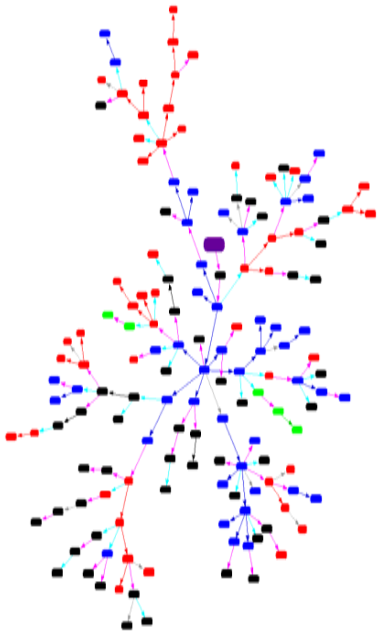
SAND2010-8560C

The Effect of Healthcare Environments on a Pandemic Influenza Outbreak



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Modeling for Public Health Action
Centers for Disease Control and Prevention
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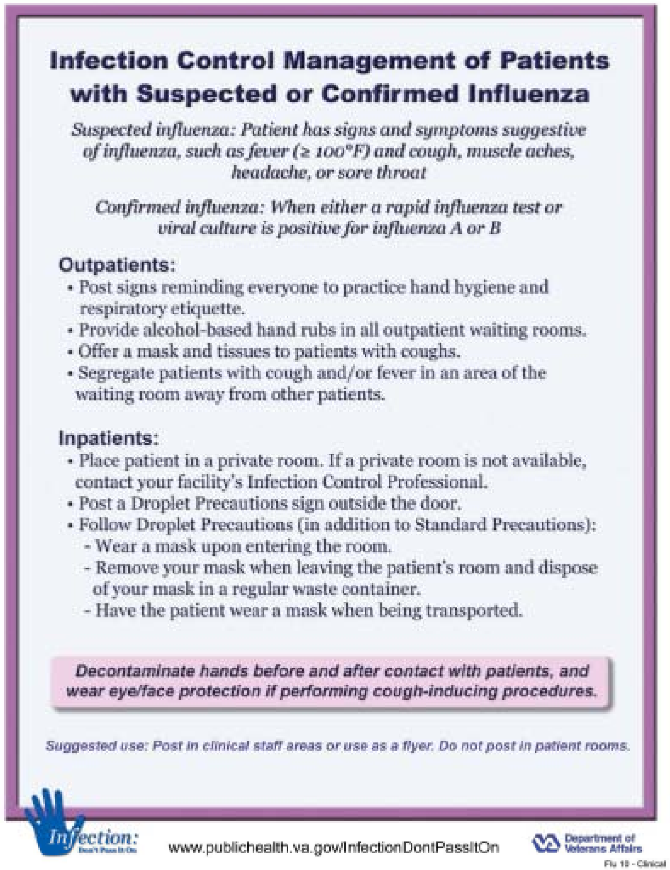
Context: Influenza transmission within healthcare settings

- **Patients, staff, visitors** bring influenza into healthcare settings
  - Outbreaks cause morbidity and mortality among staff, inpatients, long term residents (Bridges 2003)
  - H5N1 transmission occurred in hospitals (Bridges 2000, Wang 2008, Writing Comm WHO 2008, Uyeki 2007)
- **Control measures in healthcare settings** include
  - Negative pressure rooms
  - Use of PPE
  - Screening
  - Voluntary home quarantine of exposed staff
  - Visitor limitations
  - Prophylactic medications, vaccine
- **Applied by severity/pathogenicity**
  - Limit transmission in healthcare settings?
  - Few clinical studies of efficacy (Loeb 2009)



Infection Control Management of Patients with Suspected or Confirmed Influenza

Suspected influenza: Patient has signs and symptoms suggestive of influenza, such as fever (≥ 100°F) and cough, muscle aches, headache, or sore throat

Confirmed influenza: When either a rapid influenza test or viral culture is positive for influenza A or B

Outpatients:
- Post signs reminding everyone to practice hand hygiene and respiratory etiquette.
- Provide alcohol-based hand rubs in all outpatient waiting rooms.
- Offer a mask and tissues to patients with coughs.
- Segregate patients with cough and/or fever in an area of the waiting room away from other patients.

Inpatients:
- Place patient in a private room. If a private room is not available, contact your facility's Infection Control Professional.
- Post a Droplet Precautions sign outside the door.
- Follow Droplet Precautions (in addition to Standard Precautions):
  - Wear a mask upon entering the room.
  - Remove your mask when leaving the patient's room and dispose of your mask in a regular waste container.
  - Have the patient wear a mask when being transported.

Decontaminate hands before and after contact with patients, and wear eye/face protection if performing cough-inducing procedures.

Suggested use: Post in clinical staff areas or use as a flyer. Do not post in patient rooms.

Infection: Don't Pass It On — www.publichealth.va.gov/InfectionDontPassItOn — Department of Veterans Affairs

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Context: Influenza transmission from healthcare settings to community

- **Few reports of transmission** of respiratory viruses from healthcare settings to communities
  - Biologically plausible
- **Exception: 2002-2003 SARS experience**:
  - Healthcare settings were high-risk environments for transmission
  - Healthcare settings were source of infection for large percentage of victims who transmitted to community members
  - A ‘healthcare centered’ epidemic (Lloyd-Smith 2003, Possamai 2007)

Context: Related Work

- **Nuno et al. (2008)**
  - Compartmental model of a community with an embedded acute care hospital.
  - Open admittance policy rendered non-pharmaceutical measures ineffective on within-healthcare control of influenza transmission.
- **Lloyd-Smith et al. (2003)**
  - Estimated effects of patient isolation, contact tracing and quarantine on community SARS outbreak.
  - Quarantine of healthcare workers was the key measure in preventing transmission to community.

Context: Previous studies on influenza epidemic mitigation using this model

- **Glass et al. EID 2006:** determined the critical importance of children in influenza epidemic propagation. Closing schools and social distancing of children reduced infections by 90%
- **Davey et al. EID 2008:** evaluated thresholds for rescinding community mitigation strategies
- **Glass & Glass BMC Public Health 2008:** surveyed children and teenagers found teens had most contacts that could serve as influenza transmission 'backbone'
- **Davey & Glass PLoS One 2008:** a systematic evaluation of feasible mitigation strategies at wide range of pandemic severities and found critical enablers of success—rapid, stringent, regional implementation with high compliance
- **Perlroth et al. CID 2009:** evaluated cost-effectiveness of mitigation strategies, finding that the addition of school closure to adult and child social distancing and antiviral treatment and prophylaxis is not cost-effective for viral strains with low infectivity (Ro 1.6 and below) and low case fatality rates (1% and below)

Objectives

- To determine if healthcare settings serve as intensive transmission environments for influenza epidemics, increasing effects on communities.

