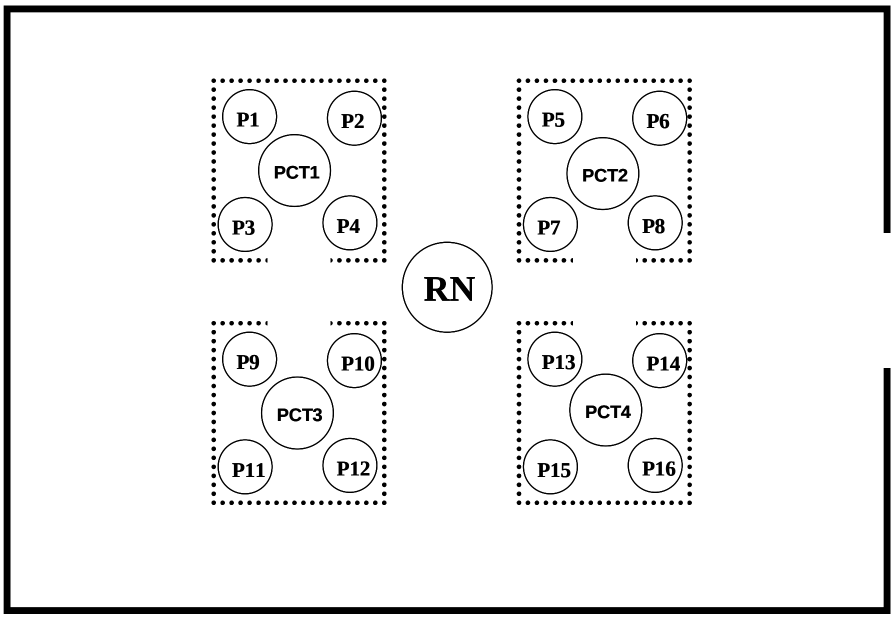
Pathogen dissemination in a hemodialysis clinic

The model configuration presented is based on clinical practices in an existing medium-sized dialysis unit in a major metropolitan area and incorporates four pods of four dialysis stations. Each pod is staffed by one patient care technician (PCT), who contacts each patient (P) in that pod at specified intervals. All treatments last 3 hours. A charge nurse (RN), who sees all patients, also sees each patient once per treatment. Patients see only one PCT per treatment. There are 16 patients per shift with 3 shifts per day (48 total patients). Staffing levels and patient assignments remain constant. “One week” consists of 3 days of dialysis treatments, thus, the model reflects patients dialyzing on either Monday, Wednesday, Friday or Tuesday, Thursday, Saturday schedules. Only patient: caregiver interactions were modeled.



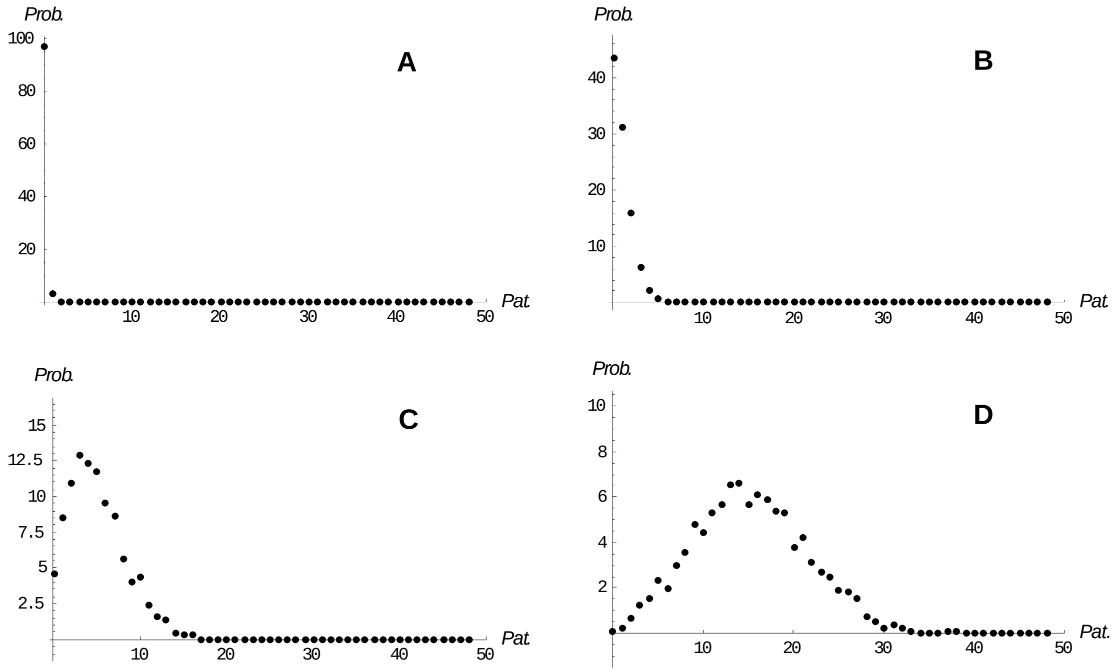
Every caregiver: patient interaction falls into one of 4 possible categories depending on the infectious state of each of the 2 participants (infectious/non-infectious). If only one participant (patient or caregiver) is infectious prior to the encounter, there is a finite probability specified as the per-encounter acquisition probability (PEAP) that the non-infectious member of the pair will become contaminated with the pathogen during the encounter. In the simulations presented the probability of transmission in either direction and between classes of participants were set equal.

