Why do we vaccinate?

*A primer on Herd Immunity*

Jared Rutledge, PhD
What is a vaccine?

- Passive – borrowing someone else’s immunity
  - Blood donation
  - Cloning antibodies

- Active
  - Attenuated Vaccine
    - Diluted
    - Augmented
    - Vector
  - In-activated Vaccine
    - Destroyed
    - Parts of an Organism
  - Toxoid Vaccine
    - Selected chemical markers

- Risk of Vaccinating versus risk of Infection
  - Yellow Fever Vaccine
  - Smallpox
  - Rabies
  - Measles

- Not every vaccine is needed in every situation...
  - Exception is always made for organisms that are highly communicable e.g. Measles


Active Vaccination Controls Outbreaks

• Vaccination can:
  – Remove people from the susceptible pool
  – Reduce infectious period
  – Limit outbreak potential
  – Protect those that the vaccine will fail

• Vaccine is rarely a treatment
  – Immunity takes time to develop
  – Vaccination is usually prevention and not treatment
  – Vaccines are most effective when administered prior to exposure

No Vaccine is 100%

• Host characteristics
  – Auto-immune diseases
  – Medications that suppress immune function
  – Immunocompromised status
    • HIV
  – Rotten luck
    • No able to make antibodies for that specific organism

• Organism characteristics
  – Antigenic Shifting
  – Weakly Antigenic
  – Dozens of serotypes
  – Virulence factors that suppress antibody response or binding

Communicable Diseases

• There are three types of people
  – Susceptible
  – Infectious
  – Recovered (Immune)
    • Vaccination
    • Exposure
    • Dead

• A communicable disease is by definition
  – Spreadable! Infectious!

• Reproductive Value (RO)
  – How many cases will be generated from one case of disease?

• What influences a RO?
  – Transmission parameter
    • Blood, Droplet, ID 50
  – Population of Susceptible
    • Lack of vaccination or waning vaccination protection
  – How long is the person infectious?

Examples of RO Values

- Often outbreak specific
- ROs appear to be somewhat stable over time, but population dynamics can shift the RO
- Observational Case Studies
  - We do not lock people up who are unvaccinated and expose them to evaluate the RO for specific diseases!

<table>
<thead>
<tr>
<th>Disease</th>
<th>Geographical Location</th>
<th>RO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diphtheria</td>
<td>New York &amp; Maryland</td>
<td>4 – 5</td>
</tr>
<tr>
<td>Scarlet Fever</td>
<td>New York, Pennsylvania, &amp; Maryland</td>
<td>5 – 8</td>
</tr>
<tr>
<td>Mumps</td>
<td>Maryland, England/Wales, Netherlands</td>
<td>7 – 14</td>
</tr>
<tr>
<td>SARS</td>
<td>Hong Kong</td>
<td>2 – 5</td>
</tr>
<tr>
<td>EBOLA</td>
<td>Africa 1976-2006</td>
<td>2 – 7</td>
</tr>
<tr>
<td>HIV</td>
<td>Male Homosexuals (Europe) Nairobi (Female Prostitutes) Kampala (Heterosexuals)</td>
<td>2 – 5 11 – 12 10 – 11</td>
</tr>
<tr>
<td>Rubella</td>
<td>Europe</td>
<td>6 – 15</td>
</tr>
</tbody>
</table>

What impact does behavior have on a reproductive value (Ro)?

• Depends on the mode of transmission:
  – Airborne
  – Airborne Droplet
  – Fecal-oral route
  – Intimate contact
    • Saliva exchange
    • Sexual Activities
  – Bodily Fluids
    • EBOLA vs. Hepatitis B or C

• Number susceptible
  – Vaccination and recovery with immunity remove these people from the Ro calculation and limit the spread

• Length of infectivity Impact

• Severity of Disease

Ro in Practice

http://www.npr.org/blogs/health/2014/10/02/352983774/no-seriously-how-contagious-is-ebola
Evaluation of the potential for spread of an infection

\[ R_0 = 4 \]
with whole population susceptible

\[ R_0 = 4 \]
with 75% population immune (25% susceptible)