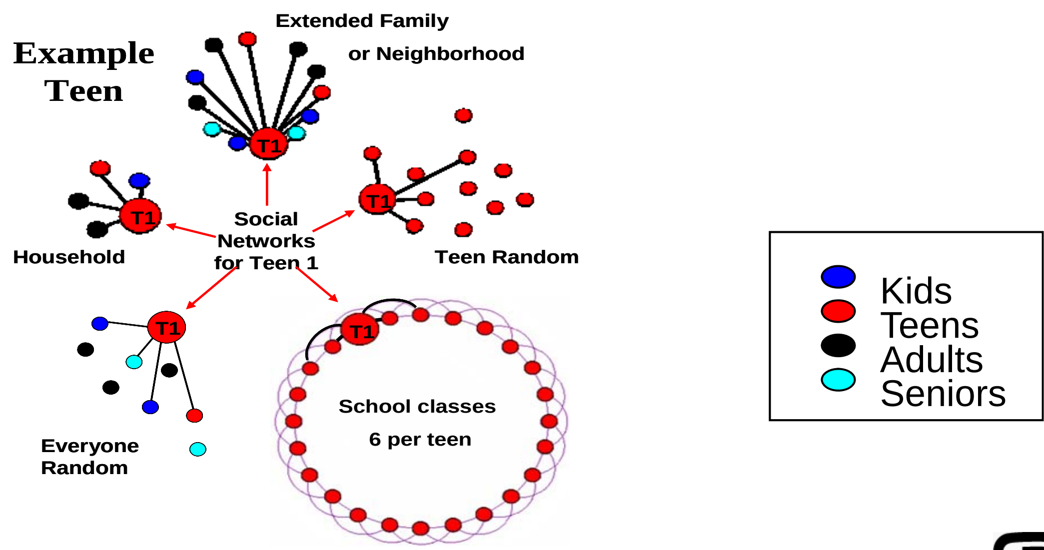
- To determine which mitigation strategies are best for use in healthcare settings and in communities to limit influenza epidemic effects.

- To determine which mitigation strategies are best to prevent illness in healthcare workers.

Methods: Base Social Network Design

A community in a networked agent-based model:

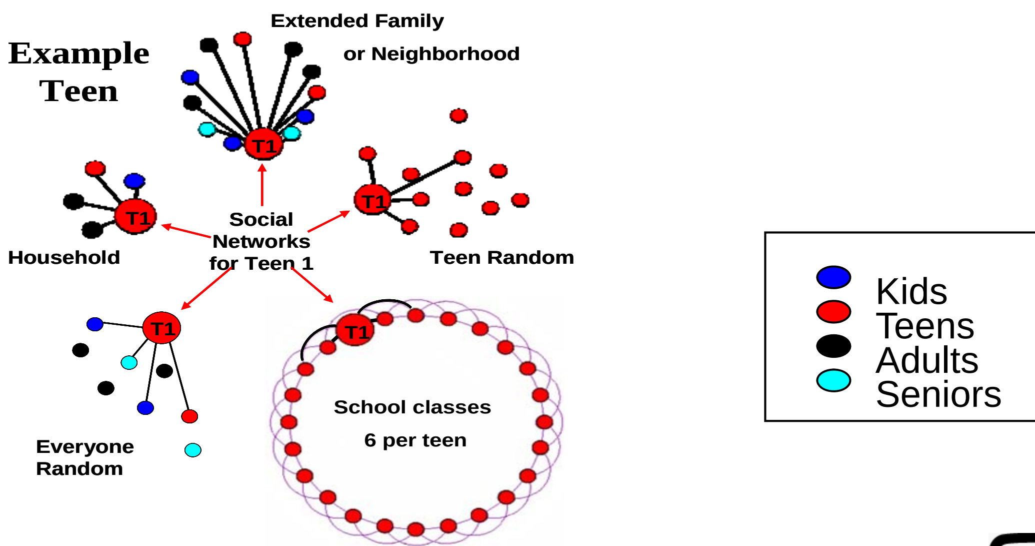
- Explicit social contact network
- Stylized US community of 10,000
- Agents: Children 18%, Teen 11%, Adult 59%, Senior 12% (US Census, 2000)
- Individuals live in overlapping groups of varying sizes: households, schools, workplaces, neighborhoods, extended families, gatherings, random meetings (RJ Glass et al. 2006; L Glass et al. 2008)
- Model constructs links between individuals that are potential connections; the numbers of links and configurations determined by pre-defined network topology (here: random, ring, fully connected)