Contaminated caregivers can immediately transmit the pathogen to other patients (“touch contamination”), have a specified probability of clearing their state of contamination following each encounter (decontamination), and remain contaminated for at most one day (3 shifts). The probability of caregiver decontamination can reflect measures ranging from effective hand and fomite cleansing to full barrier precautions. Once contaminated, a patient becomes infectious following a specified incubation period, and remains infectious for a specified infectious duration.

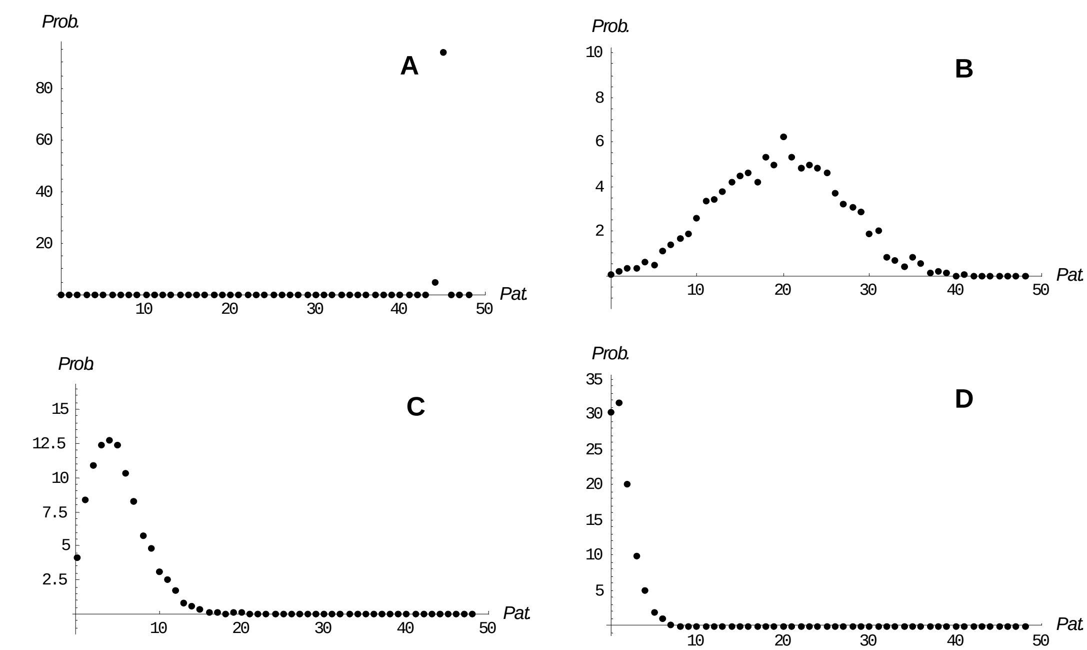
The initial number of positive patients and caregivers, their locations (pod and shift), and the PEAP for each class of caregiver (charge nurse or PCT) are specified. Unless otherwise noted, the simulations presented comprise 12 treatment days (1 month of thrice weekly dialysis treatments). The model is then re-set to the initial conditions and the simulation repeated. Each panel presents a probability distribution obtained by repeating the simulation 2000 times. The probability of observing a given number of patients becoming positive over the examined time period was determined by dividing the number of simulations resulting in that level of dissemination by 2000.

