Foundations of Global Health

Communicable Diseases (Part 1): Control & Smallpox Eradication

Nature, that lovely lady to whom we owe polio, leprosy, smallpox, syphilis, tuberculosis, cancer... ~Dr. Stanley Cohen

Importance of Communicable Diseases

• Over 13 million people die each year from infectious and parasitic diseases
• Immensely important to the global burden of disease
  – Most important burden of disease in Sub-Saharan Africa
• Poor people, women, children, and the elderly are the most vulnerable
• Enormous economic consequences
• Much of burden unnecessary
• Relevance to MDGs

Communicable Disease Definitions

Case—An individual with a particular disease.
Case Fatality Rate—The proportion of persons with a particular condition (cases) who die from that condition.
Control (Disease Control)—Reducing the incidence and prevalence of a disease to an acceptable level.
Eradication (of Disease)—Termination of all cases of a disease and its transmission and the complete elimination of the disease-causing agent.
Palliative Care—End of life care.
Parasite—An organism that lives in or on another organism and takes it nourishment from that organism.

Disease Triangle

• Need host, pathogen & environment to produce disease
• Multiple external factors can influence this cycle
  – Reservoir
  – Vectors
  – Abiotic conditions
  – Culture & behavior

Chain of Infection

• Model to visualize transmission of a communicable disease from its source (reservoir) to a susceptible host

Learning Objectives

• Identify components of the disease triangle and links in the chain of transmission
• Define prevention, control, elimination, eradication and extinction for infectious diseases
• Identify eradication indicators
• Outline successful interventions against communicable diseases (smallpox)
• Define the International Health Regulations
• Identify Nationally Notifiable Diseases
Pathogen

- Disease causing agent

Malaria  Smallpox  Polio  HIV (top) & Tuberculosis

Reservoir

- Habitat where infectious agent normally lives
  - Human: symptomatic or asymptomatic
  - Animal: zoonotic
  - Non-living (environmental): plants, soil, and water contribute to life cycle

Portal of Exit

- Path by which an agent leaves the reservoir or source host

Transmission

- How pathogens are passed
  - Direct
  - Direct contact
  - Droplet spread
  - Indirect
    - Airborne
    - Vehicleborne
    - Vectorborne

Portal of Entry

- Agent enters susceptible host

- Portals:
  - Respiratory
  - Oral
  - Skin
  - Intravenous
  - Gastrointestinal

New Host

- Final link is a susceptible host
Basic Reproductive Ratio ($R_0$)

- $R_0$ definition: expected number of secondary infections arising from a single individual during his or her entire infectious period, in a population of susceptibles

Herd Immunity

- Sustained transmission
  - Transmitting case
  - Susceptible
  - Transmitting case
  - Susceptible

Transmission terminated

- Transmitting case (A)
  - Immune (B)
  - Susceptible (C) (Indirectly Protected)

Herd Immunity Thresholds for Selected Vaccine-Preventable Diseases

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Diphtheria</td>
<td>6.7</td>
<td>85%*</td>
<td>83%*</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Measles</td>
<td>12.18</td>
<td>83-94%</td>
<td>92%</td>
<td>90%</td>
<td></td>
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<tr>
<td>Mumps</td>
<td>4.7</td>
<td>75-85%</td>
<td>92%</td>
<td>97%</td>
<td></td>
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<tr>
<td>Pertussis</td>
<td>12-17</td>
<td>82-94%</td>
<td>83%*</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Polio</td>
<td>5.7</td>
<td>80-85%</td>
<td>90%</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Rubella</td>
<td>6.7</td>
<td>85-88%</td>
<td>92%</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Smallpox</td>
<td>5.7</td>
<td>80-85%</td>
<td></td>
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</tbody>
</table>

*4-dose

Help—It’s Contagious!

- How do we stop these diseases that can “reproduce”?