(Dr. Effelterre, GSK, 2008)
Examples of Infectious Doses (ID 50) & Modes of Transmission

<table>
<thead>
<tr>
<th>Organism</th>
<th>Mode Of Transmission</th>
<th>ID50</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. anthracis</em></td>
<td>Inhaled</td>
<td>10,000 to 20,000</td>
</tr>
<tr>
<td><em>F. tularensis</em></td>
<td>Inhaled, direct contact</td>
<td>10</td>
</tr>
<tr>
<td>Ebola</td>
<td>Direct Contact with Bodily Fluids</td>
<td>1</td>
</tr>
<tr>
<td>Norovirus</td>
<td>Fecal-oral</td>
<td>2,740</td>
</tr>
<tr>
<td>Measles</td>
<td>Airborne</td>
<td>500</td>
</tr>
<tr>
<td>Influenza A</td>
<td>Airborne Droplet</td>
<td>3 - 66</td>
</tr>
</tbody>
</table>

*Varies depending on mode of transmission

New and Exciting Vaccination News: EBOLA Overview

Order: **Mononegavirales**
Family: **Filoviridae**
Genus: **Ebola like viruses**
Species: **Ebola**

Subtypes

- Ebola-Zaire, Ebola-Sudan, Ebola-Ivory Coast
  - disease in humans
- Ebola-Reston
  - disease in nonhuman primates
EBOLA: Symptoms and Diagnostic Tests

• Early symptoms
  – muscle aches, fever, vomiting
  – red eyes, skin rash, diarrhea, stomach pain

• Acute symptoms
  – bleeding/hemorrhaging from skin, orifices, internal organs

• Early Diagnosis
  • very difficult
  • signs & symptoms very similar to other infections

• Laboratory Test
  • PCR detection
  • ELISA (enzyme-linked immuno-absorbant) assay
EBOLA: Life Cycle

Ebolavirus Ecology

Enzootic Cycle
New evidence strongly implicates bats as the reservoir hosts for ebolaviruses, though the means of local enzootic maintenance and transmission of the virus within bat populations remain unknown.

Ebolaviruses:
- Ebola virus (formerly Zaire virus)
- Sudan virus
- Tai Forest virus
- Bundibugyo virus
- Reston virus (non-human)

Epizootic Cycle
Epizootics caused by ebolaviruses appear sporadically, producing high mortality among non-human primates and duikers and may precede human outbreaks. Epidemics caused by ebolaviruses produce acute disease among humans, with the exception of Reston virus which does not produce detectable disease in humans. Little is known about how the virus first passes to humans, triggering waves of human-to-human transmission, and an epidemic.

Following initial human infection through contact with an infected bat or other wild animal, human-to-human transmission often occurs.

Bush Meat

Human-to-human transmission is a predominant feature of epidemics.
Characteristics of EBOLA

- EBOLA outbreaks occur every 3 to 4 years
- Recent outbreak was largest on record and due to porous isolation procedures
- Bush meat will not stop being consumed by poorer African regions
  - Continuous vaccination would be the only way to prevent these epidemics from cycling
- Current Vaccine
  - rVSV (vector vaccine)
    - Vesicular stomatitis virus
    - Phase 1
      - No serious side effects
      - Immunogenic after 1 dose
    - Phase 2
      - Trials promising
    - Phase 3 – field testing
      - Begins the end of February


Fast Tracking the Vaccine

- Anti-viral therapies are approved and effective
  - In short supply
- A vaccine has shown
  - Strong immune response
  - Safe
- Ethical issues surrounding a person’s ability to say no to a vaccine like this in face of a disease with a 60% Case Fatality Rate

If successful:
- The vaccine will have to be a mainstay of these populations
- Vaccination could interrupt the cycle of EBOLA in Africa
- Due to the wild animal reservoir it is unlikely that EBOLA will be eradicated
- Persistent vaccination will eventually be pursued

So, why do we vaccinate?

- Do we vaccinate to protect the individual alone?
  - No, no vaccine is 100%
- Do we vaccinate to eradicate a disease?
  - Sometimes, it has been done with smallpox and it is possible to do it with measles and polio
- We vaccinate to remove those susceptible from the population to limit the impact of outbreaks