Results are presented as the probability (y-axis, *Prob*) of observing a given number of patients (x-axis, *Pat*) becoming positive over the examined time period. The model output is thus the probability distribution for a given number of patients becoming contaminated under specified spatial, initial prevalence, and dynamic conditions.

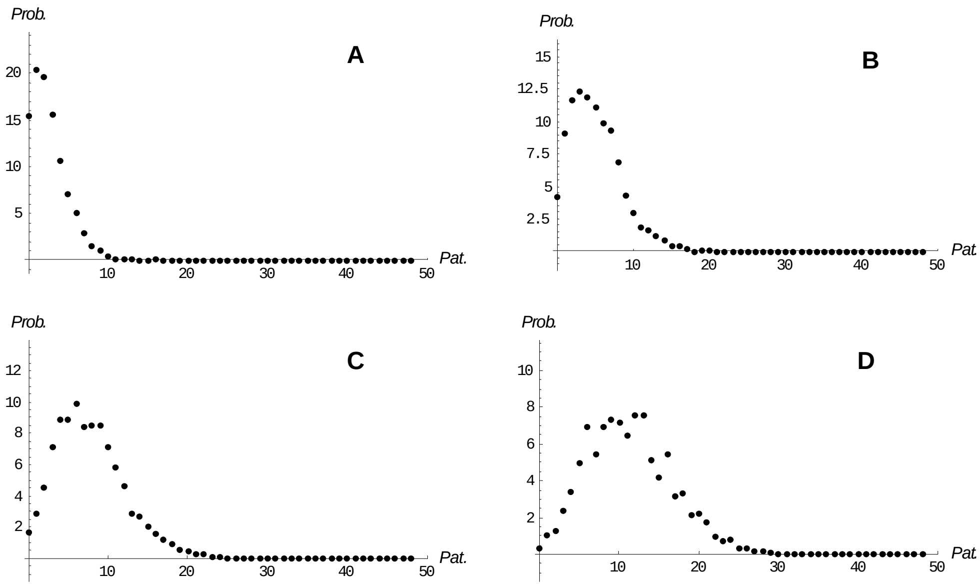
Influence of rising per-episode acquisition probability on dissemination.
In all panels there are 3 shifts of 16 patients, 4 patient care technicians, 3 hour dialysis treatments with PCT visits twice per hour and one charge nurse visit per treatment. Caregiver decontamination probability is 50% in all panels, and there are 3 infectious patients at baseline (one in each shift). Patients can transmit the pathogen immediately following contamination (incubation period zero). Panel A: PEAP 1%; Panel B: PEAP 5%; Panel C: PEAP 10%; Panel D: PEAP 15%.