Methods: Influenza Transmission

Process of influenza transmission

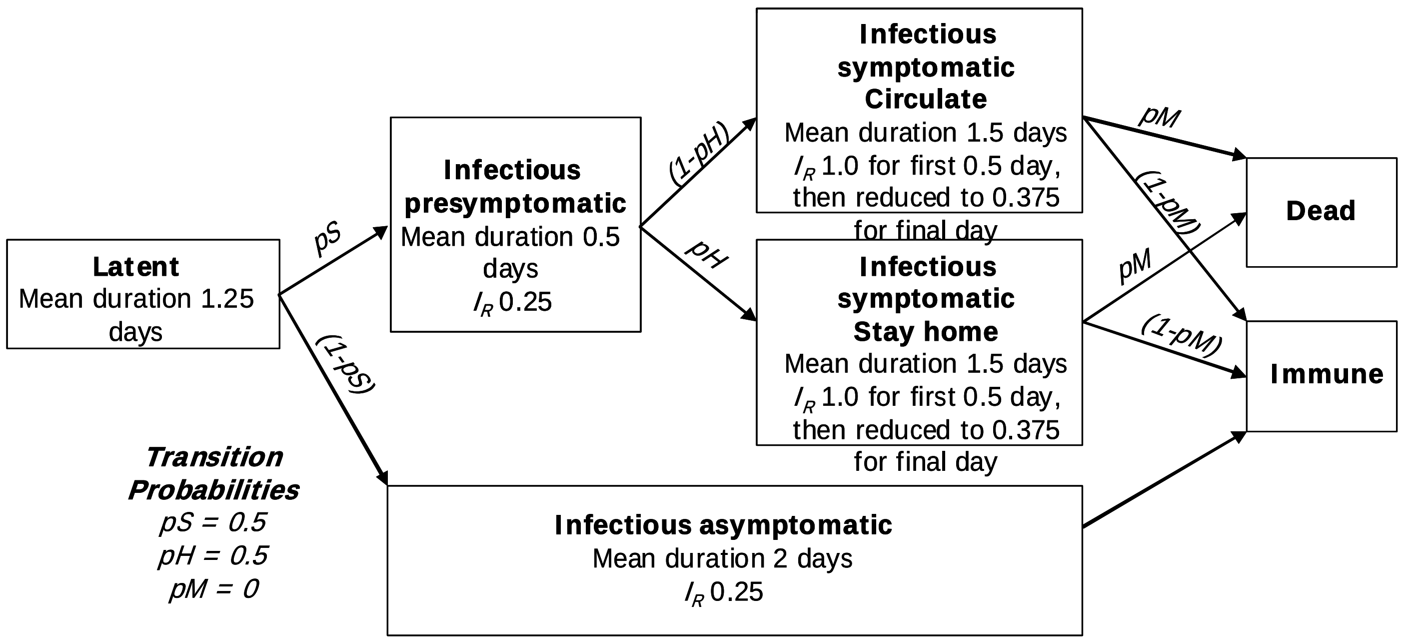
- Links are assigned an associated mean frequency of contacts per link per day, depending on group type (e.g. classroom or household)
- Contacts (realized links) present opportunity for influenza transmission
- Successful transmission = infectious contacts that result from a set of stochastically scheduled events that vary with each simulation.



Methods: Influenza Transmission

Influenza transmission occurs as two events

- **First event**: State transition—describes an individual's experience with influenza illness
  - State transitions are based on observed and experimental human influenza infections (Carrat 2008, Ferguson 2006, Germann, 2006, Monto 1985)



Methods: Influenza Transmission

Second event: individual to individual influenza transmission

- probability that a contact will occur, p_c in a small time interval, ***dt,*** along a link with contact frequency v_c is: $p_c = v_c dt$
- The percentage of total contacts between two linked individuals that actually result in transmission is scaled by $I_D * I_R * I_A * S_P * S_A$ where

  I_D =the infectivity of the disease

  I_R =the relative infectivity of the disease state

  I_A =the relative infectivity of the individual who is transmitting

  S_P =the susceptibility of people to the disease (here taken as 1.0)

  S_A =is the relative susceptibility of the individual being infected

- The probability of an influenza transmission event along a given link between an infectious and a susceptible individual, p_i , is given by:

$$p_i = I_D * I_R * I_A * S_P * S_A * v_c * dt$$

Methods: Healthcare Sites

- **Two healthcare delivery sites**
  - Outpatient
  - Capacity maximum 60 patients and escorts; 24/7 operation
- **3 shifts of healthcare workers (mean shift size: 20; range 10-50)**
  - Healthcare workers are of many disciplines
  - Equal likelihood to expose or be exposed to influenza at healthcare site
- **Community members come to healthcare site**
  - Patients receive care for influenza or other illness
    - 50% of symptomatic influenza patients seek healthcare (HHS Pandemic Influenza Plan 2005)
    - 70% of entire community population seeks healthcare at least once per year for any reason (VA Benefits and Healthcare Utilization, 2008)
  - **Escorts accompany patients**
    - Asymptomatic teenager, adult, or senior family member if available.
- **At healthcare site**
  - Infected and non-infected patients and escorts mingle in waiting area
  - Patients are assigned to one of 4 intake queues with shortest waiting time
  - Mean visit times determined from published data (Nat'l Health Statistics Reports 2008)

Methods: Design of Healthcare Sites

- **Patients' and escorts' links, contacts, and infectious contacts** are formed independently
- **Links are:**
  - Patient to patient
  - Patient to escort
  - Escort to escort
  - Healthcare worker to patient
  - Healthcare worker to escort
  - Healthcare worker to healthcare worker
- **#s of links are scaled** according to occupancy of site
- **Frequencies of contacts per link** are assigned and determine #s of infectious contacts
- **If healthcare workers are not able to work,** the number of patients able to be seen is decreased linearly according to proportion available.
- **Healthcare workers with influenza return to work** after a 7 day recovery period

Community-Based Interventions

S	**Close Schools**	Schools closed, **all school contacts reduced by 90%**, household contacts doubled
CTsd	**Social Distance Children and Teenagers**	Child & Teens social distancing, **all non-school and non-household contacts with or between children and teens reduced by 90%**, household contacts doubled
ASsd	**Social Distance Adults and Seniors**	Adults & Seniors social distancing, **all non-household non-work contacts with or between adults and seniors reduced by 90%, work contacts reduced by 50%**, household contacts doubled
T	**Antiviral Treatment**	Antiviral Treatment, **% of people (by level of compliance)** given antiviral course immediately after diagnosed, reduces infectivity by 60% (from Ferguson et al., 2006)
P	**Household antiviral prophylaxis**	Antiviral Prophylaxis, % **of household members (by level of compliance)** given antiviral for 10 days immediately after individual is diagnosed, reduces susceptibility by 30%, and if they become infected: reduces probability of symptomatic by 65%, reduces infectivity by 60% (from Ferguson et al., 2006)

Healthcare Worker Interventions

PPE	**Personal Protective Equipment for Healthcare Workers**	Healthcare workers wear masks, gloves, gowns, protective eyewear with probability based on a compliance factor from the first day of strategy implementation until there are 0 community cases in 7 days. We assume PPE reduce susceptibility and infectivity by 50%.
ObP	**Outbreak Prophylaxis for Healthcare Workers**	Healthcare workers take daily antivirals with probability based on a compliance factor from the first day of strategy implementation until there are 0 community cases in 7 days. Reduces susceptibility by 30%, probability of becoming symptomatic by 65% and infectivity by 60%.
PPV	**Partially Effective Pandemic Vaccine**	Healthcare workers get vaccine with probability based on a compliance factor prior to the local onset of the epidemic. We assume vaccine reduces the probability of infection by 50%.

