Effects of Healthcare Sites on Community Pandemic Influenza Transmission and Mitigation

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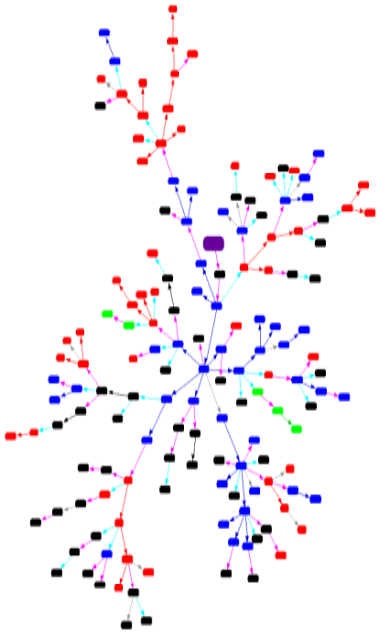

Infectious Disease Modeling Meeting
January 6-7, 2010

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Outline

- Context
- Objectives
- Design and Methods
- Interventions
- Results
- Summary Points & Influenza Policy Implications

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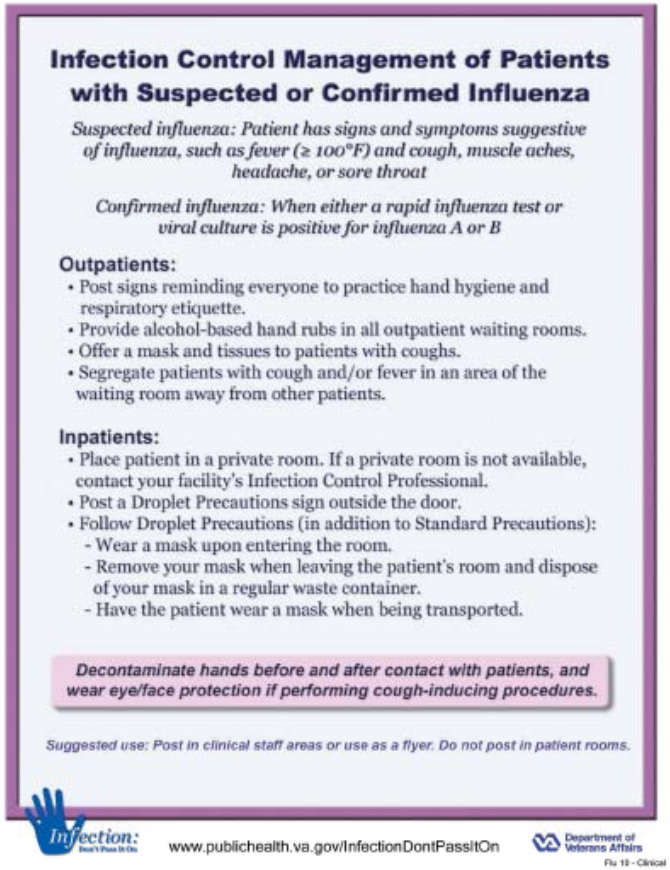
Context—Influenza transmission within healthcare settings

- **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

Fig 10 - Clinical

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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)

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Context—Modeling studies examine relationships between healthcare settings and community disease outbreaks

- **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

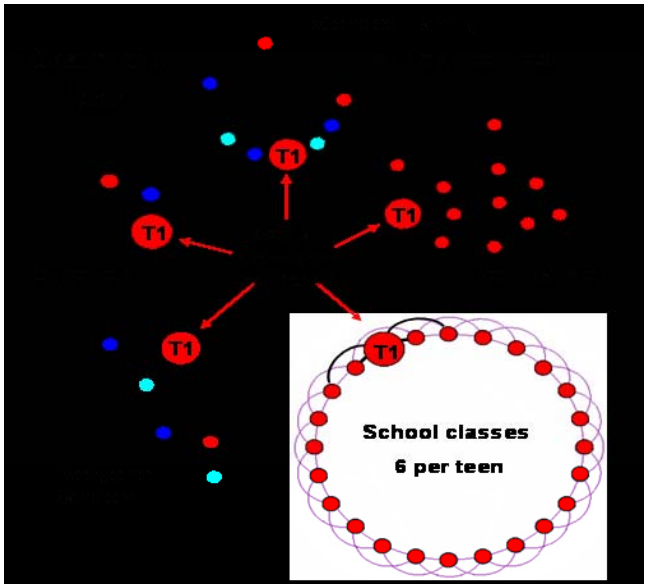
- To determine which mitigation strategies are best for use in healthcare settings and in communities to limit influenza epidemic effects

- 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)