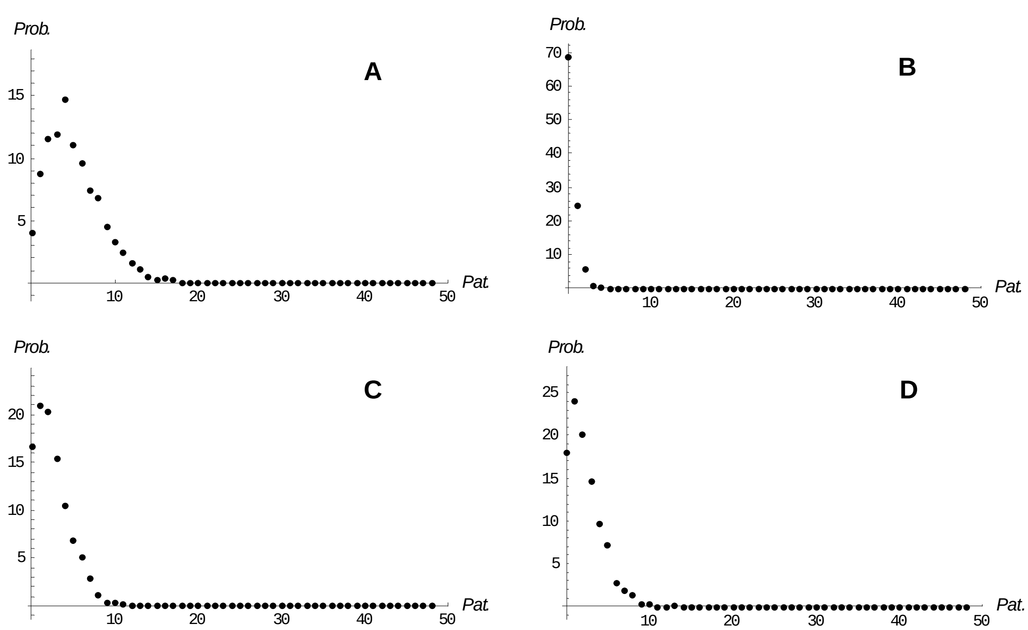
Influence of rising probability of post – encounter caregiver decontamination on dissemination. In all panels there are 3 shifts of 16 patients, 4 patient care technicians, 3-hour dialysis treatments with PCT visits twice per hour and one charge nurse visit per treatment. Per episode acquisition probability is 10% in all panels, and there are 3 infectious patients at baseline (one in each shift). Patients can transmit the pathogen immediately following contamination (incubation period zero). Panel A: Decontamination probability 0%; Panel B: Decontamination probability 25%; Panel C: Decontamination probability 50%; Panel D: Decontamination probability 75% (decontamination probability 100% eliminates dissemination and is not presented).



Influence of increasing frequency of PCT visits on dissemination.
In all panels there are 3 shifts of 16 patients, 4 patient care technicians, 3 hour dialysis treatments, one charge nurse visit per treatment, PEAP 10%, caregiver decontamination probability 50%, and 3 infectious patients at baseline (one in each shift). Patients can transmit the pathogen immediately following contamination (incubation period zero). Panel A: PCT visits each patient in pod once per hour; Panel B: PCT visits each patient in pod twice per hour; Panel C: PCT visits each patient in pod three times per hour; Panel D: PCT visits each patient in pod four times per hour.



Influence of different combinations of PCT and charge nurse probability of post – encounter caregiver decontamination on dissemination in the setting of a highly transmissible pathogen with a 2-day incubation period.
Simulations in this figure predict new infections over a 1-week period. In all panels there are 3 shifts of 16 patients, 4 patient care technicians, 3-hour dialysis treatments with PCT visits twice per hour and one charge nurse visit per treatment. Per episode acquisition probability is 50% in all panels, and there is initially one contaminated patient per shift. Panel A: Decontamination probability 50% for both PCTs and charge nurse; Panel B: Decontamination probability 90% for both PCTs and charge nurse; Panel C: Decontamination probability 50% for charge nurse and 90% for PCTs; Panel D: Decontamination probability 90% for charge nurse and 50% for PCTs.



Implications

If an institutionally defined acceptable risk for a given level of dissemination of a particular pathogen is specified, the control strategies most likely to attain this target, and their probability of failure, can be predicted using simulation based approaches. The resource utilization and quality of care costs associated with each level of prevention can then be weighed against both the most probable (expected) level of dissemination and the accompanying potential for much more widespread dissemination. Ultimately, such simulation-based techniques could be used to optimize infection control strategies for a given dialysis unit configuration and pathogen, subject to user-defined acceptable levels of transmission and resource constraints. Quantitative optimization of infection control strategies could focus on either pathogens of considerable importance but lesser transmissibility (such as MRSA), or on highly contagious agents that are seasonal or episodic in nature (such as the influenza virus). Such optimization could prove particularly useful in the hemodialysis clinic, given the closely spaced, recurrent visits made by patients, the relatively long duration of their stays, and the high burden of comorbidities in this population.