Knowledge Gaps amenable to traditional epidemiologic approaches

Knowledge Gaps NOT amenable to traditional epidemiologic approaches

Traditional epidemiologic research/surveillance

Modeling approach

Epidemiologic Data

Informed estimates
- Burden
- Economics
- Intervention strategy
- Surveillance Strategy

Action
Mathematical Modeling of Healthcare Associated Infections and Multidrug Resistant Organisms

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What is Mathematical Modeling?

- Development of a virtual representation of a real-world system
- Simulation of infectious disease transmission that allows for herd immunity effect
  - Calibrated with historic data
- Goal is to improve scientific understanding and to inform decision making
  - Simplification of a real-world system
  - Assumptions utilized are explicit
  - Systematically conduct experiments
Can mathematical modeling complement traditional epidemiologic studies?

Does addressing this problem lend itself well to a traditional study?

- Is conducting the proposed study ethical?
- How long should the study run to record an intervention's full impact?
- Is an appropriately designed study economically feasible?
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Synergies between mathematical modeling and traditional epidemiology

- Models informing epidemiologic studies
  - Refining study design
  - Guiding sample size estimation
  - Quantifying indirect effects of interventions
  - Exploring “what if” scenarios for future prevention
- Epidemiologic studies informing models
  - Refining model structure and parameterization
- May aid in the understanding of conflicting findings
Mathematical Modeling Studies Used in Development of National and Multinational Guidance

<table>
<thead>
<tr>
<th></th>
<th>First known use of modeling (year)</th>
<th>Number of pathogens modeled</th>
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<tr>
<td>HICPAC</td>
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<td>2</td>
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<td>ACIP</td>
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<td>3</td>
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<td>WHO SAGE</td>
<td>2008</td>
<td>11</td>
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<td>UK Dept Health</td>
<td>2005</td>
<td>8</td>
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- The data for this table were based on a convenience sample. Therefore, the “Number of pathogens modeled” represents a lower bound and the “First known use of modeling” is an upper bound.
- HICPAC: Healthcare Infection Control Practices Advisory Committee
- ACIP: Advisory Committee on Immunization Practices
- WHO SAGE: World Health Organization Strategic Advisory Group of Experts (SAGE) on Immunization
- UK Dept Health: Data were combined for a) National Institute for Health and Clinical Excellence (NICE), b) Joint Committee on Vaccination and Immunisation (JCVI), and c) Advisory committee on Antimicrobial Resistance and Healthcare Associated Infection (ARHAI).
Intramural Mathematical Modeling Activities in the Division of Healthcare Quality Promotion

- Newly created mathematical modeling unit in the Epidemiology Research and Innovations Branch
- Comprised of 4 doctoral scientists
- Support projects throughout the Division of Healthcare Quality Promotion
  - Understanding transmission of key healthcare-associated infections
  - Improving the design and interpretation of epidemiologic studies
    - Investigating validity and power of alternative epidemiologic studies to improve the evidence base
  - Supporting outbreak investigations
Intramural Modeling Unit Presentations at Recent Scientific Meetings

- Role of asymptomatic *Clostridium difficile* carriers in intra-hospital transmission and healthcare-associated *Clostridium difficile* infection: a transmission modeling analysis (O’Hagan IDWeek 2016)
  - Both carrier isolation and antibiotic stewardship could have been important in the success of the carrier screening intervention at reducing CDI

- Association Between Healthcare Facility Connectedness and the Incidence of *Clostridium difficile* Infections, Washington and Oregon (Slayton IDWeek 2016)
  - Connectedness to other healthcare facilities was independently associated with facility-level CDI incidence
Intramural Modeling Unit Presentations at Recent Scientific Meetings

- Using Patient Transfer and Length of Stay Data to Target Regional Carbapenem-resistant Enterobacteriaceae (CRE) Prevention Effort (Paul SHEA Spring Meeting 2016)
  - Hospitals with longer length of stay and that are more connected by patient transfer played a disproportionate role in the spread of CRE in a regional network