Agents

- Kids
- Teens
- Adults
- Seniors

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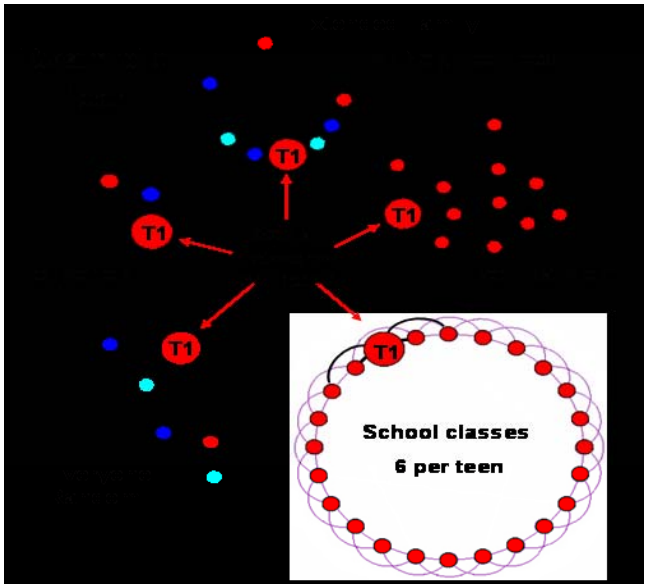
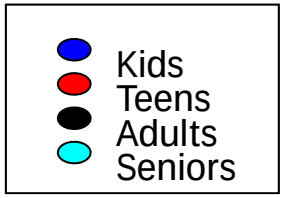
Methods ■ Influenza Transmission

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





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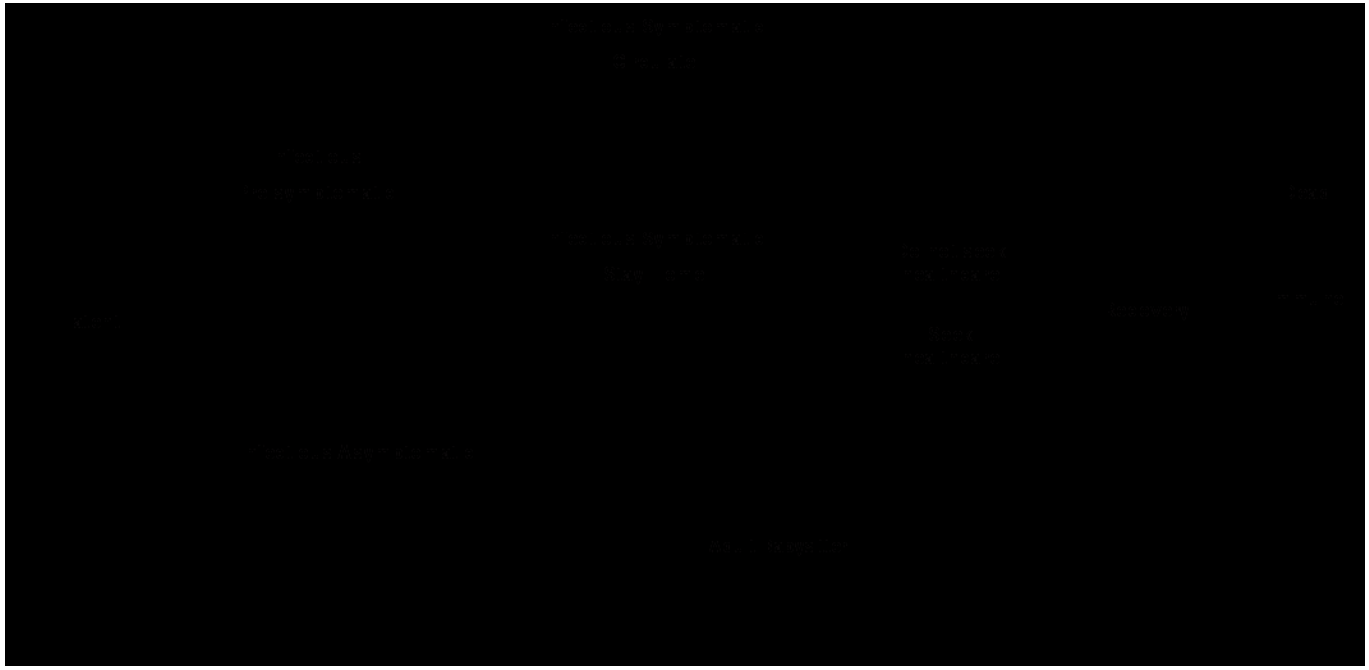
Methods ■ Influenza Transmission

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)



I_R is the relative infectivity of the disease state, with 1.0 being fully infectious. Probabilities of state transitions can be modified but in our model were *pS [symptomatic]* = .5, *pH [of going home]* = .8, *pHC* [of seeking healthcare]= .5, *pM* [of mortal illness] = .02 (for a 1918-like epidemic). The dashed boxes and arrow are not a state transition, but are included for clarity.

