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A burgeoning population, more rapid travel, and the ongoing evolution of bacterial and viral pathogens create increasing concerns regarding our ability to respond to novel or emerging agents of disease. Although many elegant models have been developed addressing pathogen dissemination in the general population, less attention has been paid to modeling or quantitating the spread of pathogens through health care institutions, such as intensive care units, hospitals, or clinics. As the recent severe acute respiratory syndrome outbreaks demonstrated, health care facilities can be important elements in the dynamics of pathogen dissemination. Quantitative models of pathogen dissemination within health care institutions could be used to optimize control policies, an application whose importance is amplified because of the increasingly limited resources for health care in general. Health care facilities are spatially intricate, inhomogeneous, and dynamically complex ecosystems because of the intensity, heterogeneity, and regional nature of interactions between disparate sets of individuals. In the inpatient setting, patients are seen relatively frequently, and there are multiple classes and subgroups of caretakers. A given patient is usually seen by a subset of the nurses, primary physicians and consultants, and the “caregiver domains” (assigned patients) of different caregivers usually overlap. These limited but overlapping domains create a highly heterogeneous contact network that can interact with the number and distribution of colonized patients to modulate pathogen dissemination. In addition, the order in which patients are seen can strongly modulate the dissemination of pathogens, and the pattern of contacts is often partially stochastic (because of random ordering of visits or unanticipated contacts), and even a “large” hospital represents a statistically small population.

Traditional methods of modeling pathogen dissemination are based on representing the venue of dissemination as a spatially and temporally well-mixed environment and using differential equation approaches to describe the growth of the infected population. For reasons enumerated above, health care facilities significantly violate such assumptions, rendering the applicability of traditional techniques suspect.

In contrast to more traditional equation-based approaches, conceptually simple discrete element (agent- or individual-based) models can readily and explicitly address “geographic” considerations, temporal elements of transmission, and probabilistic transmission dynamics germane to the spatially intricate environments and small population sizes characteristic of health care institutions. We have developed stochastic discrete event models of pathogen dissemination that explicitly account for temporal and spatial factors in the dissemination of pathogens through the hospital, the intensive care unit, the emergency department, and the outpatient clinic.

Results generated using Monte Carlo simulations for each of these venues demonstrate common themes. First, there is tremendous variability in the levels of pathogen transmission from simulation to simulation within each venue, suggesting that interventional clinical trials will need to be very large to adequately test predictive models. Second, spatial heterogeneity can dramatically reduce the dissemination of pathogens at a constant level of transmissibility. This finding suggests that spatial factors could be important considerations in models for optimizing control strategies, and that well-mixed (homogeneous) models that are parameterized with population-level epidemiological data might underestimate the risk of person-to-person transmission.

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