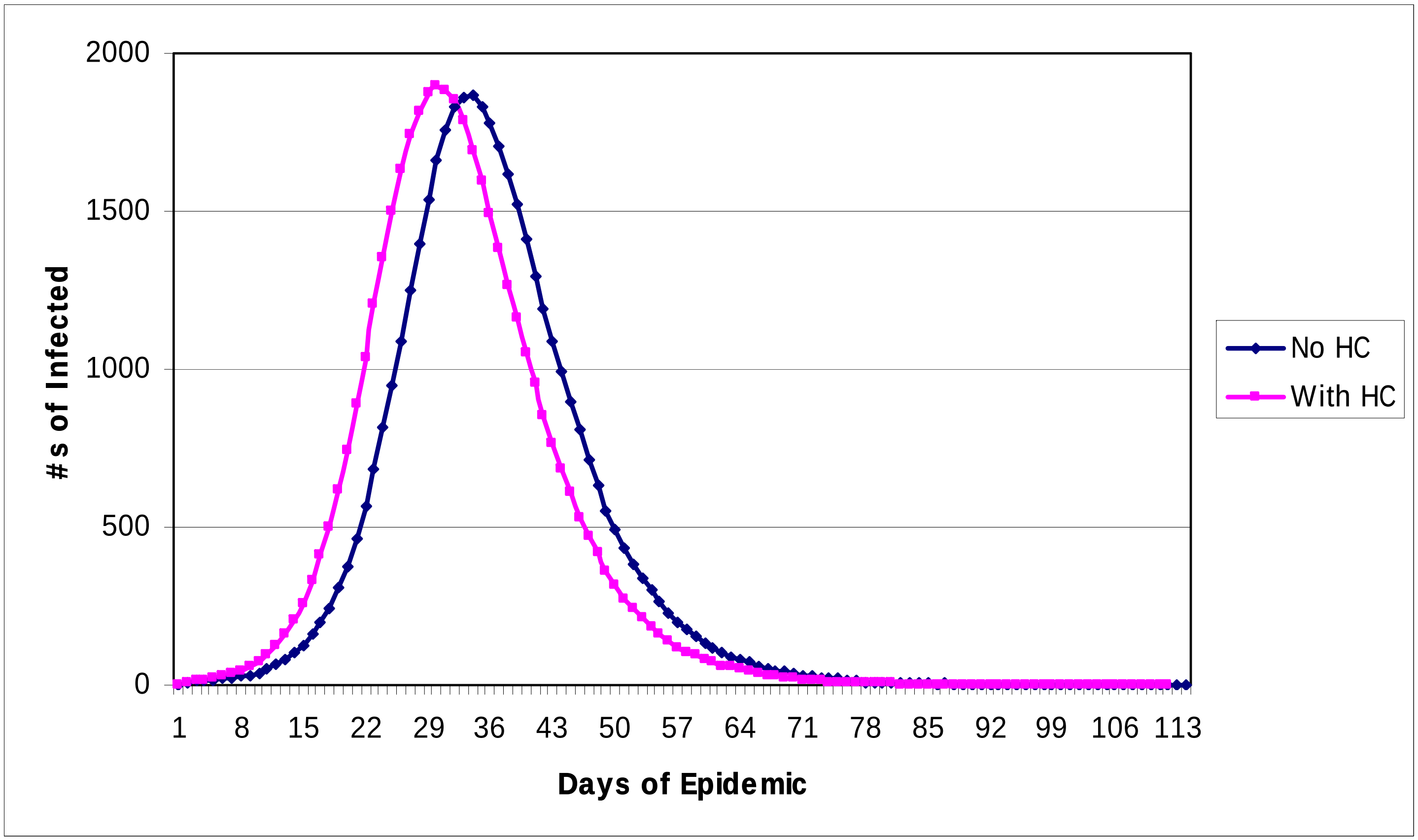
Outcome measures

- Number of simulations that yield epidemics
- Infection rates, community members and HCW
- Illness attack (symptomatic) rate
- Deaths
- Peak infected, community and HCW
- Time to peak infected
- Peak symptomatic
- Time to peak symptomatic
- Epidemic duration (from implementation threshold to last diagnosed)
- Total time of effects (from initial seeding to last person recovered)
- Number of days strategies imposed
- Number of containment cycles needed
- Number of external infections
- Number of antiviral courses given
- Number of days adults are at home (either sick, quarantined, or tending sick or children sent home from school)
- Healthcare site patient throughput

