STD Control: Introduction to Mathematical Models and STDs

Jonathan M. Zenilman, MD
Johns Hopkins University
Section A

Mathematical Models and STDs
Mathematical Models and STDs

- Allows the development of interventions
- Models can be used to predict intervention impact effects (if they are accurate)
Mathematical Models: Types

- Deterministic models—attempts to control all variables and arrive at an exact solution
  - Intuitive, but mathematically impossible because of multiple variables
Stochastic Models

- Approximate a population and arrive at a statistical solution
- Populations can be varied in terms of risk, connectivity, and susceptibility
- Large population groups are modeled (for many iterations)
- Interventions can be modeled (imposed on the population)
Reproductive Rate Equation

\[ R_o = \beta \ c \ D \]

- Reproductive rate
- Probability of transmission
- Number of sexual contacts
- Duration of infectiousness

Source: Anderson and May (1992)
Section B

The Core Transmitter
The “core transmitter” is a key component of intervention and control. Targeting core transmitters for prevention and treatment services. Changing social norms:
- Safer sexual behaviors
- Condom use
- Altering substance use/sex equation
Additional Risk Factors

- Relationships between social and sexual networks
- Structure of sexual networks
  - Concurrency
  - Serial sexual partners
  - Mixing patterns
- Core group and core transmitters
- Frequency and type of substance use/abuse
Why Are Core Groups Necessary

- Transmission efficiency for STIs is never 100%
- In a simple linear partner chain, therefore the disease would “burn out”
  - If \( B = 0.7 \) for gonorrhea, the probability of the fifth partner in a linear transmission chain being infected is \( 0.7^5 = 0.117 \) (117%)
- Therefore, a density function is required
Section C

Groups and Mixing Patterns
Core Neighborhoods and Core Transmitters

- **Core neighborhoods**—geographic units with high prevalence of STDs
- **Core transmitters**—individuals in core neighborhoods who engage in “risky” social behaviors and experience a large proportion of diagnosed STDs
Core Groups and Transmission Dynamics

- Core groups are critical to maintaining high rates of gonorrhea in community-based models of STD transmission
  - Cores are characterized by high transmission density
Link Between Neighborhood Characteristics and STDs

- Studies have consistently found higher rates of STDs in neighborhoods with the following characteristics:
  - Poverty
  - Social disadvantage
  - Segregation (Thomas, 1995)
  - Drug abuse

- Few studies have linked community level characteristics to individuals
The Unique Aspect of STD-Partner Effects

- Without partners, there is no STD
- STD prevalences are different in different populations
- Therefore, “types” of partners may have an enormous impact on STD risk
Sexual Mixing

- The extent of sexual contact within and among definable segments of the population
- Segments of the population can be defined by factors such as
  - Age, race/ethnicity, sex
  - Geography
  - Drug-use patterns
Partner Mixing Patterns

- **“Assortative” mixing** (or “like with like”)
  - In other words, partners are recruited from a population whose STD risk is demographically similar to one’s own
  - For example, the next-door neighbor is a good approximation of assortative mixing!

- **“Dissortative” mixing**—recruitment of partners from different groups
  - For example, contact with commercial sex workers, or with persons from different ethnic groups

- **“Mixed”**—many people have assortative and dissortative mixing patterns
Mixing Pattern

Assortative  Random  Disassortative

Source: Boily, STD, 2000: 27(10);560-71
Section D

Qualitative Aspects of Partners
Laumann, 1998

- Higher STDs in African Americans is partly due to patterns of sexual networks
- STDs remain endemic because partner selections are more assortative by race/ethnicity
- Partner selection among African-Americans is more disassortative, by demographic characteristics, than in other groups
Sex Partner Selection and Mixing Patterns

- Aral, 1996
  - STD morbidity concentrations create potential partner pools of high risk and high STDs
  - These geographic and social contexts create a higher probability of exposure to infection for each sex act
Public Health Strategies: Core Transmitters

