

COVID-19 Modelling

Simple Approaches to Disease Transmission Risk at Gatherings

Limiting the number of people at venues is considered crucial for slowing the COVID-19 epidemic. Intuitively, the size of gatherings is directly related to the infection rate, hence limiting their size aims to avoid a large number of infections during a short time span. Because gatherings can be highly variable in their form (e.g., birthday parties, weddings, or conferences) and duration, the variables that drive transmission during gatherings can also be highly diverse. Disease transmission is driven by factors such as mixing, contact rates and patterns, gathering duration, and prevalence among participants. The complexity of transmission risks in such variable gatherings would require detailed models suited for specific events, but the findings of these models may not be generalizable.

The authors of [this paper](#) developed modelling frameworks to assess transmission risk of respiratory infectious diseases during gatherings. Although limited for precise guidance of particular gatherings, their model frameworks can help support high-level public health decision-making.

In their models, the authors considered unrepeated and recurrent gatherings, and evaluate mitigation strategies that use testing and cohorting.

Unrepeated gatherings occur only once or infrequently enough to be considered unrepeated, such as conferences, weddings and funerals. The probability that at least one infectious person is present is the first determinant of risk. General approaches assume these potential infectious agents are randomly dispersed within a homogenous population. The prevalence of a disease within a general population is thus proportional to the risk of one of these persons being present at a gathering.

This assumption may not be realistic because individuals may be present from sub-populations that may be more or less infected. The authors introduce heterogeneity

in their model by directly changing the baseline prevalence according to the expected exposure of the gathering's participants.

After the probability of an infected person being present is determined, the model estimates the likelihood of the individual transmitting the disease to others. Assuming homogenous mixing, the expected minimum number of infections that will occur can be calculated.

The number of susceptible people that become infected can be calculated from the maximum number of contacts an infectious individual makes at a gathering and the minimum number of infectious individuals needed to infect the entire gathering. Time influences the risk of transmission insofar as the longer the duration people are together, the more likely virus transmission occurs. Findings from reported studies can provide the necessary estimates for a specific gathering.

Recurrent gatherings occur regularly, with the same participants. They include regular interactions of hospital staff, students and teachers at a school, as well as employees at a work place, among others. Participants at recurrent gatherings interact preferentially. To limit the spread in large recurrent gatherings, the participants can be split in isolated groups, or cohorts, such that the spread within the recurrent gathering is limited to one cohort if disease introduction occurs.

The three main transmission pathways at recurrent gatherings with cohorts are introduction of infected individuals in a cohort, transmission within a cohort, and transmission between cohorts.

The introduction of transmission risk in recurrent gatherings is similar to in unrepeatd gatherings but adds a time element of contact frequency. Community disease prevalence and gathering size over time also contributes to transmission risk. Transmission within a cohort is similar to unrepeatd gatherings, however with a larger number of contacts due to the recurring nature.

Reductions in transmission risk are accomplished by reducing the chance of contact and/or reducing the probability of transmission, given a contact. For example, physical distancing can reduce the probability of contact through maintaining two (2) metres between participants. Other examples include hand and surface sanitization, mask usage and screening participants before and during gatherings.

Mitigation using testing - Pre-gathering screening with PCR testing can reduce the risk of transmission. Periodic testing – where participants are tested at regular intervals – can also mitigate the risk of transmission. A measure to assess the effectiveness of mitigations is ‘freedom of disease’, which is the probability that the disease is absent from a population given multiple rounds of testing. Because the model assumes independence between the results of serial testing, the probability of detecting an infection may over-estimate the observed probability if there is correlation between periodic tests. Probability of detection is maximized when testing is done as much as possible. However, a test with sub-optimal specificity may lead to too many false positives and cause organizational constraints due to closures and isolation for personnel.

There is a delicate balance between maximizing detection probability and minimizing false positives when choosing test frequency and sample size. Test frequency and accuracy affect the duration between the introduction of an infectious case with its detection. Test sensitivity does not have a large effect on the speed of detection during high frequency testing less than three days.

Summary

This paper explores the factors that influence the risk of disease transmission at gatherings and the potential effects of mitigation strategies. This mathematical model is built on general principles and provides a simple and pragmatic application of these principles in order to assist decision-making.

After risk is introduced at a gathering, it can be assessed with population prevalence and the size of gathering. Gathering size was found to drive the risk of transmission, whereas contact rate has a saturation effect. For recurrent gatherings, the number of cohorts does not significantly influence transmission between participants, but their isolation between one another does. For example, small numbers of well-isolated cohorts were more beneficial than a large number of poorly isolated cohorts. Testing strategies can mitigate the risk of transmission at gatherings but also increase the likelihood of false positives.

More detailed analysis can be built from this model using this online tool:

nccid.ca/phac_gatherings_model/