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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:

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

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Methods ■ Healthcare Setting Design

- **Two healthcare delivery sites**
  - Outpatient
  - Capacity maximum 60 patients and escorts; 24/7 operation
- **3 shifts of healthcare workers (avg size shift 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 ■ Healthcare Setting Design

- **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

Interventions

Community-based mitigation strategies, in model

- modify contact networks
- modify agent's susceptibility given antiviral drugs or vaccine

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)

Interventions

Healthcare-based mitigation strategies, in model

- modify contact networks
- modify agent's susceptibility given antiviral drugs or vaccine

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

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Results

- Unless otherwise noted
  - Community includes 2 healthcare settings
  - Results are given for mild-moderate epidemic (IF 1.0, ~ R_0 of 1.6 by branching factor analysis) (see Glass 2006; Davey and Glass 2008)
  - Compliance with community-based measures = 60%
  - Compliance with healthcare-based measures = 90%
  - Measures begin with 10 cases in community; end when 0 cases/7 days; strategies are reimplemented if epidemic recurs
  - 10 simulations were done for each scenario

Matrix of Simulations

- 160 strategy combinations
- At 3 levels of pandemic severity
- At 30%, 60%, 90% compliance
- 10 simulations per combination
- 160*3*3*10 simulations = 4800

	None	PPE	PPE + ObP	PPE + PPV	ObP	ObP + PPV	PPV	PPE + ObP + PPV
None								
S								
S + CTsd								
S + ASsd								
S + T								
S + T + P								
S + CTsd + ASsd								
S + CTsd + ASsd + T								
S + CTsd + ASsd + T + P								
CTsd								
CTsd + ASsd								
CTsd + T								
CTsd + T+ P								
CTsd + ASsd + T								
CTsd + ASsd + T+ P								
ASsd								
ASsd + T								
ASsd + T + P								
T								
T + P								

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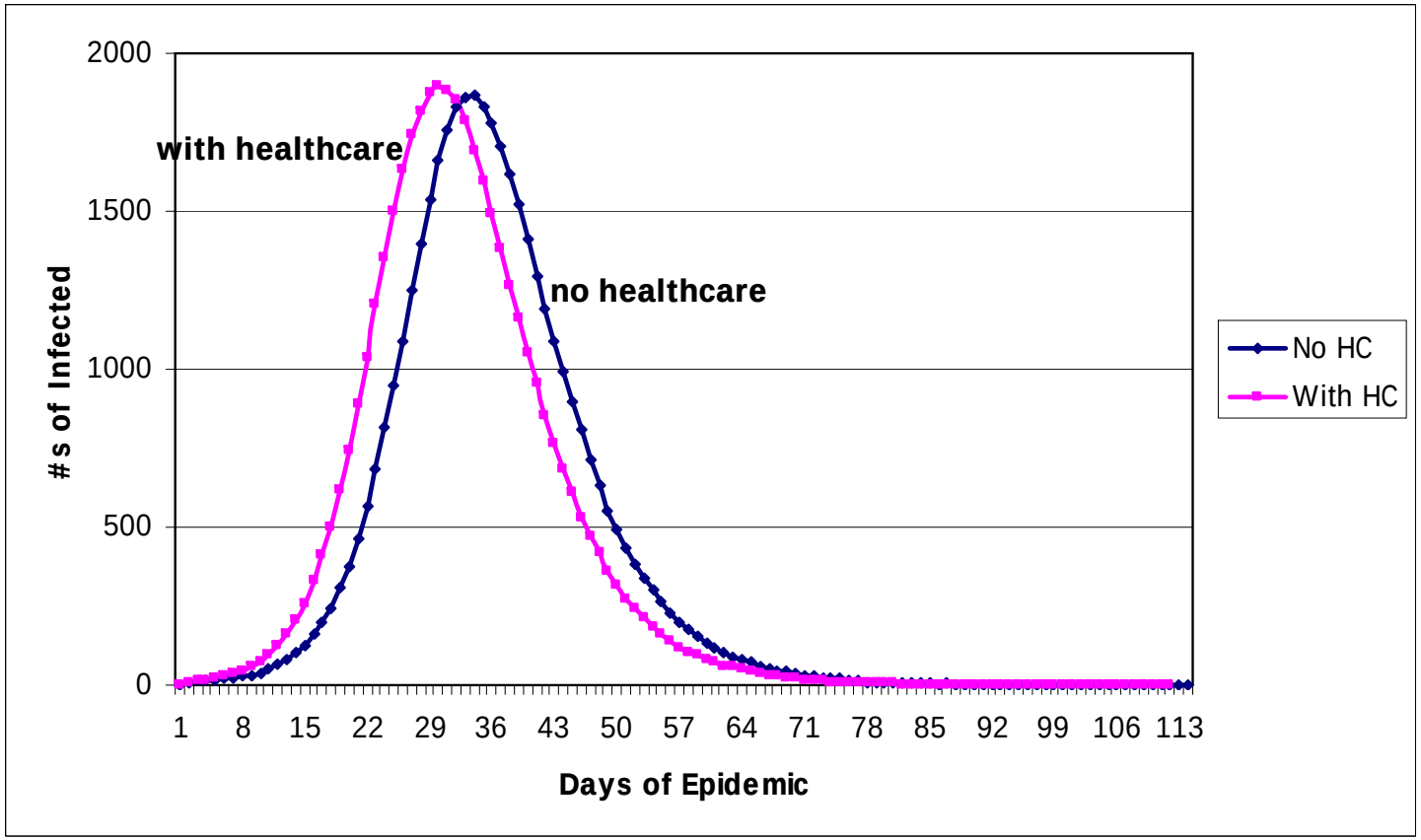
Results—Effects of Healthcare Settings on #s of Infections

