Prevention and Control of Infectious Diseases

by
Dr. Sten Vermund

This session seeks to...

- Review lessons learned from prior successes and failures in major disease control efforts
- Highlight key strategies for infectious disease control and prevention in the context of past successes and failures

Considerations in Infectious Disease Control and Prevention

- Societal contacts and factors influence the risk of disease
- Some IDs and vaccines confer life long immunity
- Many are asymptomatic or subclinical
- Outbreak prevention may have a timetable of days
- ID epidemiology is concerned with risk factors, host characteristics, and agent transmission details that impact on prevention and control

Basic Reproductive Rate

- Number of new infections expected from a single infected person, measure of infectivity

Examples

- High: Measles, BRR>30
- Moderately High: Rubella, BRR=12
- Moderate: Smallpox, Polio, BRR=4
- Low: Malaria in the southeast USA and in southern Italy, BRR<2
- Lower BRR makes elimination/eradication more feasible

Control, Elimination, or Eradication of infectious diseases?

Control: When eradication/elimination are unrealistic for biological or economic reasons, control of disease and reduced transmission is the goal with cost-effective measures

Elimination: Such low transmission in a given region that the problem is no longer of major public health concern

Eradication: Global absence of transmission with possibility of ending control programs
WHO definitions

- "Control of disease", when applied to many communicable and some non-communicable conditions, is defined as ongoing operations or programs aimed at reducing the incidence and/or prevalence, or eliminating such conditions”.
- Elimination of disease is defined as the reduction of case transmission to a predetermined very low level; e.g., elimination of TB as a public health problem was defined by WHO in 1991 as a reduction of prevalence to a level below one case per million population.
- Eradication of disease is defined as achievement of a status whereby no further cases of a disease occur anywhere, and continued control measures are unnecessary.
- NOTE: bioterrorism issue makes the last clause problematic.

Eradication with vaccines
Examples of Smallpox (successful) and Polio (in progress)

Smallpox: The Virus

- Variola virus
- “Crowd disease” - requires a large, densely populated area in order to propagate extensively (BRR=4)

Smallpox Transmission

- Moderately contagious
- Transmitted through saliva or by direct contact with the lesions on the skin
- People with cough most infectious

Smallpox Virulence

- Variable CFR
  - Variola minor: <2%
  - Variola major: 20-70%
  - Fulminating smallpox: 99%
    - Among children <5 years of age with smallpox in the 18th century, 80% died in London, 98% in Berlin
- Major contributor to morbidity, especially blindness, and mortality in some nations

Symptoms

- After 12-14 day incubation period
  - Fever to 41°C
  - Chills
  - Back/Headaches
  - Nausea
  - 4 days later
    - Some relief
    - Rashes appear on face, chest, arms, back, and legs
- Next few days
  - Spots change to raised, blister-like pustules
- Nine days
  - Pustules split open, dry up, and form scabs that then fall off leaving obvious scars
Edward Jenner (1749 - 1823)
- Observation: milkmaids with past cowpox had fair skin, i.e., no pock scars
- In 1796, Jenner used cowpox fluid pustule from milkmaid Sarah Nelmes to inoculate 8-yr-old James Phipps via two half-inch arm incisions
- Six weeks later, Jenner variolated the child
- No evidence of smallpox infection ➔ child protected!!

Global eradication waited for nearly 2 centuries: Surveillance-containment
- Also known as ring-containment strategy
- Relies on excellent surveillance, especially during the seasonal transmission nadir
- Case-finding drives quarantine of communities with universal vaccination within the “ring”
- Success in driving incidence to zero with as low as 5% overall coverage (but >90% of persons in exposed regions)

Smallpox Eradication: last case, laboratory accident
- Last human smallpox event in UK, 1978
- Virology laboratory with very poor safety precautions caused airborne transmission to a closed space, a dark room, two flights away
  - A young, female hospital photographer was infected (died from smallpox)
  - The virology lab director committed suicide due to his self-professed guilt and shame

Smallpox Eradication: last natural case
- Last recorded “wild” case of smallpox
  - Somalia, Oct. 1977
  - 23 year old, Mr. Ali Maalin (survived)

Why were we successful with smallpox? - I
- Relatively low BRR
- Herd immunity feasible with relatively low overall coverage
- Excellent vaccine, lyophilized, stable
- Vaccinia incubation period 2 days less than variola
Why were we successful with smallpox? - II

- No animal reservoir
- Pock mark scars facilitated epidemiology
- One serotype, no mutations
- Seasonal transmission with natural nadir enabled surveillance-containment strategy

Why were we successful with smallpox? - III

- Obvious clinical syndrome
- Global collaboration despite “cold war”
- Strong national and international commitments of expertise and monetary support
- Motivated local populace

Global Polio Eradication Strategy

- High routine TOPV immunization coverage
- Supplementary immunization with national immunization days (NIDs)
- Effective clinical and environmental/lab surveillance
  - Acute Flaccid Paralysis
  - Wild-type virus
  - Door-to-door “mopping up” campaigns

Warm Springs, GA: Polio Museum
Polio Eradication by 2005?