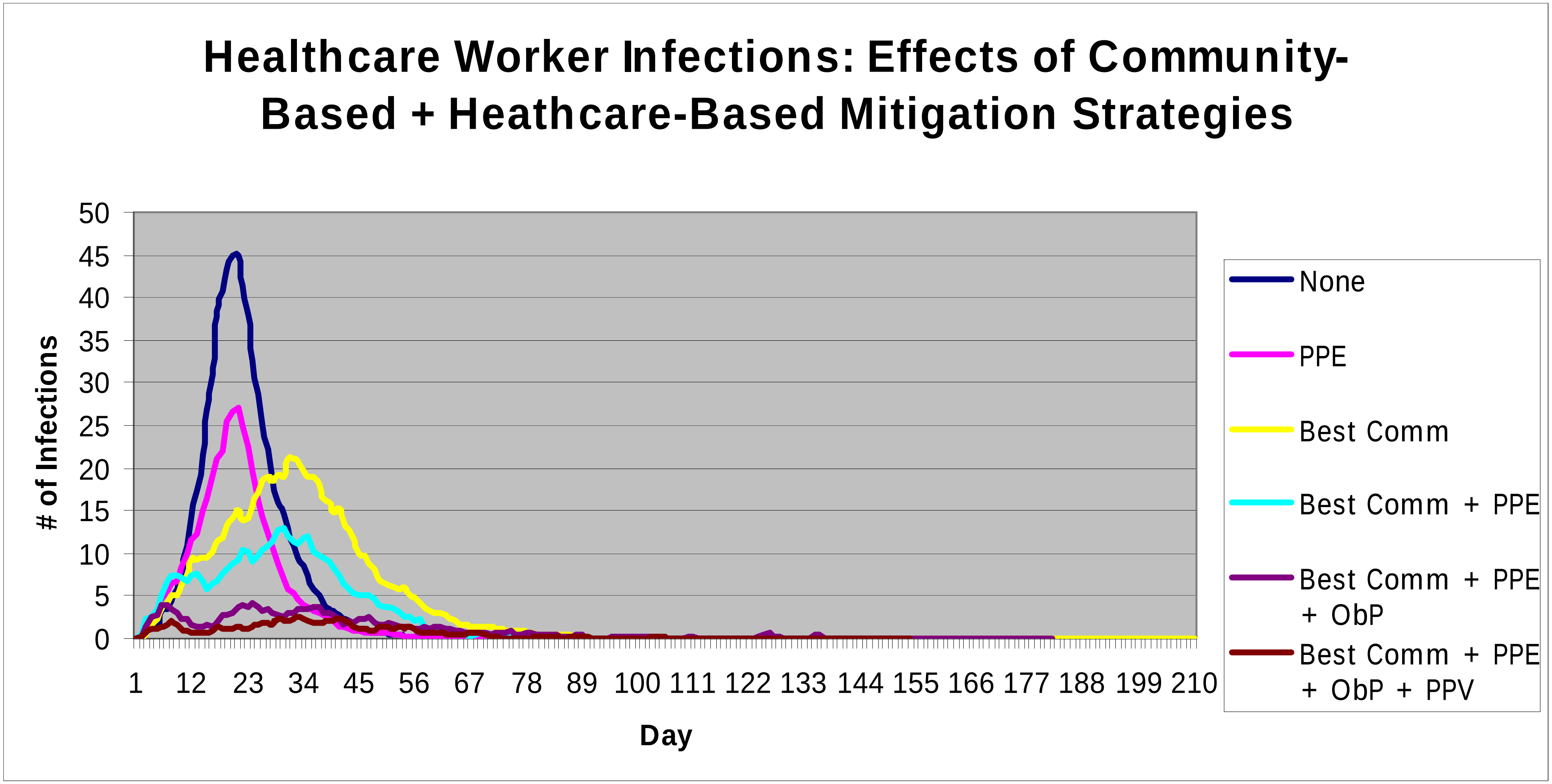
Simulations

- Three community compliance rates: 30%, 60%, and 90%.
- Two healthcare worker compliance rates: 60% and 90%.
- Three attack rates.
- Twenty combinations of community mitigation strategies.
- Eight combinations of healthcare worker strategies.
- 100 simulations for each configuration.
- Total of 18,000 simulations for base community (no healthcare delivery sites) and 270,000 simulations with healthcare delivery sites (288,000 total).

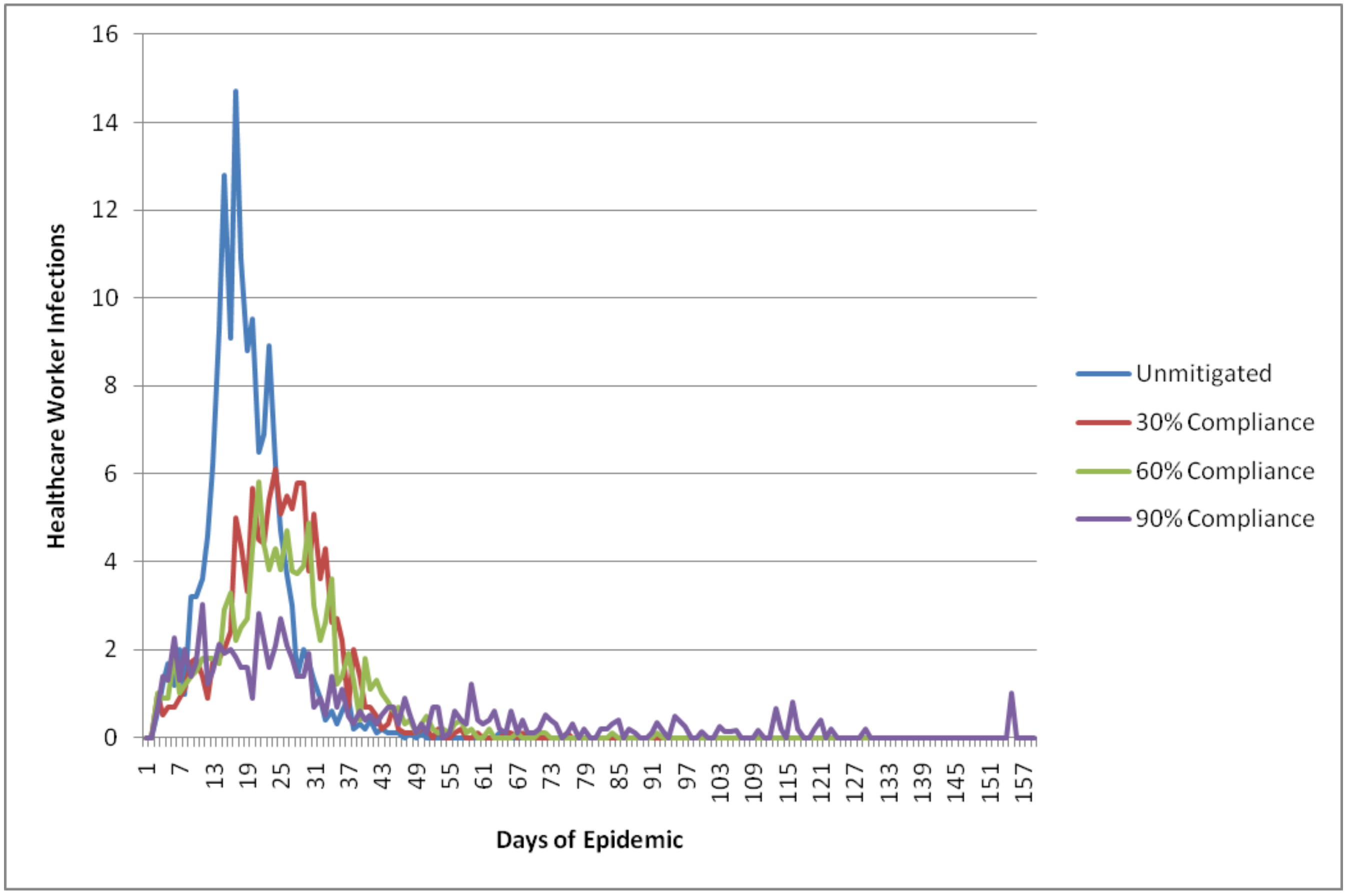
Effect of Healthcare Sites on Number of Infections