Moderate (IF 1.0) Epidemic



- With healthcare: Peak infected day 26 Duration 110 d
- No healthcare: Peak infected-day 30 Duration-113 d

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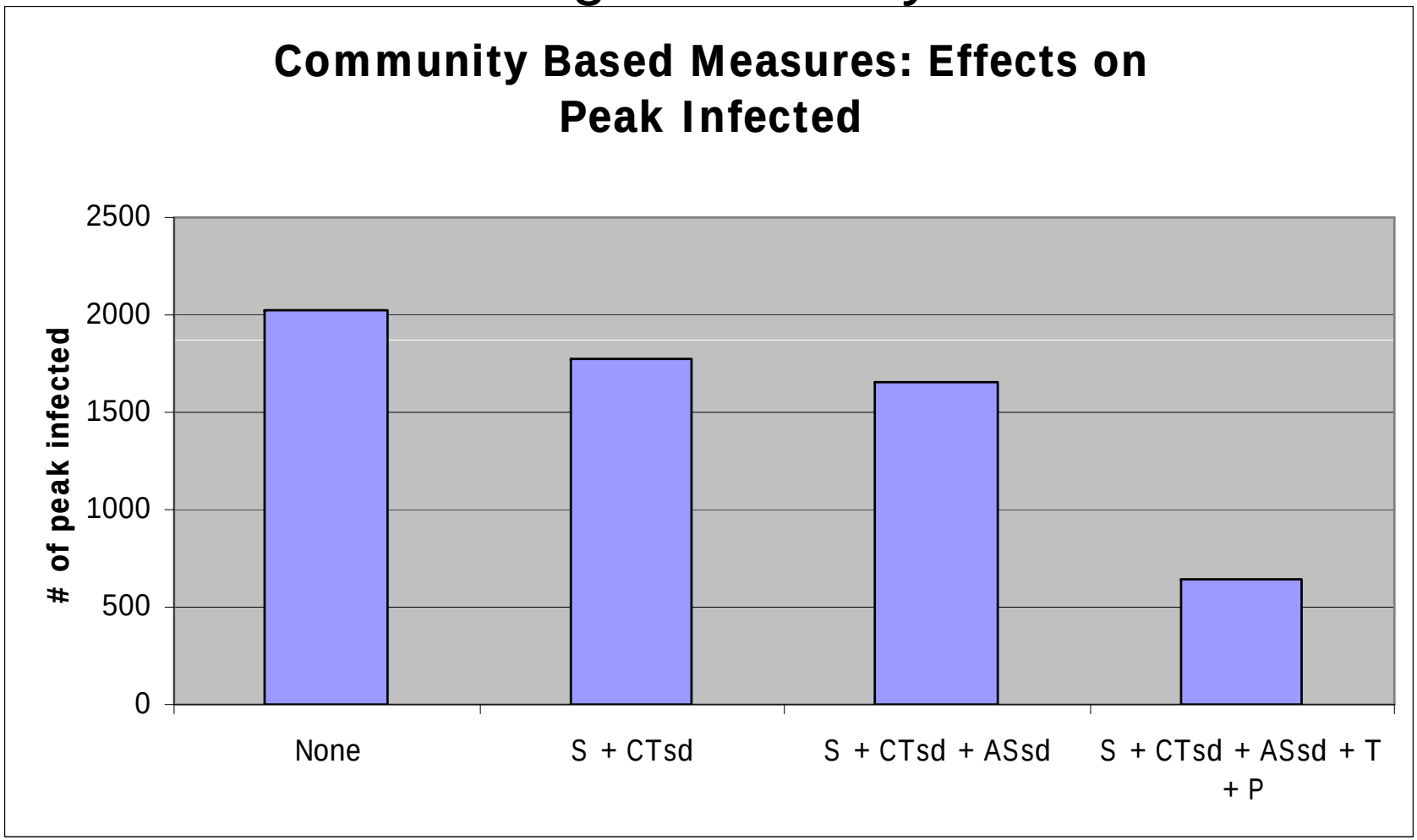
Results—Which mitigation strategies are best at reducing community infections?