Disease Prevention

- whole population
  - well population
  - primary prevention/promotion of well being
  - at risk
  - secondary prevention/early intervention
  - established disease/rehab/continuing care
  - tertiary prevention/disease management

Disease Control

- Reduction of disease incidence, prevalence, morbidity or mortality to a locally acceptable level as a result of deliberate efforts
- Need continued intervention measures to maintain control
**Elimination**

- **Reduction to zero** of the incidence (new cases) of disease or infection in a defined geographical area
- **Need continued surveillance and measures** to prevent re-establishment of transmission

**Eradication & Extinction**

- **Eradication**: permanent reduction to zero of **worldwide** incidence of disease or infection
  - Intervention measures no longer needed
  - Smallpox
- **Extinction**: infectious agent **no longer exists** in nature or in laboratory
  - NONE

<table>
<thead>
<tr>
<th>Control</th>
<th>Elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing infection, cases, deaths and illness due to a disease. &quot;Acceptable&quot; levels of disease may vary by region. Consistent, sustained prevention and treatment interventions are necessary to ensure ongoing reduction of illness.</td>
<td>Reducing the number of cases and new infections to zero. Efforts often focus on a defined geographical area in which the infectious agent is endemic. Continued intervention measures are required to ensure that the infectious agent does not re-emerge in a region that has experienced elimination.</td>
</tr>
<tr>
<td>Examples: diarrheal diseases, onchocerciasis (Africa), malaria, tuberculosis</td>
<td>Examples: tetanus, poliomyelitis, leprosy, lymphatic filariasis, measles, onchocerciasis in Americas</td>
</tr>
</tbody>
</table>

**Eradication**

- Permanent worldwide elimination of an infectious agent in nature - no new infections or cases of disease. The agent may exist in designated laboratories.
- After a period of years, intervention measures are no longer needed.
- Examples: Smallpox

**Extinction**

- The specific infectious agent no longer exists in nature or in the laboratory.
- Examples: None

Source: CDC

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**The 1st Smallpox Vaccination Jenner 1796**

Cowpox lesions on the hand of Sarah Nelmes (case XVI in Jenner's Inquiry), from which material was taken for the vaccination of James Phipps below in 1796

**Smallpox Endemic Areas 1945**

**Smallpox Endemic Areas 1967**
R & D Contributions

Bifurcated Needle
98%+ take
Freeze-Dried Smallpox Vaccine

Smallpox Eradication Strategy

1. Mass vaccination campaigns in each country, using vaccine of ensured potency that would reach ≥80% of population.
2. Development of a system to detect and contain cases and outbreaks.

† Henderson DA, Mass B, Smallpox and Vaccinia in Vaccines, 3rd edition, 1999

Mass Vaccination

Surveillance and Containment Strategy

• Search for cases
• Containment of spread by vaccinating primary contacts and their contacts
• Most efficient strategy

Progression of Smallpox
**Last Cases of Smallpox**

Rahima Banu – 10 October 1975
Variola Major, Bangladesh

Ali Maow Maalin – 26 October 1977
Variola Minor, Somalia

**Two laboratory acquired cases occurred in UK in 1978.**

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**Why Worry About Smallpox?**

- Allegations that Soviet BW program produced smallpox virus for use in bombs and ICBMs
- Concerns that smallpox virus could be obtained and used by others as terrorist weapon

**1980**

*smallpox is dead!*

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**The Faces of Smallpox**

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**Eradication: Principle Indicators**

- **Effective intervention** is available to interrupt transmission of the agent
- Practical **diagnostic tools** are available to detect levels of infection that can lead to transmission
- Humans are **essential** for life-cycle of agent
  - no other vertebrate reservoir
  - does not amplify in the environment
ITFDE

- Targeted six infectious diseases for eradication
  - mumps, polio, rubella, guinea worm disease, lymphatic filariasis, and cysticercosis
- And, now measles!
- Eradication is defined as "reduction of the worldwide incidence of a disease to zero"

<table>
<thead>
<tr>
<th>Disease targeted for eradication</th>
<th>Current annual toll worldwide</th>
<th>Chief obstacles to eradication</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallpox</td>
<td><em>&lt;1,000 persons per year</em></td>
<td>Spread, scrutiny</td>
<td>Eradicated</td>
</tr>
<tr>
<td>Mumps</td>
<td><em>700,000 deaths</em></td>
<td>Lack of timely effective vaccine for young infants, poor public recognition of disease</td>
<td>Potentially eradicable</td>
</tr>
<tr>
<td>Polio</td>
<td><em>2,000 cases of paralytic disease</em></td>
<td>Lack of focus on impact in developing countries; difficult diagnosis</td>
<td>Eradicated</td>
</tr>
<tr>
<td>Measles</td>
<td><em>1,000,000 deaths</em></td>
<td>Lack of data on impact of disease</td>
<td>Potentially eradicable</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td><em>100,000 deaths</em></td>
<td>Lack of vaccine coverage</td>
<td>Not possible</td>
</tr>
<tr>
<td>Yellow fever</td>
<td><em>&lt;1,000 deaths</em></td>
<td>Not yet eradicated</td>
<td>Not possible</td>
</tr>
</tbody>
</table>