- Peak incidence was in the 1950s with tens of thousands of cases each summer, especially in North America and Europe.
- Last case in United States in 1979 among religious objectors to vaccination.
- Last case in Western Hemisphere in 1991 until DR/Haiti vaccine-related cases in 2000.
- Western Hemisphere certified polio free in 1994, still true for wild type strains.
- Goal of global eradication goal by 2000 failed, but still anticipated in 2005 or so.

Polio Eradication Status - I

- 7 endemic, 190 polio-free countries or territories.
- Vaccines via EPI (WHO Expanded Program on Immunizations).
- NIDs (National Immunization Days).
- Public private partnerships: national programs & international donors.
- Includes Rotary International, WHO, CDC.
- Intensive surveillance, both clinical and laboratory.
- India, Bangladesh, Nigeria, Afghanistan, Ethiopia, Angola, Egypt.
- Acute flaccid paralysis and virology environmental surveillance.
- Huge global polio network of laboratories for both environmental surveillance and case ascertainment.

Polio Eradication Status - II

- # of endemic countries at an all-time low in 2002, but actual number of cases is ≈ 4x higher than 2001.
- Due to greatly increased number of cases in India and Nigeria.
- 9 states w/in 3 countries (incl. Pakistan) responsible for >90% of 2002 cases.
- 1005 of 1878 2002 global cases (66%) in India, northern state of Uttar Pradesh with a pop. ≈ 173M.

Polio Eradication Status - III

- The remaining polio burden caused by failure to vaccinate at-risk children both in routine and supplementary immunization activities, as judged by surveillance and program evaluations.
- Managerial, operational, and political barriers will lead to continued polio transmission in the 2003-04 time period.
- Global eradication by 2005 will occur only if these barriers are addressed and overcome.

Remarkable Polio Eradication Milestones

- Polio genome sequenced.
- Mass vaccination on a scale hitherto unknown.
- 76 million children immunized in 17 West/Central African countries in "synchronized" NIDs in 2000.
- 152 million children immunized in India in just a single month, December 2000.
- Largest coordinated network of public health laboratories in world history.
Why will we be successful with polio? - I

- Relatively low BRR
- Herd immunity feasible with relatively low overall coverage
- Excellent trivalent vaccine, oral, stable if frozen
- No global viral variation of immunological importance within each of the three types
- No animal reservoirs

Why will we be successful with polio? - II

- Obvious clinical syndrome can be detected as a “tip of the iceberg,” permitting AFP surveillance
- 90% of cases are asymptomatic, but environmental virology surveillance works well
- Global collaboration despite cold war (to 1989) and subsequent war/civil strife in target countries like Angola, Sudan, Congo, Somalia, Rwanda, Uganda, Cambodia
- Strong national and international commitments of expertise and monetary resources
  - Public-private partnerships with Rotary International
  - Motivated local populace

Elimination with vaccines and environmental control

Measles, Dengue, and Malaria

Measles Elimination

- One of the most infectious IDs with BRR>30
- Measles causes ≈800,000 deaths yearly, the largest single cause of childhood vaccine-preventable deaths
- 5th cause of death worldwide in children <5 years
- From 1997-02, all confirmed measles cases in the USA (<1000 cases) are documented or likely importations from measles-endemic countries
  - i.e., no current autochthonous transmission in the USA
- Goal of measles-free Western Hemisphere is in sight
- Measles vaccine is safe, effective, and cheap
  - $0.30 per dose incl. sterile needle, syringe, & disposal

Dengue Virus

- A flavivirus with 4 serotypes
- Can cause shock and hemorrhagic fever
- Transmitted by a peridomestic breeder
  - Aedes aegypti
  - Aedes albopictus
- Control depends on the reduction of the vector
  - Education and behavior change
  - Sanitation, Breeding site reduction, Insecticides
- May have vaccine w/in 10 yrs

Early “Ae. aegypti Eradication Campaigns” Promising

- In 1930s-1950s, adequate local and external funding for personnel, equipment and insecticides
- Emphasis on source reduction
- Effective residual insecticide (DDT for many yrs)
- Centralized, vertically-structured programs with military-type organization, strict supervision, high level of discipline
Resurgence of Dengue

- Cut-backs in control programs
- Global warming and expanding geographic distribution
- Increased epidemic activity with higher population densities, often poor sanitation
- DSS and DHF increased

