Comparison of public health strategies to reduce COVID-19 in the sheltered homeless populations in the United States

Pre-analysis Study Plan

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Background

The COVID-19 pandemic caused by infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) poses a high risk to people experiencing homelessness across the United States. Recent outbreaks of COVID-19 in homeless shelters with high attack rates highlight the pressing need for guidelines on how to best reduce or prevent rapid transmission of COVID-19 in congregate shelter facilities.

Objective

To estimate the effectiveness of infection control strategies to reduce SARS-CoV-2 transmission in homeless shelters.

Hypothesis

Combined infection control strategies of routine PCR testing, universal masking, and removal of high-risk persons is the minimum required to prevent an outbreak of COVID-19 in the sheltered homeless population.

Interventions tested

The following intervention strategies will be tested:

1. Active symptom screening
2. Passive symptom screening + routine PCR testing (twice per week, assuming 80% compliance)
3. Active symptom screening + universal masking (assuming 80% compliance)
4. Active symptom screening + removal of high-risk individuals (>60 years old, presence of co-morbidities)
5. Active symptom screening + routine PCR testing (twice per week, assuming 80% compliance) + universal masking (assuming 80% compliance) + removal of high-risk individuals (>60 years old, presence of co-morbidities)

Additional scenario analyses may examine various combination strategies. We will test strategies under three epidemiologic scenarios (low, moderate, and high force of infection) based on calibrated distributions of force of infection.

Study outcomes

Primary outcome:
Proportional reduction in total case counts of COVID-19

Secondary outcome:
i) Probability of COVID-19 outbreak (defined as 3 or more cases linked in space and time)
ii) Proportional reduction in hospitalizations due to COVID-19
iii) Proportional reduction in deaths due to COVID-19
iv) Estimated reduction in absolute case counts of COVID-19 in the United States
v) Outbreak peak case count

Methodology

A stochastic individual-level susceptible-exposed-infectious-recovered transmission model of SARS-CoV-2 within a homeless shelter in San Francisco, California, will be developed. The model will be calibrated to data on the number of PCR positive individuals from testing during the outbreak at the MSC South shelter in San Francisco using an approximate Bayesian computation sequential Monte Carlo algorithm. The model will then be used to simulate different intervention strategies for an average homeless shelter.

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Fitted parameters

We will estimate one parameter – the transmission coefficient in the SEIR transmission model. The remaining natural history parameters will be sourced from the literature. We will perform simulations using the median of the distribution (representing overall force of infection), and also the lower and upper ends of the distribution in pre-specified analyses.

Model

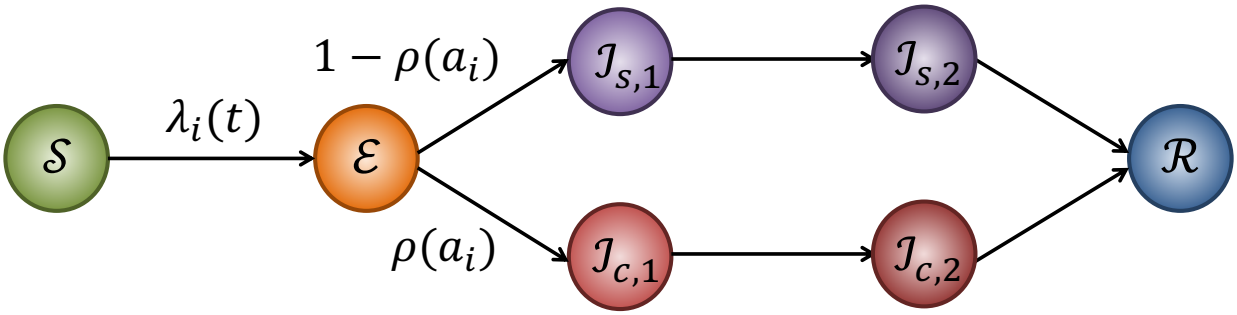

Figure 1. Structure of stochastic individual-level model of COVID-19 transmission in homeless shelter. Notation defined in Table 1 and text below.

Table 1: Definition of states in the transmission model

State	Symbol	Infectious	Symptomatic	Virus detectable?	Immune
Susceptible	$\mathcal{S}(t)$	×	×	×	×
Exposed to infection	$\mathcal{E}(t)$	×	×	×	×
Early subclinical infection	$\mathcal{I}_{s,1}(t)$	✓	×	✓	×
Late subclinical infection	$\mathcal{I}_{s,2}(t)$	✓	×/✓ (no/mild symptoms)	✓	×
Early clinical infection	$\mathcal{I}_{c,1}(t)$	✓	×	✓	×
Late clinical infection	$\mathcal{I}_{c,2}(t)$	✓	✓	✓	×
Recovered	$\mathcal{R}(t)$	×	×	✓	✓

The force of infection, $\lambda_i(t)$, on each individual i on day t is proportional to the number of infectious individuals they are exposed to on day t and their infectiousness:

$$\lambda_i(t) = \beta \mathbb{I}_i(t) \left(h \left(\alpha I_{s,1}(t) + I_{s,2}(t) \right) + \alpha I_{c,1}(t) + I_{c,2}(t) \right) + \epsilon. \quad (1)$$

where β is the overall transmission coefficient within the shelter, $\mathbb{I}_i(t)$ is an indicator function for whether individual i is present in the shelter on day t, the $I(t)$'s denote the number of infectious individuals inside the shelter on day t in different states of infection (see Table 1), h is the infectiousness of subclinically infected individuals relative to those with clinical symptoms (assumed to be 50% as infectious as clinical infections), α is the infectiousness of the early infectious stage relative to the late infectious stage (assumed to be 2x more infectious in early compared to late infection), and ϵ is the transmission rate outside of the shelter.

The probability that individual i is infected on day t given that they are susceptible to infection is thus:

$$p_i(t) = 1 - e^{-\lambda_i(t)}, \quad i \in \mathcal{S}(t)$$

Infected individuals progress through a latent infection stage ($\mathcal{E}$), after which they enter either an early (presymptomatic) infectious stage ($\mathcal{I}_{c,1}$) leading to clinical symptoms ($\mathcal{I}_{c,2}$) with age-dependent probability $\rho(a_i)$, where a_i is i's age group (<60 years/≥60 years), or an early infectious stage ($\mathcal{I}_{s,1}$) leading to subclinical infection ($\mathcal{I}_{s,2}$) or very mild symptoms with probability $1 - \rho(a_i)$.

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