Urbanization and the Epidemiology of Infectious Diseases

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Objectives

- Explore the impact of urbanization on the epidemiology of infectious diseases
- Understand some simple and complex interactions between urbanization and patterns of infectious disease transmission
- Examine research methods to study the impact of urbanization on infectious diseases
Section A

Introduction
What does this photograph tell you about the risk of infectious diseases in Harare, Zimbabwe?
Addis Ababa, Ethiopia

What does this photograph tell you about the risk of infectious diseases in Addis Ababa, Ethiopia?

Photo by William Moss
“Almost all studies that attempt to reconstruct the history of infectious diseases indicate that the burden of infection has tended to increase rather than decrease as human beings adopted civilized lifestyles.”

— Mark Cohen, *Health and the Rise of Civilizations*
Urban Squalor—Victorian London
Improved Sanitation in Urban London
What Is Urbanization?

- Urbanization is ...
  - Population density
  - Land use patterns
  - Housing materials and construction
  - Economic differentiation
  - Sanitation and water supplies
  - Access to services
  - Transportation
  - ...

Urbanization and Infectious Diseases

- How does urbanization impact the epidemiology of infectious diseases?
Urbanization and Infectious Diseases

- Sanitation and access to clean water
- Increased population density
- Changes in human contact patterns
- Changes in vector breeding sites
- Access to health services
Transmission of Infectious Diseases

- Direct transmission
  - Fecal-oral
  - Respiratory
  - Sexual contact
  - Blood-borne

- Indirect transmission
  - Vector-borne

- Zoonoses
Section B

How Does Urbanization Affect Fecal-Oral Transmission?
Fecal-Oral Transmission

- Cholera
### Urbanization and Cholera in Mexico

<table>
<thead>
<tr>
<th>Stratum (urbanization %)</th>
<th>Cholera cases</th>
<th>Population</th>
<th>Rate (per 100,000)</th>
<th>Rate ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Very low (19.9–38)</td>
<td>14,816</td>
<td>15,103,046</td>
<td>98.1</td>
<td>4.01 (3.9–4.12)</td>
</tr>
<tr>
<td>II. Low (40–51)</td>
<td>13,867</td>
<td>21,045,578</td>
<td>65.89</td>
<td>2.69 (2.62–2.77)</td>
</tr>
<tr>
<td>III. Medium (53.7–67.4)</td>
<td>7,455</td>
<td>14,906,438</td>
<td>50.01</td>
<td>2.04 (1.98–2.11)</td>
</tr>
<tr>
<td>IV. High (68.4–98.3)</td>
<td>7,388</td>
<td>30,194,583</td>
<td>24.47</td>
<td>Reference</td>
</tr>
</tbody>
</table>

\( \chi^2 \) for linear trend = 10,843.6 \( (P = 0.000001) \)

- Urbanization: proportion of state population residing in settlements of >15,000 persons in 1990
- Four-fold higher rate ratio in *least urban* stratum compared to highest urban stratum
Fecal-Oral Transmission

- Polio virus
Poliomyelitis in the United States

Epidemiological Patterns

- **Endemic**
  - Disease of infancy
  - Asymptomatic or subclinical infection
  - Partial protection by maternal antibodies
  - All children immune by 4 years of age

- **Epidemic**
  - Improved hygiene and sanitation
  - Primary infection later in childhood
  - Increased risk of paralysis

- **Post-vaccination**
Section C

How Does Urbanization Affect Respiratory Transmission?
Respiratory Transmission

- Measles virus
Population Size and Measles Virus Transmission

- Measles virus is one of the most highly infectious agents known.
- When the virus is introduced, it infects almost entire population
- In small populations, transmission patterns feature waves of infection interrupted by fade-out periods.
- In larger populations, new susceptibles continuously enter population to maintain transmission. Continued transmission between wave peaks, maintaining an endemic state.
- See Barlett’s findings on city size and epidemic recurrence
Age Distribution of Measles Cases

Mean Age of Attack in Months by Urban and Rural Areas

Reported Cases by Settlement Type

Adapted by CTLT from Sydenstricker and Collins (1931, Fig. 1, p. 103) and Collins (1929).
Respiratory Transmission