- S = school closing
- CTsd = child/teen social distancing
- ASsd = adult/senior social distancing
- T = treatment
- P = prophylaxis of householders

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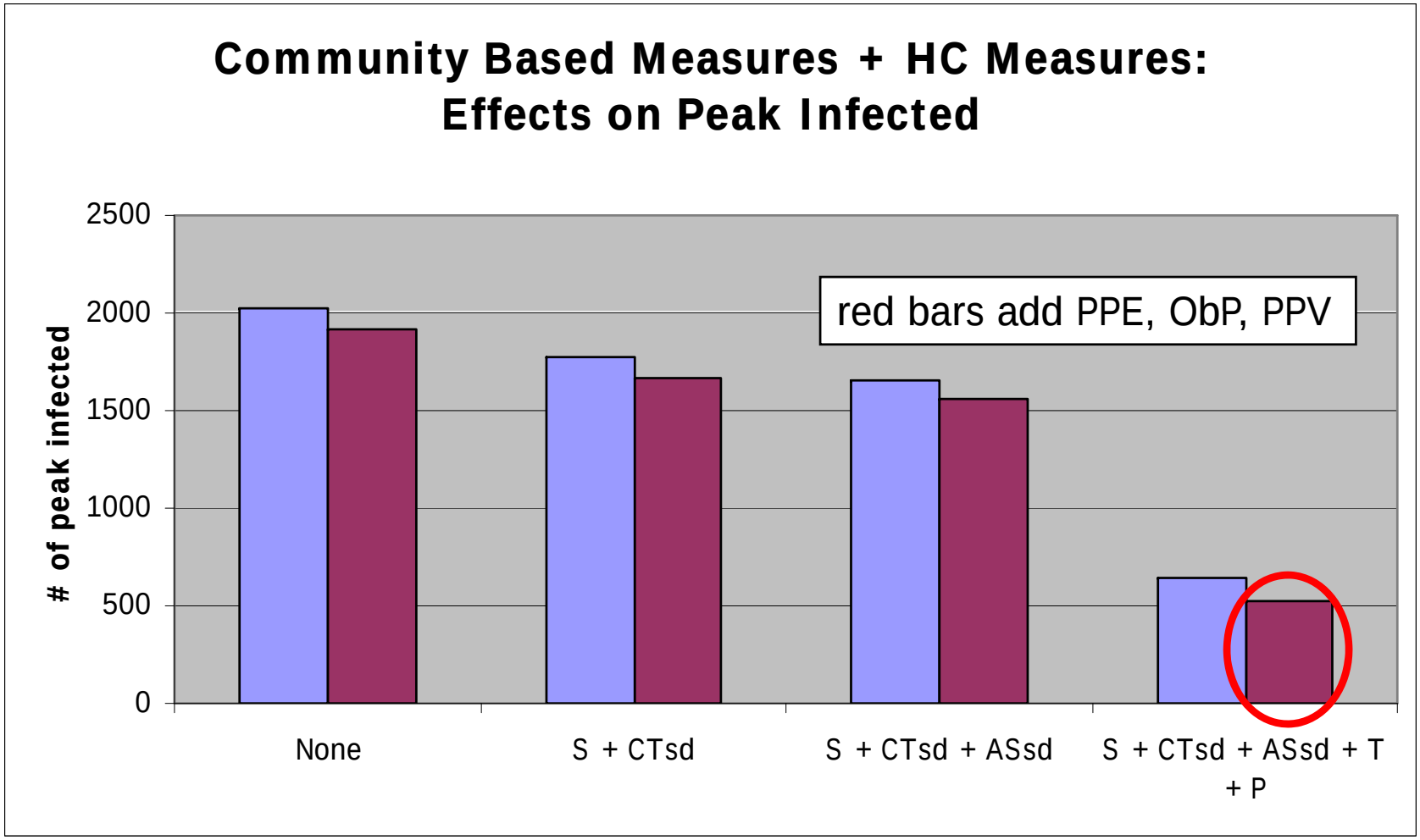
Results—Which mitigation strategies are best at reducing community infections?



