of the findings. To assess for potential lagged associations between crowding and SARS-CoV-2 incidence owing to the estimated incubation period of infection,[14-16] we evaluated the same 3 models but specified lags of crowding 1 week and 2 weeks prior to the outcome. We also evaluated whether the sex of the incarcerated population in each prison could be a confounder by including sex in our multivariable models. Although prison security level was considered as a possible covariate in sensitivity analyses, we did not analyze this variable owing to its collinearity with the prison crowding variables.

Secondary Analysis

As a secondary analysis, we compared the overall incidence rate of COVID-19 among incarcerated persons in our study with the concurrent rate of the general population of Massachusetts. The COVID-19 incidence rate among incarcerated persons was calculated as the total number of positive tests during the study period divided by the observed person-time. The COVID-19 incidence rate in the Massachusetts general population was calculated as the number of new cases during the study period divided by the observed person-time. All analyses were conducted using Stata, version 16.1 (StataCorp LLC.).

Results

Prison Characteristics

The 14 prisons included in the analysis have a total design capacity of 7287 persons (range, 100-1084 persons per prison). Twelve prisons were designated male and 2 were designated female. During the study period, there was an average of 6876 persons housed within the 14 facilities. Prisons ranged in their median crowding level during the study period from 25% to 155% of design capacity. Prisons ranged from a median of 7% of people housed in single-cell units during the study period to 100% of people housed in single-cell units (**Table 1**).

Primary Analysis

In model 1, COVID-19 incidence was significantly greater among prisons operating at a higher percentage of their design capacity (incidence rate ratio [IRR] [per 10-percentage-point difference], 1.14; 95% CI, 1.03-1.27) (**Table 2**). In model 2, COVID-19 incidence was significantly greater among facilities operating above 100% of design capacity (IRR, 4.86; 95% CI, 1.37-17.27), compared with less than 70% of design capacity. Prisons operating at 70% to 100% of design capacity also had a higher estimated COVID-19 incidence (IRR, 3.39; 95% CI, 0.83-13.84), but this was not statistically significant in the primary analysis. In model 3, COVID-19 incidence was significantly lower in prisons in which a higher percentage of people were housed in single-cell units (IRR [per 10-percentage-point difference in single-cell occupancy]. 0.82; 95% CI, 0.73-0.93).

Across all regression models, community COVID-19 transmission in the county where each prison is located was associated with prison-level COVID-19 incidence (IRR [per 10 cases per 100 000 person-weeks], 1.06; 95% CI, 1.05-1.08 for model 1). Graphical depiction of the incidence of COVID-19 in prisons during the study period across strata of crowding and COVID-19 incidence in surrounding counties is presented in the **Figure**.

Sensitivity Analyses

When using 1- and 2-week lags, the crowding metric for all 3 models retained statistical significance and had point estimates within the CI of the primary analysis. Furthermore, prisons operating at 70% to 100% of design capacity also had a statistically significant association with higher COVID-19 incidence when specified with a 1- or 2-week lag (**Table 3**) compared with those operating at less than 70% design capacity (1-week lag IRR, 5.08; 95% CI, 1.51-17.02; 2-week lag IRR, 4.39; 95% CI, 1.09-17.73). All crowding metrics were robust to inclusion of sex as a covariate. COVID-19 incidence in the county surrounding each prison remained significantly associated with prison cases in all sensitivity analyses.

Table 1. Prison Characteristics and Crowding Metrics in Massachusetts Prisons, April 21, 2020, to January 11, 2021