Aedes aegypti Distribution in the Americas

Emergence of Dengue/DHF in the Americas

Dengue/DHF in the US

Note: Substantial theoretical risk in southeast USA, especially Florida
**Hemispheric eradication of *Aedes aegypti* is not realistic**

- Problem greater than during previous campaign
- Insufficient resources
- Resistance to vertical disease control programs and use of insecticides
- Lack of effective insecticides
- Low priority, lack of sustainability
- Introduction of *Aedes albopictus*

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**Malaria**

- Parasitic disease transmitted by Anopheline mosquitoes
- One of the major causes of morbidity and mortality worldwide, with 300M. new cases/year
  - Endemic throughout most of the tropical/subtropical world (91 countries)
  - 2M. deaths/year, most in children
  - Significant threat to travelers
  - Endemic in the US until the 1940s

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**The Parasite, *Plasmodium spp.***

- *P. falciparum*
- *P. vivax*
- *P. malariae*
- *P. ovale*

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**Preventive Measures**

- Elimination or reduction of impounded water
- Use of residual insecticide
- Use of screens, bed nets, insect repellants
- Prompt diagnosis and effective treatment
- Chemoprophylaxis with antimalarials to travelers to endemic areas

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**Early “Eradication” Efforts - I**

- Before the 1940s: Organized malaria control in some countries/areas, chiefly through land reclamation, larviciding
- 1941-1945: Malaria control in USA considered as part of the war effort
- 1945-1955: Use of chloroquine and DDT
- Large-scale control globally countries
- 1953: Eradication of malaria in Cyprus

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**Early “Eradication” Efforts - II**

- 1955: WHO recommended the policy of malaria eradication
- 1956-1970s: Malaria eradication programs
  - Lebanon (1963), Palestine (~1965), Jordan (1970), Qatar (~1970), Libya (1973), Bahrain (1979), Tunisia (1979), Kuwait (no indigenous malaria; vector present from 1981)
  - 1970: Interruption of transmission of *P. falciparum* in Iraq, Syria, Morocco
- 1970s: Containment of malaria in Iran, Pakistan, Afghanistan, Egypt, Saudi Arabia
**Stagnation in Control Efforts Leads to Reemergence**

- **1980s-mid 1990s:** Setbacks in countries with internal problems: Afghanistan, Iraq, Sudan, Djibouti, Somalia, Yemen
- **1991-1993:** Formulation, adoption and dissemination of the revised Global strategy for malaria control
- **1991 - now:** Malaria Eradication Program in Oman, but attitude is focused on regional elimination when feasible, control where BRR is high (hyper- or holo-endemic transmission status)

**Factors Contributing to the Resurgence of Malaria - I**

- Rapid spread of resistance of malaria parasites to chloroquine and other antimalarial drugs
- Frequent armed conflicts and civil unrest in many countries, with refugees and marching armies as source of infection, collapse of control programs
- Migration (for reasons of agriculture, commerce, and trade) of nonimmune populations from nonmalarious and usually high to low parts of the same country where transmission is high

**Factors Contributing to the Resurgence of Malaria - II**

- Changing rainfall patterns as well as water development projects such as dams and irrigation schemes, which create new mosquito breeding sites
- Adverse socioeconomic conditions leading to a much reduced health budget and gross inadequacy of funds for drugs
- High birth rates leading to a rapid increase in the susceptible population under 5 years of age
- Changes in the behavior of the vectors, particularly in biting habits, from indoor to outdoor biters
- Global warming with increased vector lifespan and expansion of optimal habitats

**WHO targeted diseases For eradication in early 21st century**

- Dracunculiasis (guinea worm)
- Poliomyelitis
- Leprosy
- Lymphatic Filariasis
- Neonatal tetanus
- Chagas disease
- Iodine deficiency disorders

**Control and Prevention: Summary I**

- Vaccines
- Environmental and vector control
- Physical and chemical barriers
- Health education and behavior change
- Over 30 examples
- West Nile, EEE, SLE, WEE, Dengue, Malaria
- Condoms, Mosquito repellents
- HIV/STD control, smoking cessation

**Control and Prevention: Summary II**

- Case finding and treatment
- Isolation and quarantine
- Directly observed therapy (DOT)
- Water, Sanitation, Hygiene
- Housing improvements (crowding)
- Excellent primary and preventive health care
  - e.g., Obstetrics, Geriatrics, Pediatrics

- TB, STD
- Smallpox, SARS
- TB, HIV, STD
- Diarrheal, parasitic, nosocomial
- TB, meningococcus, pneumococcus
- Maternal and neonatal sepsis and “TORCH” infections, pneumonia and influenza in the elderly, childhood infection prevention or prompt treatment
Complacency is inappropriate, but it is worth celebrating successes!!

*For 100,000 population per year.