- S = school closing
- CTsd = child/teen social distancing
- ASsd = adult/senior social distancing
- T = treatment
- P = prophylaxis of householders

- PPE = protective equipment for HCW
- ObP = outbreak duration antivirals for HCW
- PPV = vaccine for HCW

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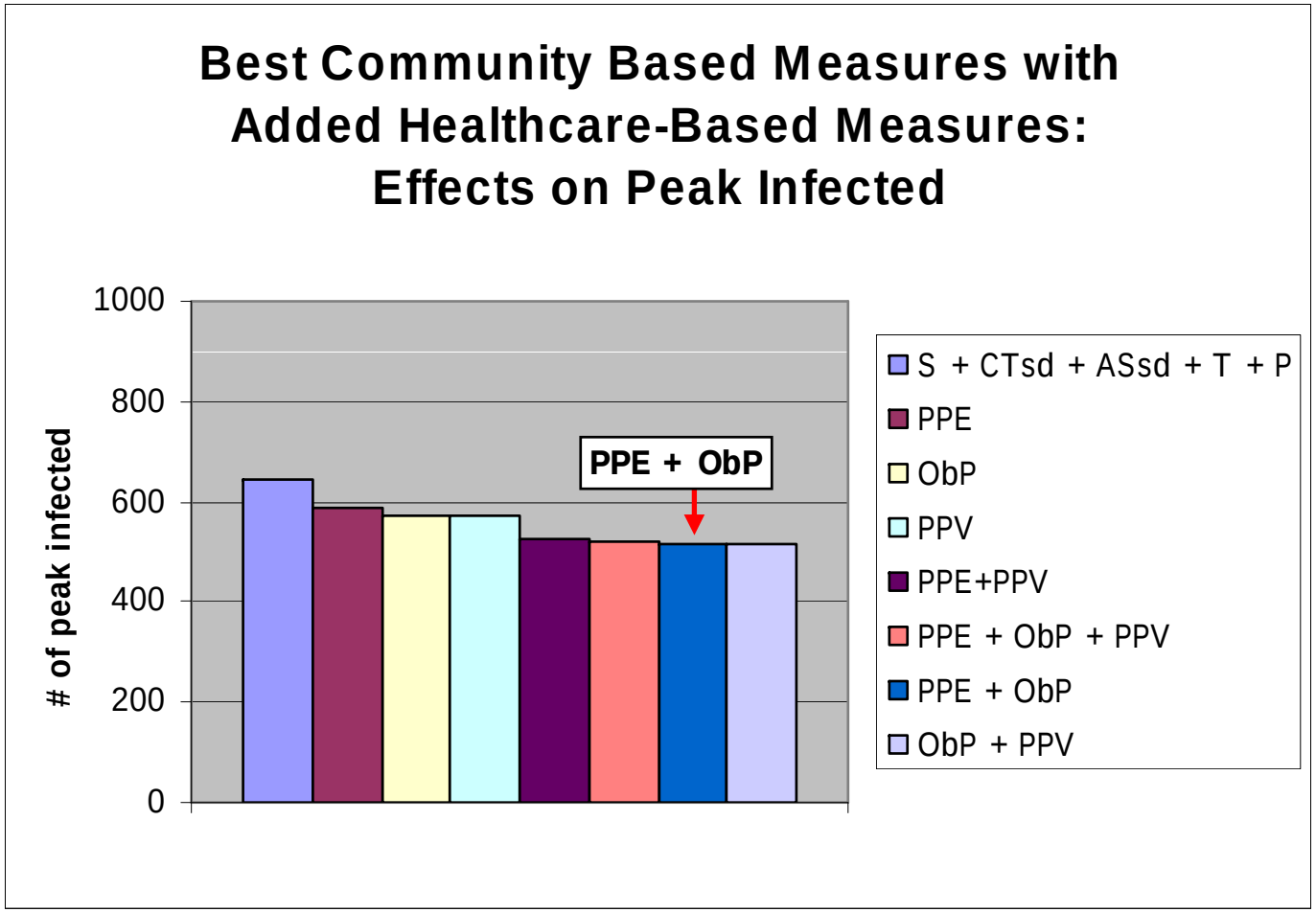
Results--Discerning effects of healthcare-based measures on the community



- S = school closing
- CTsd = child/teen social distancing
- ASsd = adult/senior social distancing
- T = treatment
- P = prophylaxis of householders

- PPE = protective equipment for HCW
- ObP = outbreak duration antivirals for HCW
- PPV = vaccine for HCW