Facility ID	Security level	Sex	Design capacity	Incarcerated population, No. (% design capacity)		Incarcerated persons in single cell, No. (% population)	
				Median	IQR	Median	IQR
01	Minimum	Male	100	116 (116)	109-122 (109-122)	45 (40)	40-47 (36-43)
02	Minimum	Female	125	32 (25)	29-37 (23-30)	29 (100)	29-31 (85-100)
03	Minimum	Male	150	53 (35)	43-60 (29-40)	49 (100)	41-57 (100-100)
04	Minimum	Male	150	151 (100)	144-153 (96-102)	84 (56)	82-89 (54-63)
05	Medium	Male	227	205 (90)	200-207 (88-91)	190 (92)	187-193 (91-93)
06	Medium	Female	452	180 (40)	176-184 (39-41)	106 (61)	94-112 (52-65)
07	Medium	Male	561	547 (98)	534-559 (95-100)	157 (29)	154-163 (28-30)
08	Medium	Male	568	883 (155)	854-907 (150-160)	64 (7)	57-69 (6-8)
09	Medium	Male	580	705 (121)	698-718 (120-124)	264 (38)	254-271 (36-39)
10	Medium	Male	614	527 (86)	515-559 (84-91)	115 (22)	110-123 (21-24)
11	Maximum	Male	633	417 (66)	383-474 (61-75)	397 (100)	376-431 (100-100)
12	Medium	Male	1019	1116 (109)	1092-1157 (107-114)	491 (44)	476-503 (43-46)
13	Maximum	Male	1024	668 (65)	632-675 (62-66)	508 (80)	485-523 (72-82)
14	Medium	Male	1084	1250 (115)	1233-1259 (114-116)	691 (56)	680-702 (54-57)

Abbreviation: IQR, interquartile range.

Table 2. Generalized Estimating Equation Poisson Regression Model Estimates of Factors Associated With COVID-19 Incidence in Massachusetts Prisons, April 21, 2020, to January 11, 2021

Variable	Incidence rate ratio (95% CI)[a]		
	Model 1	Model 2	Model 3
County-level COVID-19 incidence rate (per 10 cases per 100 000 person-weeks)	1.06 (1.05-1.08) (P < .001)	1.06 (1.05-1.08) (P < .001)	1.06 (1.05-1.07) (P < .001)
Prison population density (per 10-percentage-point difference)	1.14 (1.03-1.27) (P = .01)	NA	NA
Prison population density			
<70%	NA	1.00 [Reference]	NA
70%-100%	NA	3.39 (0.83-13.84) (P = .09)	NA
>100%	NA	4.86 (1.37-17.27) (P = .01)	NA
Single-cell occupancy (per 10-percentage-point difference)	NA	NA	0.82 (0.73-0.93) (P = .002)

Abbreviation: NA, not applicable.

[a] All estimates derived from generalized estimating equations Poisson regression models. Incarcerated population density is reported as percent of facility design capacity. Model 1: incarcerated population density as a percentage of design capacity modeled as a continuous variable; model 2: incarcerated population density as a percentage of design capacity modeled as a categorical variable; model 3: percentage of incarcerated persons in single-cell units.

Secondary Analysis

During the study period, there were 2497 reported cases of COVID-19 among incarcerated persons. The mean COVID-19 incidence rate in prisons was 956 cases per 100 000 person-weeks. In comparison, COVID-19 incidence in the state of Massachusetts was 150 cases per 100 000 person-weeks during the study period (IRR, 6.38; 95% CI, 6.14-6.64).

Discussion

In this study, we found that COVID-19 incidence among incarcerated persons was associated with prison crowding and with transmission in the surrounding community. We used 2 different variables to estimate the association between prison crowding and the rate of COVID-19 in Massachusetts state prisons. These 2 metrics—incarcerated population as a percentage of design capacity and the percentage of incarcerated persons in single-cell units— fluctuated during the study period, and both were associated with a higher incidence of COVID-19.

There are 3 important findings in this study. First, for every 10% increase in prison population (as a percentage of prison design capacity), there was a 14% increased risk of COVID-19. Similarly, compared with weeks when prisons maintained an incarcerated population below 70% of design capacity, prisons operating between 70% and 100% and prisons operating at more than 100% of their design capacity had approximately 3- and 5-fold higher incidence rates of COVID-19, respectively. Our study demonstrates an association between prison crowding and increased COVID-19 incidence and suggests that COVID-19 risk can remain high even in prisons that operate below their design capacity when community transmission is high. Our results are consistent with a recently published stochastic compartmental model, which showed that a strategy of decreased prison crowding was associated with reduced transmission, hospitalizations, and deaths.[17]