Core Group

People who have sex with both groups

General Population
Serial vs. Parallel Transmission

- Think about the density function
- What circumstances do these scenarios “play out”
Figure 3. Kløvdahl AS. Social network research and human subjects protection: Towards more effective infectious disease control. Social Networks. Volume 27, Issue 2, May 2005, Pages 119-137. Copyright © 2005 Elsevier B.V. All rights reserved.
Chain Link Design: Urban Network Study (Atlanta, GA, 1995-1999)

- Chain-link study design for Atlanta Urban Networks Project, 1995-1999.
- Recruited six `chains' of persons,
  - random selection of the next interviewee
  or
  - nomination by the previous interviewee
- These six chains provided information on personal behavior and network association.
Phases of STD Epidemics

- **Growth**
- **Hyperendemic**
- **Decline**
- **Endemic**

Source: Adapted from Wasserheit and Aral (1996), *JID*
Sexual Contacts among Homosexual Men with AIDS

Source: Klovdahl, Alden S.; Data from Centers for Disease Control study
Network Approach

- Find, evaluate, and treat both sex and social partners
  - Inquire about index’s social network
  - Rely on other sources of information besides interviews (e.g., community residents)
  - Include places of social significance
Social Factors that Affect Mixing and Partner Selection

- Age differences
- Sexual marketplace
- Economics
- Travel and migration
- War and conflict
- Social norms—sexuality
Summary

- Networks are the construct which integrate “core” transmitters into STD epidemiology
- Dense networks are required to maintain STD endemicity, since the random infection transmission efficiency is <100%
- “Core” network members—individuals with high “centrality” are key to population-based control, but this has never been widely actualized
Section E

Theoretical Aspects of STD Control
Objective

- Think about control strategy from the standpoint of the reproductive rate equation
- Think about control strategy as a synergistic process
- Use these constructs to help determine and make a clinical judgment which intervention is effective and cost-beneficial
R = Bcd: Partner Exposures—Interventions

- Behavioral risk reduction ("c" term)
  - Abstention
  - Reducing number of partners
  - Reducing number of exposures?
  - Increasing age of sexual debut

- Partner selection—multifactorial term
  - E.g., high-risk vs. low-risk partners!
  - Limitation = qualitative aspects
R = Bcd: Duration of Infection—Interventions

- Reduction of d = reduction of asymptomatic pool
- Disease screening programs
- Partner notification and presumptive treatment
- Increased health care access
- Treatment guidelines
STD Screening Programs

- Syphilis $
- Gonorrhea $$
- Chlamydia $$$
- HIV$$
Setting up STD Screening

- Identifying appropriate populations
- Laboratory quality assurance
- Transport, logistical, and supply issues
- Costs and cost allocation
- Development of new technology
- Notification of results
STD Screening

Clinic

Results

Lab

Specimens
Major Issues in Screening Programs

- Poor logistics
- Follow-up issues
- Inappropriate populations
- Insurance/legislative problems
Section F

Partner Notification
D: Partner Notification

- No controlled studies performed
- Probably useful for diseases with long incubation period (syphilis, chlamydia)
- Used for HIV
- Not useful in most settings for diseases with short incubation periods
- Sexual network vs. social network issues
Partner Notification—Efficacy

- Impacts “d”
- Studies in HIV and STD settings demonstrate that provider referral usually increases yield
- Partner notification is an expensive intervention and requires intensive supervision and personnel resources
- Cost-effectiveness data is inconclusive
Partner Notification—Methods

- Patient referral (usually with referral card)
- Provider referral (interview patient for sex partners with field follow-up)
- Conditional referral
# CDC Report Form