- SARS coronavirus
Chain of Transmission among Hotel Guests

FIGURE 1. Chain of transmission among guests at Hotel M — Hong Kong, 2003

- 4 HCWs
- 156 close contacts of HCWs and patients
- 3 HCWs
- 99 HCWs (includes 17 medical students)
- 0 HCWs
- 28 HCWs
- 4 other Hong Kong Hospitals
- 2 close contacts
- 3 family members
- 10 HCWs
- 2 family members
- 3 family members
- 4 family members
- 2 family members
- 2 family members
- 37 HCWs
- Unknown number close contacts
- 37 close contacts
- 34 HCWs
- HCW
- HCW

*Health-care workers.
*All guests except G and K stayed on the 9th floor of the hotel. Guest G stayed on the 14th floor, and Guest K stayed on the 11th floor.
*Guests L and M (spouses) were not at Hotel M during the same time as index Guest A but were at the hotel during the same times as Guests G, H, and I, who were ill during this period.
Chain of Transmission among Hotel Guests
Chain of Transmission among Hotel Guests

"Geography of SARS" from Epidemiology of Infectious Diseases. Available at: http://ocw.jhsph.edu. Copyright © Johns Hopkins Bloomberg School of Public Health. Creative Commons BY-NC-SA.

See Figure 3.
Urbanization and Sexually Transmitted Infections

- How does urbanization affect the epidemiology of sexually transmitted diseases?
Sexual Transmission

- Human immunodeficiency virus
Demographic Changes in Africa

- Urbanization ≠ industrialization
- Massive rural-urban migration following independence in the 1960s
- Migration of young adult males
- Changes in social networks
- Changes in sexual behavior
The proportion of the total population living in urban areas increased in all portions of sub-Saharan Africa from 1965 to 2000.

Source: Quinn TC. Population migration and the spread of types 1 and 2 human immunodeficiency viruses. *Proc Natl Acad Sci USA* 1994;91:2407-2414. See Figure 2.
Urbanization and the Spread of HIV

- The Quinn paper identifies urbanization as the second among a list of 7 factors associated with HIV dissemination in Africa.

- “Migration of poor, sexually active young people from rural regions to cities in search of employment.”

Urban Population Pyramid

Female

Male

HIV infected
Non-infected

HIV infected
Non-infected

Age

75+
70-74
65-69
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5-9
0-4

Percent distribution

Early HIV Epidemic: High Rates in Urban Populations

HIV-1 Seroprevalence by Age in Urban and Rural Samples in Rwanda and Zaire

Section D

How Does Urbanization Affect the Epidemiology of Blood-borne Diseases?
Blood-borne Transmission

- Chagas’ disease
Epidemiology

- Zoonosis (sylvatic cycle)
  - Isolated from >150 animal species
  - Wild and domestic
  - Ingestion of infected triatomine insects

- Human infection (domestic cycle)
  - Poor persons in rural areas
  - Farming and land clearing
  - Vector adaptation to human dwellings
  - Vectors reside in cracks/holes in mud, wood, stone
Blood Transfusions

- Accounts for 10% of cases
- Exacerbated by rural-urban migration
- Infectivity risk: 20%
- Critical need for blood screening
- Problem faced by developed countries with migration from endemic areas
Urbanization and Vector-borne Transmission

- How does urbanization affect vector-borne transmission?
Vector-borne Transmission

- Malaria
Malaria Transmission in Urban Sub-Saharan Africa

Urban Malaria

- Meta-analysis
  - Studies of malaria transmission in sub-Saharan Africa

- Entomologic inoculation rate (EIR)
  - Measure of transmission intensity
  - Human biting rate $\times$ sporozoite index
  - Number of infective bites per person per year
Annual Entomologic Inoculation Rate


- Average EIR
  - Urban = 7.1
  - Periurban = 45.8
  - Rural = 167.7
What Accounts for These Differences?

- Pollution
  - Affects larval habitats and life cycle

- Avoidance of mosquitoes
  - Screens, doors, bed nets, insecticides

- Increased population density
  - Reduced biting rates

- ... but adaptation of *Anopheles gambiae* to urban breeding sites
Malaria Transmission in Urban Africa


- Major factors affecting malaria transmissions
  - Human Ecological and Environmental Factors
    - Land use and demography
    - Municipal initiatives
    - Individual and household factors
  - Climatic and Topographical Factors
    - Larval Habitat
    - Adult Habitat
    - Vector
Zoonoses

- Yellow fever virus
How does urbanization affect zoonotic transmission?
Urban Yellow Fever Epidemics—19th-Century U.S.