  - Highly connected hospitals might provide a target group for coordinated public health interventions to reduce MDROs regionally
Intramural Modeling Unit Presentations at Recent Scientific Meetings

- Bias in Studies of Antimicrobial Resistant Healthcare-Associated Infection (HAI) Interventions Due to Trends in Length of Stay and Patient Census (O’Hagan IDWeek 2017)
  - National trends in lengths of hospital stay and patient census can differentially affect resistant vs sensitive strains; important for understanding changes in resistance rates over time

- Projected Burden of Complex Surgical Site Infections (SSI) following Total Hip Arthroplasty (THA) and Total Knee Arthroplasty (TKA) among Adults in the United States, 2020 through 2030 (Wolford IDWeek 2017)
  - Without improved prevention measures, complex SSI burden for primary and revision THA and TKA would increase
Intramural Use of Social Network Analysis to Support Outbreak Investigations

- Social network analysis may help identify healthcare facilities that are closely connected to facilities with known cases
  - Using historic data, describe regional patient movement from Medicare fee-for-service beneficiary claims
- Has the potential to identify targets for admission screening and/or point prevalence surveys
  - Downstream facilities which may be at increased risk of importation
  - Upstream facilities where previous undetected transmission events may have occurred
Extramural Modeling Activities

- Supporting the development of regional prevention collaboratives
  - 2015 Vital Signs
  - SHIELD-OC
  - Chicago PROTECT
- Modeling Study: Impact of Delays between Clinical and Laboratory Standards Institute and Food and Drug Administration Revisions of Interpretive Criteria for Carbapenem-Resistant Enterobacteriaceae
- Modeling INfectious Diseases in Healthcare (MIND-Healthcare)
Extramural collaboration: 2015 Vital Signs

- Worked with extramural partners to develop two independent mathematical models
- Estimated the effects of preventing carbapenem-resistant *Enterobacteriaceae* (CRE)
  - Compared a coordinated augmented approach to independent augmented efforts
Projected countywide prevalence of carbapenem-resistant *Enterobacteriaceae* (CRE) in Orange County, CA
Extramural Project: Modeling the Impact of Changes to Interpretative Criteria for CRE

- Found that delays (from 1 to 5 years) resulted in 264 to 8,498 additional CRE carriers countywide
- Timely publication of these findings supported strategic policy initiatives:
  - Provided quantitative evidence to support the 21st Century Cures Act
  - The Pew Charitable Trusts, Infectious Disease Society of America, BD, and American Society for Microbiology co-signed a letter citing these findings
  - Strengthened CDC/FDA partnership
Extramural Project: Supporting the Development of Prevention Collaborations Currently Underway

- CDC demonstration projects assessing the regional benefit from a targeted approach
- Use social network analysis and mathematical modeling to guide the design of regional prevention collaboratives for MDROs
  - SHIELD-OC (Shared Healthcare Intervention to Eliminate Life-threatening Dissemination of MDROs in Orange County)
  - Chicago PROTECT (Providing Regional Organizations with TEchniques to ConTrol MDROs)
Extramural Research Network: Modeling INfectious Diseases in Healthcare (MIND-Healthcare)

- Improve the ability to prepare for, detect, control, and prevent the growing problem of antimicrobial resistant HAI pathogens in the United States
- Create a network of multidisciplinary scientists
- Conduct applied computational, statistical, and mathematical research
- Five grantees will be funded for a 3-year research project period
MIND-Healthcare Thematic Research Areas

- Antimicrobial Resistance
- Connectedness of Patients Within and Across Healthcare Facilities
- Economic Modeling
- Genomics
- Outbreak Response
- Simulations of Epidemiologic Studies
- Surveillance
- Systems Approaches
- Zoonotics
Summary

- Evidence generated through mathematical modeling complements evidence generated through traditional trials.
- Transmission modeling has been used by national and international advisory bodies making public health policy decisions.
- DHQP is investing in intramural and extramural mathematical modeling activities.
- DHQP is developing a framework for appraising transmission modeling studies and critically interpreting their results.
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