Second, we found that for each 10% increase in the percentage of people housed in single-cell units, facility COVID-19 incidence rates were reduced by 18%. This observation is consistent with the stochastic compartmental model described previously.[17] These observations are also consistent with prior studies of other communicable diseases in prisons.[18] A recent study evaluating the association between COVID-19 incidence and nursing home crowding in Ontario, Canada, found that nursing home facilities with more single-occupancy rooms had a lower incidence of COVID-19 compared with nursing home facilities that had more multiperson rooms.[19] In prisons where cells are shared between 2 or more people, our study suggests that decreasing the prison population and maximizing single-cell occupancy may reduce the incidence of COVID-19. Single-celling strategies that involve solitary confinement are not a recommended COVID-19 risk mitigation strategy, given their harmful effects on the health of incarcerated persons.[20-23] Rather, single cells should only be used to increase physical distancing between individuals and should not prevent other prison activities, such as outdoor recreation or communication with loved ones.[4]

Our third important finding was that there was an association between COVID-19 incidence in prisons and community transmission. This association was observed despite the implementation of systemwide hygienic precautions, mask wearing, and quarantine and isolation. This suggests that COVID-19 risk in incarcerated populations is associated with the force of infection in the surrounding community and that correctional staff and contractors are important vehicles of COVID-19 transmission into prison facilities and vice versa. The transfer of incarcerated persons from jails to prison or between prisons may have introduced COVID-19 in some cases, although this was likely mitigated by the Massachusetts Department of Correction's 14-day quarantine policies for all incoming individuals. Introduction of cases into facilities by visitors is an unlikely explanation for this finding because visitation was suspended during periods of high community-level transmission.[8] This association between COVID-19 in the prison and the surrounding community is consistent with a recently published study observing that county-level incarceration rates in jails are associated with a 6.5% increase in mortality from infectious diseases.[24]

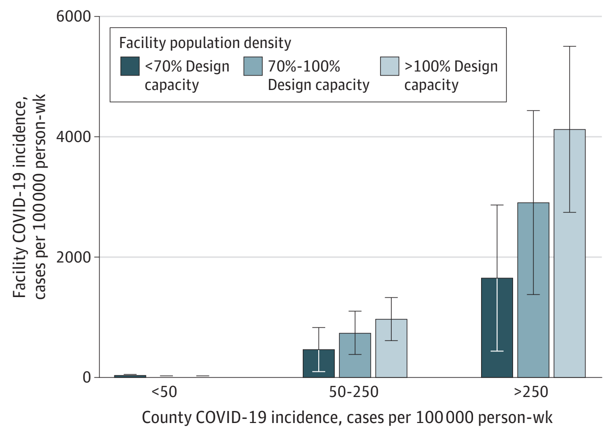
However, the burden of COVID-19 does not appear to be shared equally by incarcerated persons and those in the broader community.[25,26] During the study period, COVID-19 incidence in prisons was 956 per 100 000 person-weeks, which was more than 6 times higher than among the general Massachusetts population. Although the degree to which detected cases reflects true prevalence in these 2 populations is uncertain, our study's finding that incarcerated persons had a higher incidence of COVID-19 than the general public is consistent with similar research at both state and federal levels.[3] Our study suggests that interventions that mitigate COVID-19 risk in surrounding communities, and, by extension, among prison staff members, could serve multiple public health priorities for the incarcerated population and the population at large.

Limitations

This study should be interpreted within its design limitations. First, population density was not randomly assigned, and we did not have access to individual-level data. Unmeasured variables that are associated with both prison crowding and COVID-19 incidence could confound our estimates of the association between these 2 variables. In particular, prison architecture was not considered in this study and could have biased our estimates of the association between prison crowding and COVID-19 incidence away from the null. Second, our definition of COVID-19 incidence relied on public reporting of SARS-CoV-2 testing results, so asymptomatic and untested COVID-19 cases were not observed. The Massachusetts state prison system did not conduct regular asymptomatic surveillance testing, so our analysis might underestimate the extent of asymptomatic infection. The stated testing policy was uniform across all facilities involved in our analysis, but we cannot be certain about the extent to which underreporting was uniform across facilities. Third, we also did not include data on testing among correctional staff. Our data were limited to results captured by the Massachusetts Department of Correction and excluded health care and other external testing sources. Fourth, these analyses do not allow us to conclude the extent to which prison security level is associated with COVID-19 incidence independent of prison crowding owing to its collinearity with the crowding metrics. Security level may be related to the extent to which incarcerated persons are allowed to congregate, the amount of movement between different areas of a prison, or enforcement of COVID-19 policies. Consequently, further research is needed to delineate the exact nature of this association. Fifth, our findings are best generalizable to similar correctional facilities and may not generalize to juvenile detention centers.