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First (&amp; Nicknames)</th>
<th>Address (Street)</th>
<th>(Apt. #)</th>
<th>Home Phone</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>City</th>
<th>State</th>
<th>Zip</th>
<th>Age/D.O.B.</th>
<th>Race</th>
<th>Ethnicity</th>
<th>Sex</th>
<th>Marital Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Height</th>
<th>Size/Build</th>
<th>Hair</th>
<th>Complexion</th>
<th>Pregnancy Status</th>
<th>Place of Employment/Hours/Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Original Patient ID. Number</th>
<th>Other Identifying, Locating, or Medical Information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Referral Basis:
- Partner
- Cluster
- Positive Lab Test
- OOI/ICCR

### Examination

<table>
<thead>
<tr>
<th>Date</th>
<th>Test</th>
<th>Result</th>
<th>Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Treatment

<table>
<thead>
<tr>
<th>Date</th>
<th>Drug</th>
<th>Dosage</th>
<th>Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Interviewer

<table>
<thead>
<tr>
<th>Date Initiated</th>
<th>New Case #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Type
- Interview:
- Referral:

---

**Field Record**

U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention (CDC)

Note: See the reverse side of page one of this record for the codes and the reverse side of pages two and three for an abbreviated set of instructions. See the full set of Field Record instructions for further definition.
Parran’s Model

- Interview the infected person
- Identify their sex partners
- Find, evaluate, and treat sex partners
Prevention Therapy

- Presumptive treatment of sexual contacts
- Syndromic management
- Intentional over-treatment in most settings
- Impact on resistance-minimal—especially when single dose regimens are used
- Major issue—identification of contacts
Partner Therapy and Viral STDs

- Not generally indicated
- PEP for HIV—used in practice, efficacy unknown
Prevention and Partner Therapy

- Challenge to partner management is access
  - New approaches
    - Pharmacy delivered
    - Partner delivered
    - What do you think would be the challenges to these methods of partner management?
    - (See *New Engl J Med* Feb 17, 2005)
Section G

Transmission Efficiency
Transmission Efficiency of STDs

- STD B not 100%
- 30-70% per GC/CT exposure
- ~20-30% syphilis
- HIV: 1/100-1/10,000 depending on type of exposure
Impact of B Reduction

- Reducing transmission efficiency should have a direct effect on individual risk
- Example—consistent condom use reduces HIV transmission by more than 98% in dichotomous couples
- Population impact on STD transmission
  - Modeling studies suggest that modest reductions in B have a greater impact
Condom use and barrier methods
Microbicides
Hormonal contraceptives (?)
Circumcision
Antiviral therapy

“Doc, now that my viral load is zero, do I still have to use a condom . . . Can I get a prescription for Viagra?”
Microbicides

- Female controlled methods
- New compounds being developed, especially non-ionic, antibody approaches
- Most focus on HIV; little work on STDs
- Ascertainment issues
Microbicides: Desirable Characteristics

- Efficacy
- Texture
- Chemical interactions—pH
- Taste and smell
- “Stealth”
- Non-toxic to sperm
Vaccines

- HPV vaccine-preventive
- Hepatitis B
- SKGlaxo herpes vaccine–effective for women, not men
  - Continued clinical trials
- GC and chlamydia–little activity
- HIV vaccines
Condom Use

- Condom efficacy demonstrated for HIV, GC, herpes
- Biologically plausible
- Population impact—Thailand, Uganda
How Do You Assess Condom Efficacy?

In this course we will address these issues:

- Condom technical skills
- Behavioral assessments
- Biological markers
- The regulatory issues—condoms are a medical device regulated by FDA
- The politics of condoms
Condom Use Patterns

- Condom use often measured as consistent use
- Use patterns often include use with higher-risk partners and a potential for paradoxical effects
- Appropriate use requires training (technical efficacy) and negotiation skills
Antiviral Therapy

- Suppressive treatment of persons with herpes reduces transmission for individuals in dichotomous relationships
- Supposition that HIV treatment would do the same
- Impact of STD and HIV interaction
Sexual Transmission of HIV

- HIV pattern is that viral load is highest during seroconversion
- Early seroconverters are HIV-negative
- Is sexual transmission during HIV seroconversion the greatest public health risk?