- A yellow flag ("yellow jack") was raised in U.S. cities to warn visitors to stay away during yellow fever epidemics

New York newspaper, 1878
Urban Yellow Fever

- No urban yellow fever in Americas since 1954

- Jungle yellow fever among forest dwellers
  - Sylvatic yellow fever
  - *Haemogogus* vectors

- *Aedes aegypti* in South America
  - Reinvasion in the 1970s
  - Found in cities near sylvatic transmission
Urban Yellow Fever

- January 1998: yellow fever in urban resident

- Active surveillance
  - 51 suspected cases
  - 16 IgM antibodies against yellow fever virus
  - 11 from areas with sylvatic transmission

- Six cases of urban yellow fever
Six Cases of Urban Yellow Fever

Epidemiological findings in six confirmed yellow fever cases resident in Santa Cruz de la Sierra

<table>
<thead>
<tr>
<th>Case</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neighborhood of residence</td>
<td>183</td>
<td>160</td>
<td>160</td>
<td>128</td>
<td>183</td>
<td>30</td>
</tr>
<tr>
<td>Outcome</td>
<td>Survived</td>
<td>Died</td>
<td>Died</td>
<td>Died</td>
<td>Died</td>
<td>Died</td>
</tr>
<tr>
<td>Age (years)</td>
<td>10</td>
<td>4</td>
<td>26</td>
<td>23</td>
<td>22</td>
<td>58</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Ever vaccinated against yellow fever</td>
<td>No</td>
<td>Reportedly</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Reportedly</td>
</tr>
<tr>
<td>Left the city†</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Classification of area visited</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

A = sylvatic yellow fever ever reported in last 20 years; B = sylvatic transmission deemed possible because of entomological and ecological characteristics; C = sylvatic transmission deemed impossible; *First (possibly atypical) symptoms: fever, malaise, headache, nausea, myalgia; †During 10 days before onset of first symptoms
Investigators mapped the cases to look for clustering of cases.
Urban Yellow Fever

- Potential for large urban outbreak of yellow fever
  - Vector present in city
  - Low population immunity
  - Frequent travel to endemic areas

- Yellow fever vaccination
  - Include in EPI schedule
  - Catch-up mass campaign of urban residents
Urbanization and Co-infections

- How does urbanization affect co-infections?
Spatial clustering of measles and HIV-1

Chart prepared by William Moss.
Clustering of Measles Cases in HIV-1-Infected Children

- Clustering of measles cases in HIV-1-infected children during an inter-epidemic period
  - Study period: 1998 to 2001
  - Total measles cases: 848
  - HIV-1-infected children with measles: 130
  - Number of townships: 68
- SaTScan analysis
  - Significant clustering of measles cases among HIV-1-infected children (P = 0.02)
  - May to November 1999
HIV-1-Infected Children Hospitalized with Measles

Cluster of HIV-1-infected children hospitalized with measles

Chart prepared by William Moss.
In Contrast ...

Chart prepared by William Moss.
Urbanization and Access to Health Services

- How does urbanization affect access to health services?
Urbanization and Health

- Percentage of population with access to services, 1987-1990

## Urbanization and Infectious Diseases

<table>
<thead>
<tr>
<th>Effect of urbanization</th>
<th>Transmission pattern</th>
<th>Example</th>
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<tbody>
<tr>
<td>Water and sanitation</td>
<td>Fecal-oral</td>
<td>Cholera</td>
</tr>
<tr>
<td>Population density</td>
<td></td>
<td>Cholera</td>
</tr>
<tr>
<td>Age of infection</td>
<td></td>
<td>Poliovirus</td>
</tr>
<tr>
<td>Disease</td>
<td></td>
<td>Poliovirus</td>
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<td>Endemicity</td>
<td>Respiratory</td>
<td>Measles</td>
</tr>
<tr>
<td>Age of infection</td>
<td></td>
<td>Measles</td>
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<tr>
<td>Global spread</td>
<td></td>
<td>SARS</td>
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<td>Migration/employment</td>
<td>Sexual</td>
<td>HIV</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
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<td>Sexual networks</td>
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<td>Vector habitat</td>
<td>Vector-borne</td>
<td>Malaria</td>
</tr>
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<td>Effect of urbanization</td>
<td>Transmission pattern</td>
<td>Example</td>
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<tr>
<td>--------------------------------</td>
<td>----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Proximity to natural reservoirs</td>
<td>Zoonotic</td>
<td>Yellow fever</td>
</tr>
<tr>
<td>Effect of urbanization</td>
<td>Transmission pattern</td>
<td>Example</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Clustering of cases</td>
<td>Co-infection</td>
<td>Measles/HIV</td>
</tr>
</tbody>
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