Despite these limitations, our findings indicate that prison crowding may be an important driver of COVID-19 incidence in state prisons. Public health experts have proposed a number of potential ways to reduce COVID-19 among incarcerated persons, including decarceration and expanded applica-

Figure. Association Between Incarcerated Population Density, COVID-19 Community Incidence, and COVID-19 Incidence in Massachusetts State Prisons, April 21, 2020, to January 11, 2021



Incarcerated population density is reported as percentage of facility design capacity. In the counties in which state prisons are located, the COVID-19 incidence was, on average, less than 50 cases per 100 000 person-weeks from June 2020 to September 2020. COVID-19 incidence in these counties was, on average, greater than 250 cases per 100 000 person-weeks from December 2020 to January 2021. Error bars indicate 95% CIs.

Table 3. Sensitivity Analysis of Factors Associated With COVID-19 Incidence in Massachusetts Prisons, April 21, 2020, to January 11, 2021

	Incidence rate ratio (95% CI)[a]		
Variable	Model 1	Model 2	Model 3
1-wk Lag			
County-level COVID-19 incidence rate (per 10 cases per 100 000 person-weeks)	1.06 (1.05-1.08) (P < .001)	1.07 (1.05-1.08) (P < .001)	1.06 (1.05-1.07) (P < .001)
Prison population density (per 10-percentage-point difference)	1.16 (1.05-1.29) (P = .004)	NA	NA
Prison population density			
<70%	NA	1.00 [Reference]	NA
70%-100%	NA	5.08 (1.51-17.02) (P = .008)	NA
>100%	NA	6.97 (2.50-19.41) (P < .001)	NA
Single-cell occupancy (per 10-percentage-point difference)	NA	NA	0.80 (0.71-0.90) (P < .001)
2-wk Lag			
County-level COVID-19 incidence rate (per 10 cases per 100 000 person-weeks)	1.06 (1.05-1.08) (P < .001)	1.07 (1.05-1.08) (P < .001)	1.06 (1.05-1.07) (P < .001)
Prison population density (per 10-percentage-point difference)	1.17 (1.05-1.31) (P = .004)	NA	NA
Prison population density			
<70%	NA	1.00 [Reference]	NA
70%-100%	NA	4.39 (1.09-17.73) (P = .04)	NA
>100%	NA	7.04 (2.58-19.20) (P < .001)	NA
Single-cell occupancy (per 10-percentage-point difference)	NA	NA	0.80 (0.70-0.91) (P = .001)

Abbreviation: NA, not applicable.

[a] All estimates derived from generalized estimating equations Poisson regression models. Incarcerated population density is reported as percent of facility design capacity. Model 1: incarcerated population density as a percentage of design capacity modeled as a continuous variable; model 2: incarcerated population density as a percentage of design capacity modeled as a categorical variable; model 3: percentage of incarcerated persons in single-cell units.

tions of medical parole. Importantly, we found a gradient of increasing COVID-19 incidence even among prisons that operated well below their design capacities, suggesting that crowding reduction policies in settings of high community transmission may be most effective in reducing the risk of COVID-19 if they are based on conservative thresholds of prison crowding. Given that carceral populations experience a higher COVID-19 mortality rate compared with the general population,[27,28] policies such as decarceration could be explored as public health interventions to reduce the risk of COVID-19 infections and mortality in this vulnerable population. Although public safety must be considered when enacting decarceration policies, prior research has shown that significant reductions in prison populations can be accomplished without endangering public safety.[29] Similar risks exist in immigration detention facilities, which are also subject to crowded conditions.[30] In each of these settings, other policies should also be pursued to reduce COVID-19 transmission risk and related morbidity and mortality, such as vaccination for both correctional staff and incarcerated persons, routine symptom screening, asymptomatic testing, and mask wearing/hand hygiene.[17,31] Our study has broad implications for public health policy given that COVID-19 vaccine coverage in carceral settings continues to be suboptimal, both in the US and abroad. Future studies should also examine the associations between prison crowding (and decarceration) with other transmissible infections.