Obstacles to Elimination

- Non-human reservoirs
- Asymptomatic cases
- Drug resistance
- Weak health systems
- Vaccine safety concerns
  - Autism fears
  - Impotency
  - Contamination

Control At the International Level

The World Health Organization (WHO)

- Headquarters in Geneva, Switzerland; 193 member nations
- Uses sophisticated systems of surveillance and communication to keep track of microbial diseases on a global level
  - Influenza surveillance network; identifies strains to include in annual vaccines
- Assists countries in control of diseases
- Sets priorities and standards for disease treatment and allocation of resources

International Health Regulations

- Only binding international agreements on disease control
- Framework to prevent international spread of disease through effective national surveillance and coordination of response to public health emergencies
  - Maximum protection, minimum restriction
- IHR 1969 only applied to traditionally "quarantinable" diseases
  - Cholera, plague, and yellow fever
- Restricted surveillance to info provided by governments

WHO’s innovative approach to global disease surveillance


IHR 2005

- More effective against global disease threats
- Require countries to report certain disease outbreaks and public health events to WHO
- Enforced in 2007

Partnership for global alert and response to infectious diseases: network of networks

VSO Regional & Country Offices
VSO Collaborating Centres
Epidemiology and Surveillance Networks
Military Laboratory Networks
UN State Agencies
NGOs
Electronic Discussion sites
Media