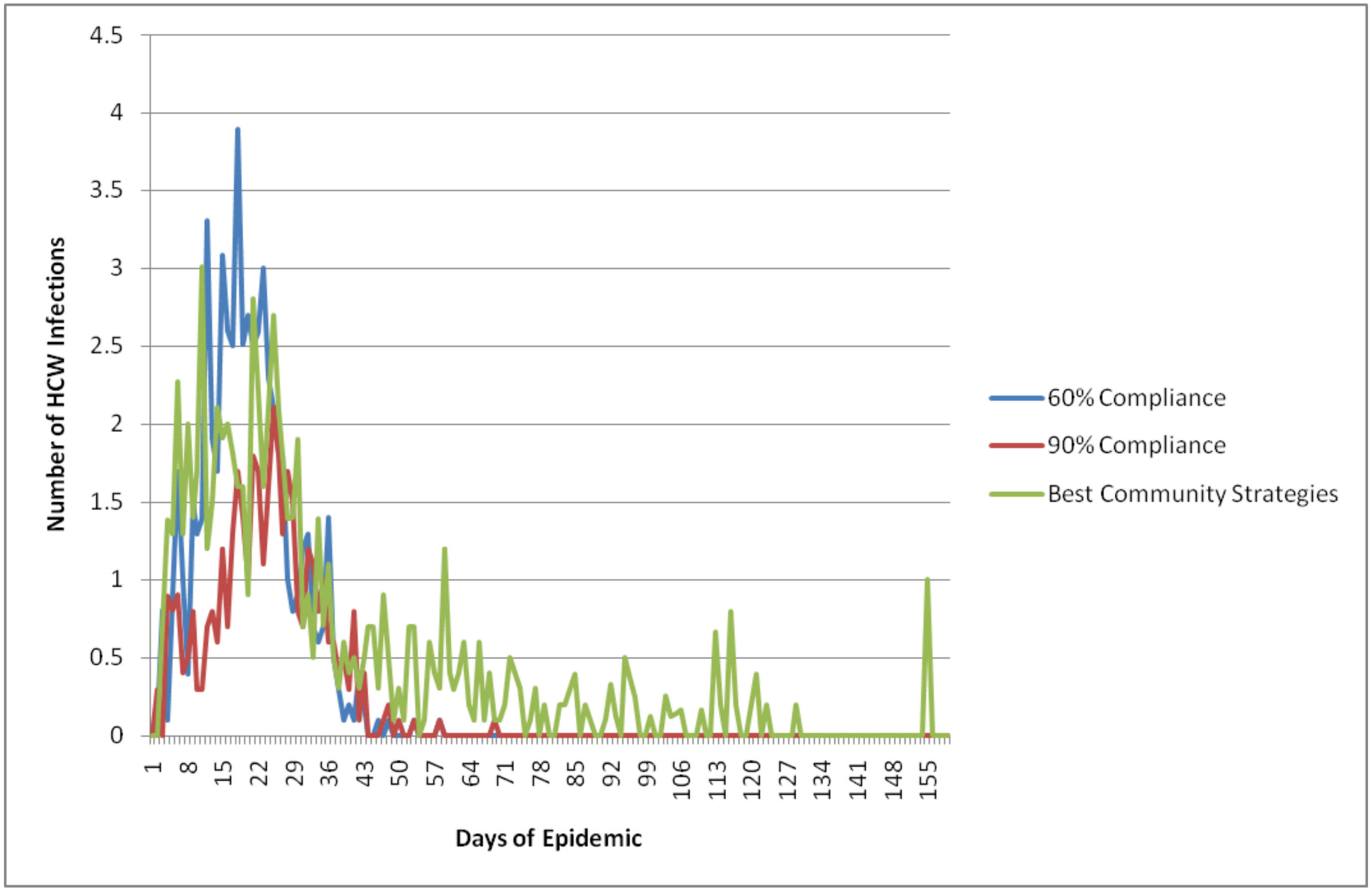
Combined Strategies



Effect of Community Compliance on HCW Infections



Effect of HCW Compliance on HCW Infections



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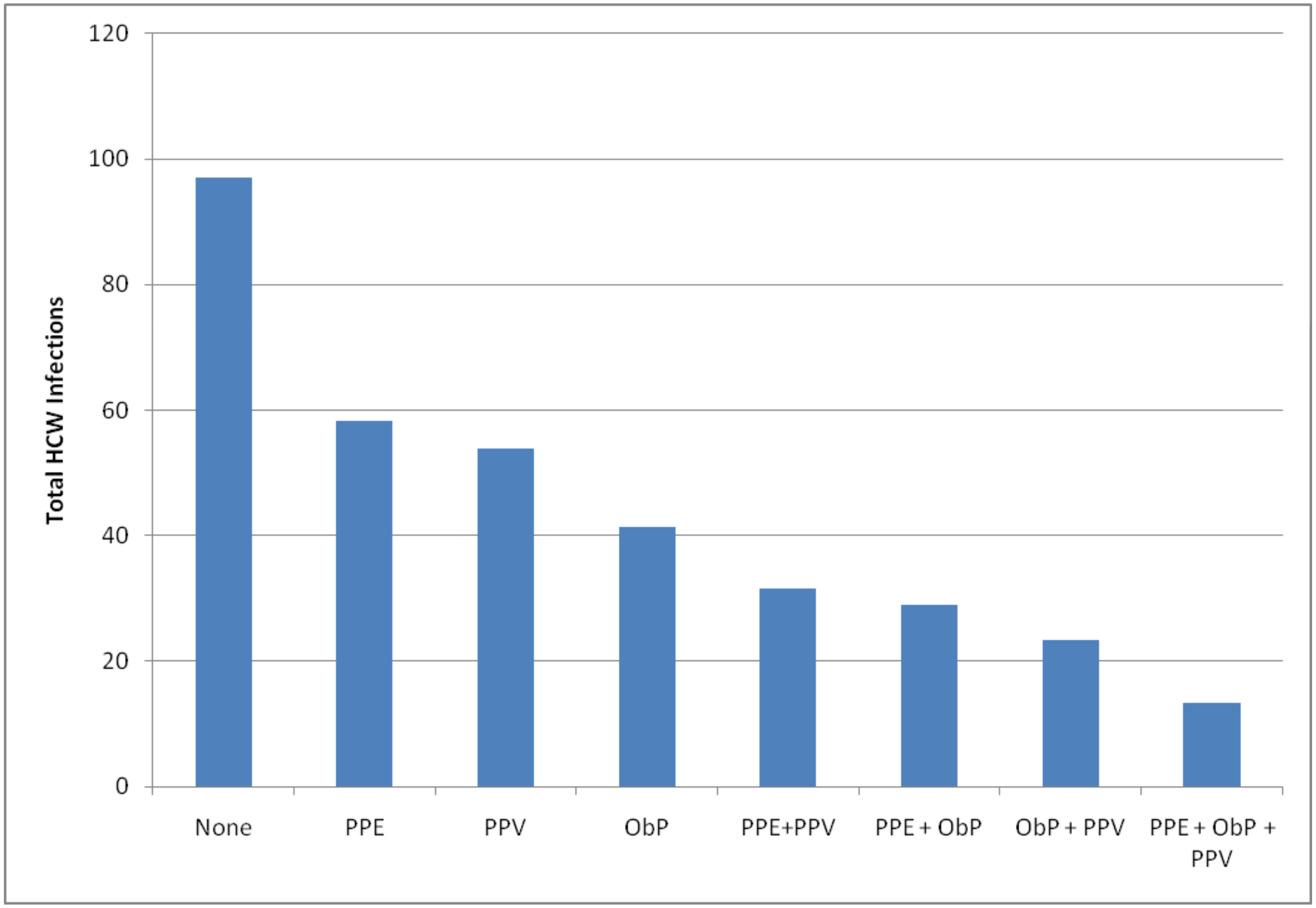
Ranking of HCW Interventions