Conclusions

In this longitudinal ecological study, COVID-19 incidence within Massachusetts state prisons during April 2020 to January 2021 was associated with prison crowding and community transmission. Interventions that promote prison depopulation and reduce staff exposure should be pursued to mitigate COVID-19 risk among incarcerated persons.

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Concept and design: All authors.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Leibowitz, Mohareb.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: All authors.
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Supervision: Tsai, Mohareb.

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REFERENCES

1. Walmsley R. World prison population list (12th edition). Accessed July 8, 2021. https://www.prisonstudies.org/sites/default/files/resources/downloads/wppl_12.pdf

2. Saloner B, Parish K, Ward JA, DiLaura G, Dolovich S. COVID-19 cases and deaths in federal and state prisons. *JAMA*. 2020;324(6):602-603. doi:10.1001/jama.2020.12528

3. Schnepel K. COVID-19 in US state and federal prisons: December 2020 update. Accessed December 22, 2020. https://cdn.ymaws.com/counciloncj.org/resource/resmgr/covid_commission/COVID-19_in_State_and_Federa.pdf

4. National Academies of Sciences, Engineering, and Medicine. *Decarcerating Correctional Facilities During COVID-19: Advancing Health, Equity, and Safety*. National Academies Press; 2020. doi:10.17226/25945

5. Pringle JC, Leikauskas J, Ransom-Kelley S, et al. COVID-19 in a correctional facility employee following multiple brief exposures to persons with COVID-19—Vermont, July–August 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(43):1569-1570. doi:10.15585/mmwr.mm6943e1

6. Hawks L, Woolhandler S, McCormick D. COVID-19 in prisons and jails in the United States. *JAMA Intern Med*. 2020;180(8):1041-1042. doi:10.1001/jamainternmed.2020.1856

7. Akiyama MJ, Spaulding AC, Rich JD. Flattening the curve for incarcerated populations—Covid-19 in jails and prisons. *N Engl J Med*. 2020;382(22):2075-2077. doi:10.1056/NEJMp2005687

8. *Foster v Mici*, No. SJ-2020-0212 (Mass 2020). Testimony of Carol Mici, Commissioner of the Department of Correction of Massachusetts. Accessed March 2, 2021. https://www.mass.gov/service-details/stephen-foster-others-v-carol-mici-commissioner-of-the-massachusetts-department-of

9. ACLU of Massachusetts. Tracking COVID-19 in Massachusetts prisons and jails. Accessed July 8, 2021. https://data.aclum.org/sjc-12926-tracker/

10. Massachusetts Department of Correction. DOC COVID-19 institution cell housing reports archives. Accessed July 8, 2021. https://www.mass.gov/lists/doc-covid-19-institution-cell-housing-reports-archives

11. Massachusetts Department of Correction. Quarterly reports on prison capacity. Accessed July 8, 2021. https://archives.lib.state.ma.us/handle/2452/35692

12. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis*. 2020;20(5):533-534. doi:10.1016/S1473-3099(20)30120-1

13. Bureau of Justice Statistics. Census of State and Federal Adult Correctional Facilities (CCF, formerly CSFACF). Accessed July 8, 2021. https://bjs.ojp.gov/data-collection/census-state-and-federal-adult-correctional-facilities-ccf-formerly-csfacf

14. Lauer SA, Grantz KH, Bi Q, et al. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Ann Intern Med*. 2020;172(9):577-582. doi:10.7326/M20-0504

15. Qin J, You C, Lin Q, Hu T, Yu S, Zhou X-H. Estimation of incubation period distribution of COVID-19 using disease onset forward time: a novel cross-sectional and forward follow-up study. *Sci Adv*. 2020;6(33):eabc1202. doi:10.1126/sciadv.abc1202