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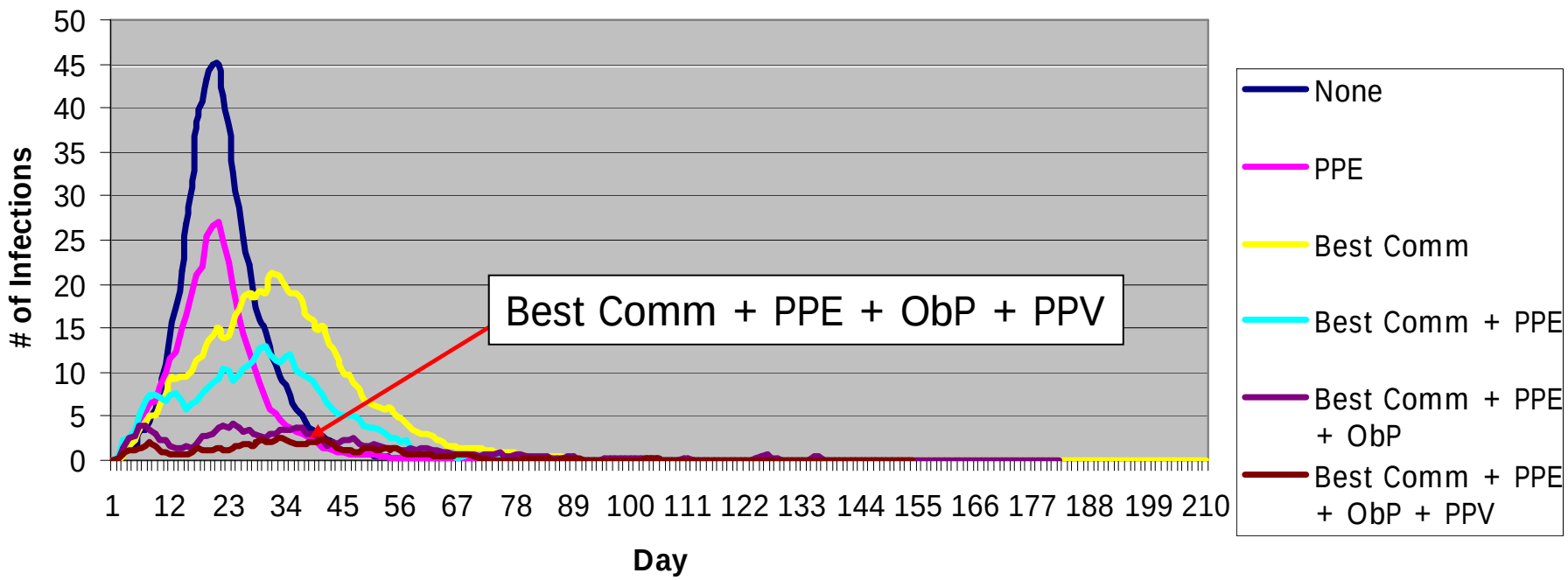
Results—Healthcare Worker Infections



Best Community Strategies

- S = school closing
- CTsd = child/teen social distancing
- ASsd = adult/senior social distancing
- T = treatment
- P = prophylaxis of householders

Healthcare-Based Strategies

- PPE = protective equipment for HCW
- ObP = outbreak duration antivirals for HCW
- PPV = vaccine for HCW