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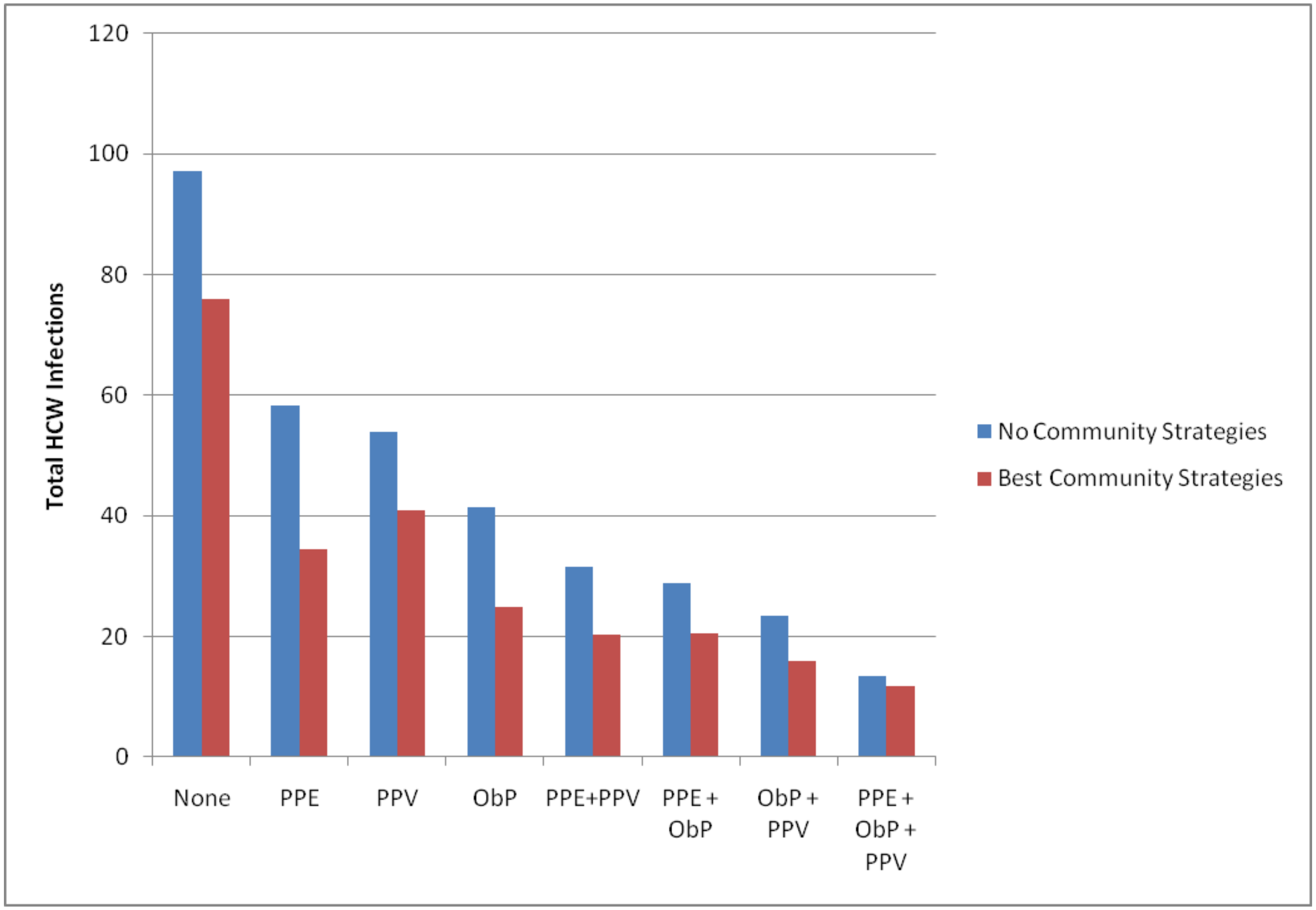