16. McAloon C, Collins Á, Hunt K, et al. Incubation period of COVID-19: a rapid systematic review and meta-analysis of observational research. *BMJ Open*. 2020;10(8):e039652. doi:10.1136/bmjopen-2020-039652

17. Malloy GSP, Puglisi L, Brandeau ML, Harvey TD, Wang EA. Effectiveness of interventions to reduce COVID-19 transmission in a large urban jail: a model-based analysis. *BMJ Open*. 2021;11(2):e042898. doi:10.1136/bmjopen-2020-042898

18. Simpson PL, Simpson M, Adily A, Grant L, Butler T. Prison cell spatial density and infectious and communicable diseases: a systematic review. *BMJ Open*. 2019;9(7):e026806. doi:10.1136/bmjopen-2018-026806

19. Brown KA, Jones A, Daneman N, et al. Association between nursing home crowding and COVID-19 infection and mortality in Ontario, Canada. *JAMA Intern Med*. 2021;181(2):229-236. doi:10.1001/jamainternmed.2020.6466

20. Haney C. The psychological effects of solitary confinement: a systematic critique. *Crime and Justice*. 2018;47(1):365-416. doi:10.1086/696041

21. Brinkley-Rubinstein L, Sivaraman J, Rosen DL, et al. Association of restrictive housing during incarceration with mortality after release. *JAMA Netw Open*. 2019;2(10):e1912516. doi:10.1001/jamanetworkopen.2019.12516

22. Wildeman C, Andersen LH. Solitary confinement placement and post-release mortality risk among formerly incarcerated individuals: a population-based study. *Lancet Public Health*. 2020;5(2):e107-e113. doi:10.1016/S2468-2667(19)30271-3

23. Reiter K, Ventura J, Lovell D, et al. Psychological distress in solitary confinement: symptoms, severity, and prevalence in the United States, 2017-2018. *Am J Public Health*. 2020;110(S1):S56-S62. doi:10.2105/AJPH.2019.305375

24. Kajeepeta S, Mauro PM, Keyes KM, El-Sayed AM, Rutherford CG, Prins SJ. Association between county jail incarceration and cause-specific county mortality in the USA, 1987-2017: a retrospective, longitudinal study. *Lancet Public Health*. 2021;6(4):e240-e248. doi:10.1016/S2468-2667(20)30283-8

25. Reinhart E, Chen DL. Incarceration and its disseminations: COVID-19 pandemic lessons from Chicago's Cook County jail. *Health Aff (Millwood)*. 2020;39(8):1412-1418. doi:10.1377/hlthaff.2020.00652

26. Puglisi LB, Malloy GSP, Harvey TD, Brandeau ML, Wang EA. Estimation of COVID-19 basic reproduction ratio in a large urban jail in the United States. *Ann Epidemiol*. 2021;53:103-105. doi:10.1016/j.annepidem.2020.09.002

27. Altibi AM, Pallavi B, Liaqat H, et al. Characteristics and comparative clinical outcomes of prisoner versus non-prisoner populations hospitalized with COVID-19. *Sci Rep*. 2021;11(1):6488. doi:10.1038/s41598-021-85916-w

28. Jiménez MC, Cowger TL, Simon LE, Behn M, Cassarino N, Bassett MT. Epidemiology of COVID-19 among incarcerated individuals and staff in Massachusetts jails and prisons. *JAMA Netw Open*. 2020;3(8):e2018851. doi:10.1001/jamanetworkopen.2020.18851

29. Sundt J, Salisbury EJ, Harmon MG. Is downsizing prisons dangerous? the effect of California's Realignment Act on public safety. *Criminol Public Policy*. 2016;15(2):315-341. doi:10.1111/1745-9133.12199

30. Physicians for Human Rights. Praying for hand soap and masks: health and human rights violations in US immigration detention during the COVID-19 pandemic. Published January 2021. Accessed May 1, 2021. https://phr.org/wp-content/uploads/2021/01/PHR-Praying-for-Hand-Soap-and-Masks.pdf

31. Lopez WD, Kline N, LeBrón AMW, et al. Preventing the spread of COVID-19 in immigration detention centers requires the release of detainees. *Am J Public Health*. 2021;111(1):110-115. doi:10.2105/AJPH.2020.305968