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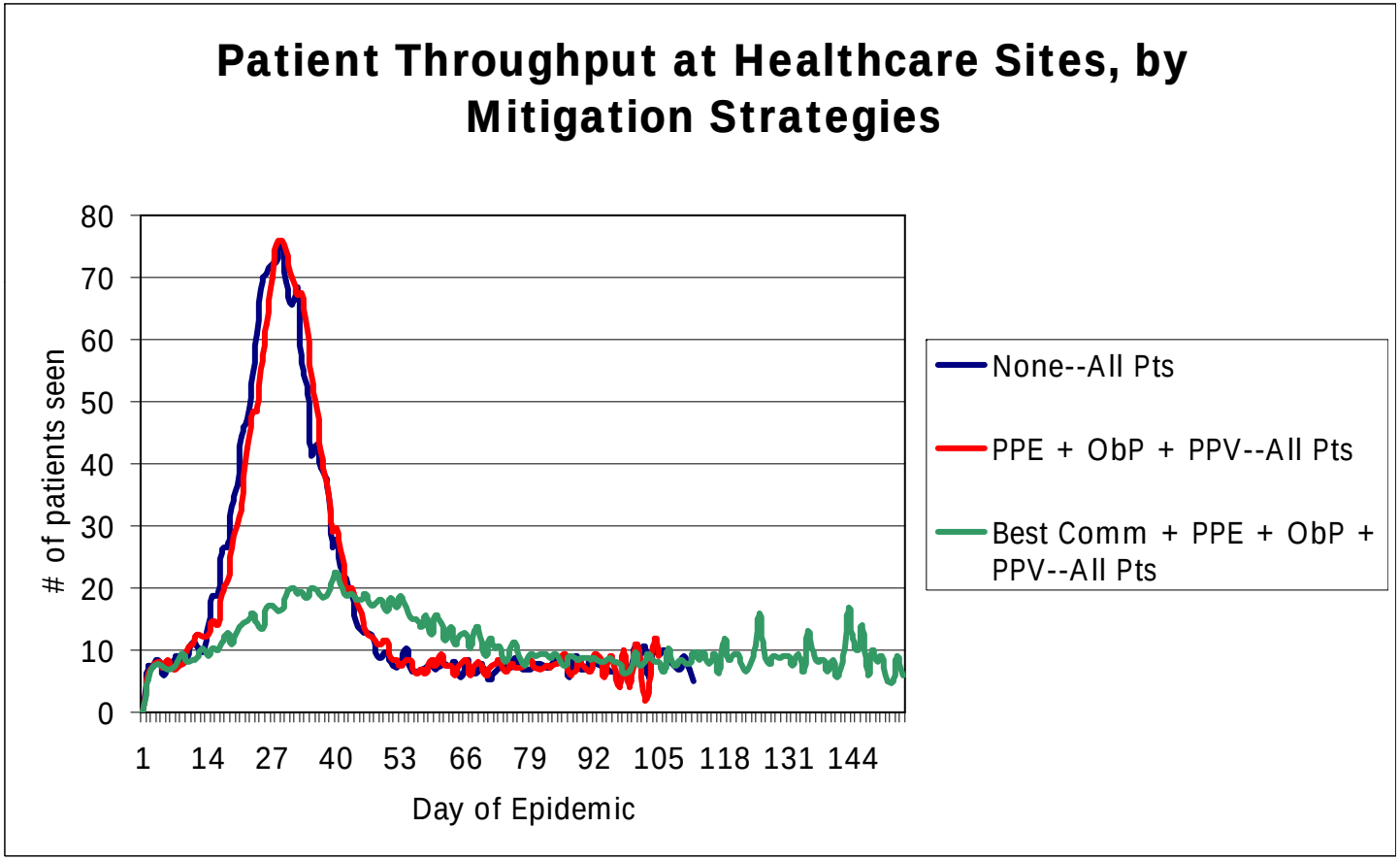
Results—Effects on Healthcare Delivery



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Summary Points & Policy Implications

- The presence of healthcare settings in the community acted as an epidemic accelerant, leading to an earlier epidemic peak and slight shorter epidemic duration.

  Policy Implication: Healthcare settings may be viewed as a source of initial infections and a potential pool to fuel an ongoing community outbreak.

http://images.google.com/imgres?imgurl=http://www.sleepwalking.org.uk/commuters

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Summary Points & Policy Implications

- As in our previous studies, the 'best' community mitigation strategy found was
  - school closing
  - child/teen social distancing
  - adult/senior social distancing
  - treatment of ill
  - prophylaxis of household members

- Adding healthcare measures of
  - personal protective equipment
  - outbreak prophylaxis
  - vaccine

- decreased community cases by an additional 5%.

Policy Implications: The economic and societal burdens of stringent community strategies must be weighed against public health outcomes (Perlroth et al. 2009). Healthcare measures add a small effect in limiting transmission to the community and community effects.

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Summary Points & Policy Implications

- Healthcare worker infections were minimal when PPE and either outbreak prophylaxis or vaccinations were used with the 'best' community mitigation.
- However, with no community mitigation measures in place, wearing PPE reduced HCW infections by 50%

Policy Implications: Even when community mitigation measures are not used (as with current H1N1 pandemic), PPE may reduce HCW illness significantly. Studies on efficacy of PPE are needed.

http://images.google.com/imgres?imgurl=http://www.sleepwalking.org.uk/commuters

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Summary Points & Policy Implications

- Patient throughput at health care sites did not differ with addition of healthcare-based measures
  - Healthcare worker infections represent a only small proportion of total infections
- Patient throughput decreased significantly with 'best' and all healthcare measures in place
  - Community members were protected from illness
  - Health care workers were protected and able to continue to work

Policy implication: prevention of community influenza illness burden and HCW protection contribute to functioning healthcare system

VA Photo: North Da[illegible] VAMC F[illegible] Shot Clinic, 2006

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Further analyses:

- Further examine transmission within healthcare settings
- Compare efficacy by pandemic severity
- Evaluate effects of lower compliance

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