Ebola and Influenza — Perception & reality

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Public Concern About Getting Sick from Ebola by Level of Education

% saying they are concerned that they or someone in their immediate family may get sick from Ebola during the next 12 months

- **Total**: 26%
- **Less than High School**: 37%
- **Some College**: 22%
- **College Grad or More**: 14%

Harvard School of Public Health/SSRS, Ebola poll, August 13-17, 2014
Ebola cases the United States

Cases from transmission in the USA

year

1976
2014
Ebola outbreaks since 1976

![Graph showing cases and deaths of Ebola outbreaks since 1976]

Influenza deaths in the United States

Ebola vs influenza

**Transmission route**
- Ebola: blood, feces, vomit
- Influenza: airborne

**Transmissibility**
- Ebola: high (in some settings)
- Influenza: moderate

**Case fatality**
- Ebola: 50–70%
- Influenza: 0.001–2%

**Annual cases**
- Ebola: hundreds
- Influenza: hundreds of millions?

**Annual deaths**
- Ebola: tens
- Influenza: hundreds of thousands?
How do we count cases?

**Active**
- Door-to-door or telephone surveys, contact tracing
- (Can be) accurate, expensive

**Passive**
- Hospital and death records, internet search, medical-related purchase histories
- Can miss mild cases, hard to extrapolate

Surveillance systems combine active and passive approaches to measure populations.
How do we count *ebola* cases?

- Hospitals and clinics (should) report how many seek care for ebola.
- But not everyone seeks care at medical facilities.
- Underreporting may be as high as 50% in the current ebola epidemic.
  - Estimating the number of cases may require comparing different data sources (hospitalization vs death reports), active surveillance in remote communities, and/or mathematical modeling.

*Since ebola symptoms are severe, it is easier to count cases.*
How do we count *influenza* cases?

**Active**

Door-to-door or telephone surveys, contact tracing

(Can be) accurate, expensive

**Passive**

Hospital and death records, internet search, medical-related purchase histories

Can miss mild cases, hard to extrapolate

How good is this for influenza?
Monitor “excess” pneumonia and influenza deaths in a sample of hospitals. Elderly influenza cases have higher mortality than younger cases.
ILI is defined as fever (temperature of 100°F [37.8°C] or greater) and a cough and/or a sore throat without a KNOWN cause other than influenza.
Influenza Positive Tests Reported to CDC by U.S. WHO/NREVSS Collaborating Laboratories, National Summary, 2014-15

http://www.cdc.gov/flu/weekly

Some influenza patient samples are tested in the lab.
How do we count influenza cases?

- As many as 140 influenza illnesses for every laboratory confirmed case.

Each level in the pyramid can introduce error and uncertainty.
How transmissible are pathogens?

- $R_0$ is a popular measure of transmissibility.
- $R_0$ is the number of people that a typical infected person infects in a fully susceptible population.

$R_0 = 2.0$
How transmissible are pathogens?

<table>
<thead>
<tr>
<th>pathogen</th>
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$R_0 = 2.0$

Disease can spread **exponentially**.
How does vaccination reduce transmission?

- **Individual-level benefit:** Vaccination reduces the chances of infection.

- **Population-level benefit:** Vaccination reduces the number of people a person can infect.

- If infected people infect less than 1 other on average ($R_0 < 1$), outbreaks will not occur.
How many people do we need to vaccinate?

\[ R_0 = 2.0 \]

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How many people do we need to vaccinate?

50% for $R_0 = 2.0$

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(assuming a perfect vaccine)
How many people do we need to vaccinate?

$R_0 = 3.0$

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How many people do we need to vaccinate?

67% for $R_0 = 3.0$

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*(assuming a perfect vaccine)*
How many people do we need to vaccinate?

\[ R_0 = 8.0 \]

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How many people do we need to vaccinate?

87.5% for $R_0=8.0$

(assuming a perfect vaccine)

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The critical vaccination fraction is the proportion of the population that needs to be vaccinated to prevent outbreaks. Basically, vaccinate enough to drive $R_0$ below 1. The critical vaccination fraction depends on $R_0$ and the vaccine efficacy, $VE$: 

$$\frac{1-1/R_0}{VE}$$
Measles vaccination coverage around the world

Vaccination coverage worldwide
With 91% of 1-year-olds vaccinated, the United States comes in ahead of the WHO’s 2015 target, but behind the 80 countries that have already attained the WHO’s 2020 target of 95%.

Local MMR vaccination coverage

https://data.kingcounty.gov/dataset/Kindergarten-MMR-Vaccine-Coverage/kbfa-mvcb
How long does it take to infect someone else?

Transmissibility + speed can be used to model outbreaks

\[
\begin{align*}
\frac{dS}{dt} &= -\beta SI \\
\frac{dI}{dt} &= \beta SI - \gamma I \\
\frac{dR}{dt} &= \gamma I
\end{align*}
\]

Calculus is often used to model epidemic dynamics.
Simple epidemic dynamics

**Time in days**

**Infected**

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<tr>
<td>Influenza</td>
<td>1.1–1.5</td>
<td>3.4 days</td>
</tr>
<tr>
<td>Ebola</td>
<td>1.83</td>
<td>15.3 days</td>
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Epidemic dynamics of a simple mathematical model.
What outbreaks are containable?

**Influenza:** Many asymptomatic but infectious cases. Short generation time.

**Ebola:** Cases are not very infectious until late. Longer generation time. Clinical disease is debilitating.

**SARS:** Most cases are symptomatic. Little transmission before symptoms appear.

**Measles:** Highly transmissible. Vaccination is very effective.

**HIV:** Highly infectious before symptoms appear.
Projecting the ebola epidemic with models

With initial $R_0$ and generation time estimates, one can forecast epidemic spread.

(Over-) estimating Ebola

Models overestimate Ebola cases

Rate of infection in Liberia seems to plateau, raising questions over the usefulness of models in an outbreak.


Projections may assume that the epidemic will maintain its initial course.
Ebola transmission in hospitals and funerals

• “Ebola virus disease who were not health-care workers infected a mean of 2.3 people (95% CI 1.6–3.2): 1.4 (0.9–2.2) in the community, 0.4 (0.1–0.9) in hospitals, and 0.5 (0.2–1.0) at funerals.”

• “After the implementation of infection control in April, the reproduction number in hospitals and at funerals reduced to lower than 0.1.”

• “In the community, the reproduction number dropped by 50% for patients that were admitted to hospital, but remained unchanged for those that were not.”

Behaviors change and authorities take action during large outbreaks.
Summary and conclusions

- Epidemiologists design surveillance systems to detect and quantify infectious disease transmission.
- Mathematical modelers use these data for projections and to estimate the impact of interventions.
- Early projections may be inaccurate, but can be useful. One should not extrapolate trends too far into the future.
- It is hard to predict behavioral responses to epidemics. Fear (or lack of fear) can have a large effect.
- Someone else needs to communicate infectious disease risk to policymakers and the general public.
Thank you!

Boukan Kare, Haiti.
Photo by D. Chao

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