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### National Notifiable Infectious Diseases (2007)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Virus Type</th>
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<tbody>
<tr>
<td>AIDS/HIV</td>
<td>HIV</td>
</tr>
<tr>
<td>Anthrax</td>
<td>Adenovirus</td>
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<tr>
<td>Arbovirus disease</td>
<td>Flavivirus</td>
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<tr>
<td>California encephalitis virus</td>
<td><em>Western equine encephalitis virus</em></td>
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<tr>
<td>Eastern equine encephalitis</td>
<td><em>Eastern equine encephalitis virus</em></td>
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<tr>
<td>*Newton virus</td>
<td><em>Newton virus</em></td>
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<tr>
<td><em>Rift Valley virus</em></td>
<td><em>Rift Valley virus</em></td>
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<tr>
<td><em>St Louis encephalitis virus</em></td>
<td><em>St Louis encephalitis virus</em></td>
</tr>
<tr>
<td><em>Western equine encephalitis virus</em></td>
<td><em>Western equine encephalitis virus</em></td>
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<tr>
<td>Botulism</td>
<td><em>Clostridium botulinum</em></td>
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<tr>
<td>Brucellosis</td>
<td><em>Brucella</em></td>
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<tr>
<td>Chancroid</td>
<td><em>Klebsiella</em></td>
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<tr>
<td>Chlamydia trachomatis</td>
<td><em>Chlamydia trachomatis</em></td>
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<tr>
<td>Cholera</td>
<td><em>Vibrio cholera</em></td>
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<tr>
<td>Coccidioidomycosis</td>
<td><em>Coccidioides immitis</em></td>
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<tr>
<td>Cryptosporidiosis</td>
<td><em>Cryptosporidium</em></td>
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<tr>
<td>Cyclosporiasis</td>
<td><em>Cyclospora</em></td>
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<tr>
<td>Diphtheria</td>
<td><em>Corynebacterium diphtheriae</em></td>
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<tr>
<td>Dissease</td>
<td><em>Mycoplasma pneumoniae</em></td>
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<tr>
<td>Escherichia coli</td>
<td><em>Escherichia coli</em></td>
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<tr>
<td>Filarial disease</td>
<td><em>Wuchereria bancrofti</em></td>
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<tr>
<td>Giardiasis</td>
<td><em>Giardia lamblia</em></td>
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<tr>
<td>Gonorrhea</td>
<td><em>Neisseria gonorrhoeae</em></td>
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<tr>
<td>Hantavirus</td>
<td><em>Hantavirus</em></td>
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<tr>
<td>Hepatitis A</td>
<td><em>Hepatitis A</em></td>
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<td>Hepatitis B</td>
<td><em>Hepatitis B</em></td>
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<tr>
<td>Hepatitis C</td>
<td><em>Hepatitis C</em></td>
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<tr>
<td>Hemolytic uremic syndrome</td>
<td><em>Klebsiella</em></td>
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<tr>
<td>Influenza mortality</td>
<td><em>Influenza</em></td>
</tr>
<tr>
<td>Legionellosis</td>
<td><em>Legionella</em></td>
</tr>
<tr>
<td>Listeriosis</td>
<td><em>Listeria</em></td>
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<tr>
<td>Lyme disease</td>
<td><em>Borrelia burgdorferi</em></td>
</tr>
<tr>
<td>Malaria</td>
<td><em>Plasmodium falciparum</em></td>
</tr>
<tr>
<td>Measles</td>
<td><em>Morbillivirus</em></td>
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<tr>
<td>Meningococcal disease</td>
<td><em>Neisseria meningitides</em></td>
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<tr>
<td>Mumps</td>
<td><em>Rubella</em></td>
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<td>Mumps</td>
<td><em>Rubella</em></td>
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<tr>
<td>Mumps</td>
<td><em>Rubella</em></td>
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<tr>
<td>Novel influenza A virus infxn</td>
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<tr>
<td>Pertussis</td>
<td><em>Bordetella pertussis</em></td>
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<tr>
<td>Plague</td>
<td><em>Yersinia pestis</em></td>
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<tr>
<td>Poliomyelitis</td>
<td><em>Polyomaviridae</em></td>
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<tr>
<td>Psittacosis</td>
<td><em>Psittacosis</em></td>
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<tr>
<td>Q fever</td>
<td><em>Q fever</em></td>
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<tr>
<td>Rabies</td>
<td><em>Rabies</em></td>
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<tr>
<td>Rockey Mountain spotted fever</td>
<td><em>Rabies</em></td>
</tr>
<tr>
<td>Salmonellosis</td>
<td><em>Salmonella</em></td>
</tr>
<tr>
<td>SARS</td>
<td><em>Coronavirus</em></td>
</tr>
<tr>
<td>Shiga toxin-producing E. coli</td>
<td><em>Escherichia coli</em></td>
</tr>
<tr>
<td>Shigella</td>
<td><em>Shigella</em></td>
</tr>
<tr>
<td>Smallpox</td>
<td><em>Variola</em></td>
</tr>
<tr>
<td>Streptococcal infections</td>
<td><em>Streptococcus</em></td>
</tr>
<tr>
<td>Syphilis</td>
<td><em>Treponema pallidum</em></td>
</tr>
<tr>
<td>Typhoid fever</td>
<td><em>Salmonella</em></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td><em>Mycobacterium</em></td>
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<tr>
<td>Tularemia</td>
<td><em>Francisella tularensis</em></td>
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<tr>
<td>Typhus fever</td>
<td><em>Salmonella</em></td>
</tr>
<tr>
<td>Varicella</td>
<td><em>Herpesvirus</em></td>
</tr>
<tr>
<td>Yellow fever</td>
<td><em>Herpesvirus</em></td>
</tr>
</tbody>
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### Practice Questions

- Define case, case fatality rate.
- What are the components of the disease triangle?
- What are links in the chain of transmission?
- What is the basic reproductive rate?
- Define prevention, control, elimination, eradication, extinction.
- What strategies were used to eradicate smallpox? What indicators made it possible?
- Define the international health regulations. What diseases were reportable under IHR 1969? IHR 2005?
- Name 5 nationally notifiable diseases in the United States.

### In Summary...

- Infectious diseases represent a major burden on public health
- Prevention, control and elimination are possible in significantly reducing this burden for many diseases
- Eradication of infectious diseases are more challenging
- Proven success story for eradication of smallpox... can it be repeated?
- International Health Regulations and reporting of notifiable diseases will aid these efforts