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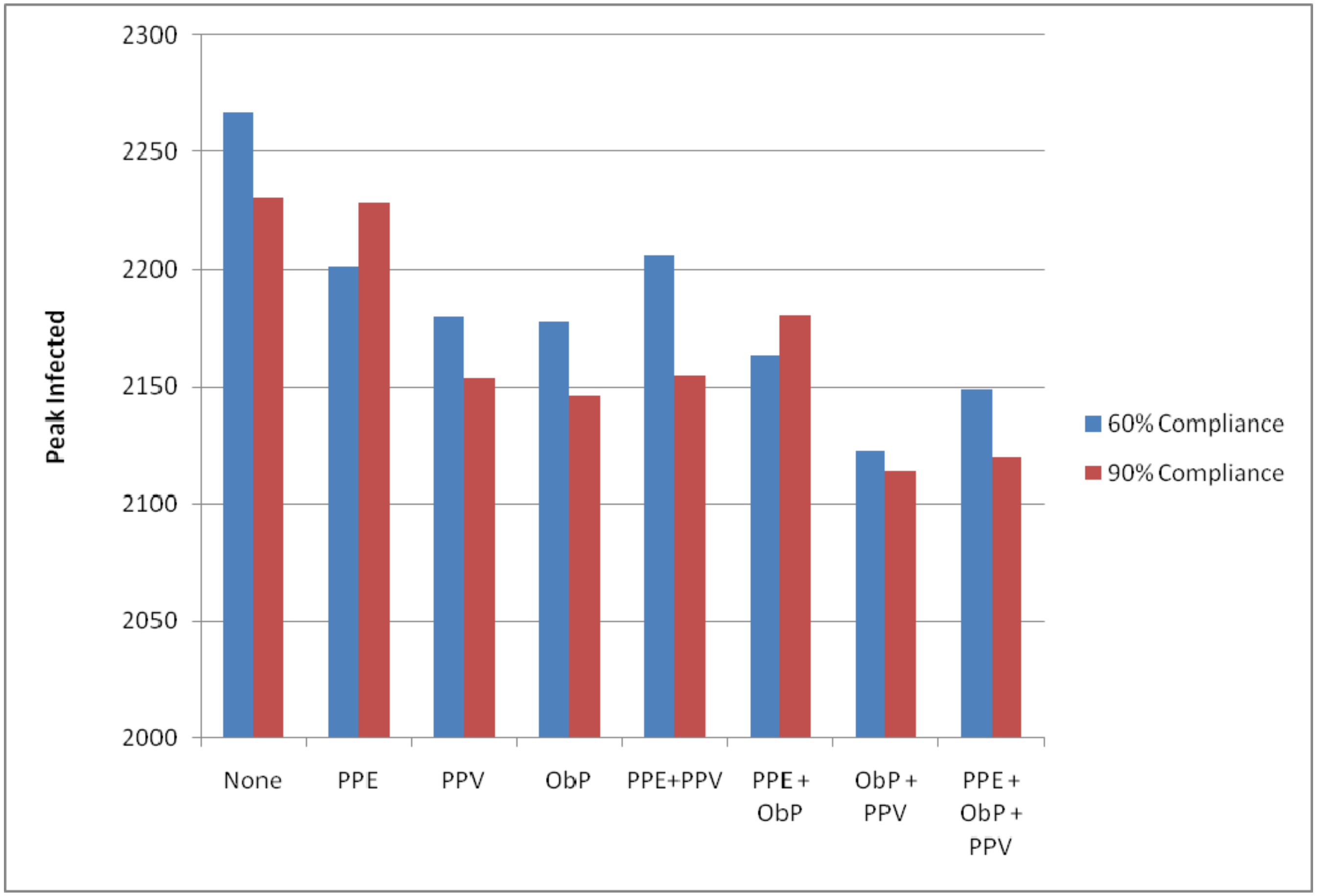
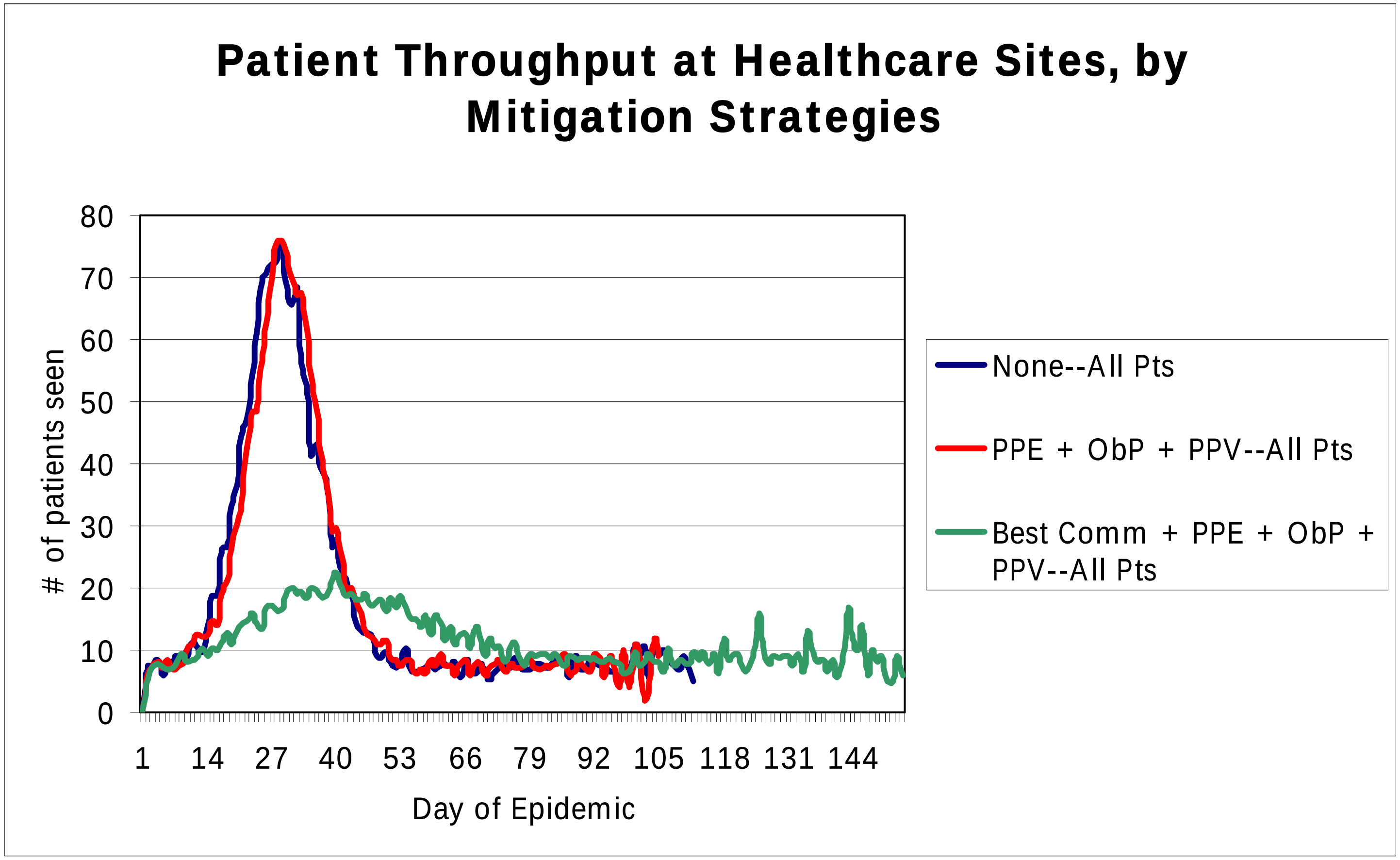


Healthcare Delivery



Conclusions

- Extension of model to study effects of presence of healthcare sites in community on pandemic effects.
- Healthcare sites accelerate the pace and peak of the pandemic wave.
- Use of community mitigation measures protects HCW
- Use of HCW measures significantly protects healthcare workers and slightly blunts the pace and peak of community effects.
- Compliance with measures remains key.