Infectious disease risk assessment

Short course on Infectious Diseases in Humanitarian Emergencies
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What is happening to the burden of infectious diseases in such a setting?

[from Reuters AlertNet]
Health crisis = excess mortality

- "A retrospective mortality survey conducted in the camps around Goma in November 2008 shows that, before displacement, the crude mortality rate (CMR) was 0.8 deaths per 10 000 persons per day. After displacement, CMR increased to 2.3 per 10 000 persons per day. 11% of the deaths after displacement were due to intentional injuries."

- What **epidemiological processes** explain the increased rate of mortality due to infectious diseases as a result of mass displacement?
Why does the mortality rate increase?

- The mortality rate due to any infectious disease is a mathematical function of the following **three factors**:
  - Rate of *transmission* of the pathogen
  - Probability that the pathogen will actually cause *disease* in the individual
  - Probability that the disease will lead to *death* (case-fatality ratio or *CFR*).

- If any one of the above increases, mortality will also increase
  - We must understand how certain crisis conditions (e.g. displacement, flooding, food insecurity) can affect the above three factors
  - Classifying infectious diseases according to their route of transmission helps us to know what problems (diseases) to expect, and when
Infectious disease risk assessment
What is likely to happen?

- **Which epidemiological and demographic setting?**
  - Pre-, mid- or post-transition

- **Which crisis condition(s)?**
  - “Entrapment” due to protracted insecurity (probably most common)
  - Mass displacement into camps (classical scenario, best described)
  - Displacement into host communities (far less well studied)
  - Sudden environmental change due to natural disaster
  - Food crisis

- **Which specific risk factors?**
  - Mostly follow from crisis conditions

- **What infectious diseases have occurred in this community in the past?**
Examples of distal, intermediate and proximate risk factors of excess morbidity (disease) and mortality (death) in a crisis

Distal risk factors
- Extreme poverty
- Political instability
- Inequalities
- Ethnic rivalry
- Economic stagnation
- Competition for resources
- Arms proliferation
- Climate
- Seismic risk
- Environmental vulnerability

Intermediate risk factors
- Armed conflict
- Abusive relationships
- Displacement
- Psychological and physical stress
- Access to/utilisation of health services
- Natural disaster
- Food insecurity/shortage
- Breakdown of government services

Proximate risk factors
- Overcrowding
- Insufficient vaccination coverage
- High exposure to disease vectors
- Inadequate shelter
- Poor water, sanitation, hygiene conditions
- Lack of and/or delay in treatment
- Insufficient nutrient intake
- Violence

Susceptibility
- Infection/exposure
- Progression to disease
- Disease (outcome)
- Case-fatality (CFR)
- Death (impact)
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
The effects of overcrowding

- **High population density**
  - Greater opportunity for contact ("c") between infectious and susceptible people = higher transmission

- **Large concentration of population**
  - Once an epidemic starts, it spreads faster = higher transmission

- From a purely epidemiological perspective, providing sufficient residential space and avoiding very large camps are high-impact public health interventions
High density versus Large population

“epidemiological barrier” versus
Predicted progression of a measles epidemic, in the absence of interventions, according to different population densities (m² per person)
The effects of overcrowding

- **Airborne droplet diseases**
  - Measles, meningitis, ARI, TB
  - Vaccine-preventable diseases: greater requirements for vaccination! (see later)

- **Faecal-oral diseases**
  - Diarrhoeal diseases including shigella and cholera

- Public health message: don't force people into camps
  - Different from security message
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Inadequate shelter

- **Exposure to the elements**
  - Hypothermia
  - Dehydration

- **Indoor smoke**
  - ARI (higher disease progression)

- **Exposure to vectors**
  - Preventive tools less feasible
Understanding risk factors

- Overcrowding
- Inadequate shelter
- **Insufficient nutrient intake**
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Insufficient nutrient intake

Correlation between mortality rate and prevalence of acute malnutrition among children under 5 years in refugee camps

Insufficient nutrient intake

Major causes of death among children under 5 years of age and neonates in the world, 2000-2003

Undernutrition is an underlying cause of 53% of deaths among children under five years of age.
Insufficient nutrient intake

Known important interactions between underlying and immediate causes of disease and death

- Evidence has recently emerged that malaria may speed up HIV/AIDS progression

Note: Direction of arrow indicates cause and effect link. Note that more interactions may be discovered in the future
Insufficient nutrient intake

- **Malnutrition = lower immunity**
  - Higher "c", "p" and probably "d" of most infectious diseases = higher R = higher transmission
  - Higher probability that infection progresses to disease
  - Higher CFR

- **Nutritional crises can precipitate epidemics**
  - Lower immunity means lower vaccine efficacy, higher susceptibility = greater transmission

- **Epidemics can precipitate nutritional crises**
  - e.g. if measles attack rate = 20%, you could expect that something like 10% more children will become acutely malnourished
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Insufficient vaccination coverage

- "Yesterday our field medical officer saw one case of measles in the camps around Masisi. Now we can finally go ahead with an expensive mass vaccination campaign targeting all children."

- "The national measles vaccination coverage is about 71%. In the camps, it's 85%. That's as high as the UK's!"
Insufficient vaccination coverage

**Measles in a rural setting**

- **Low overcrowding → low ‘c’**
- $R_o = 6$ (i.e. on average, one case will result in 6 additional cases, assuming everyone is susceptible)

To avert an outbreak, at least 5 of the 6 transmissions must be prevented, i.e. 5 out of 6 must be immunised (83%)

**Measles in a refugee camp**

- **High overcrowding → high ‘c’**
- $R_o = 12$ (i.e. on average, one case will result in 12 additional cases, assuming everyone is susceptible)

To avert an outbreak, at least 11 of the 12 transmissions must be prevented, i.e. 11 out of 12 must be immunised (92%)
## Insufficient vaccination coverage

- **Northern Uganda IDP camps (2005)**

<table>
<thead>
<tr>
<th>District</th>
<th>Estimated vaccination coverage (2005)</th>
<th>Outbreak predicted in 2006?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulu</td>
<td>95%</td>
<td>NO</td>
</tr>
<tr>
<td>Gulu municipality</td>
<td>96%</td>
<td>NO</td>
</tr>
<tr>
<td>Kitgum</td>
<td>85%</td>
<td>YES</td>
</tr>
<tr>
<td>Pader</td>
<td>91%</td>
<td>YES</td>
</tr>
</tbody>
</table>
## Insufficient vaccination coverage

### Northern Uganda IDP camps (2005)

<table>
<thead>
<tr>
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<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
Insufficient vaccination coverage

<table>
<thead>
<tr>
<th>Status of individual X:</th>
<th>Not vaccinated and not immune due to previous exposure to disease</th>
<th>Vaccinated or immune due to previous exposure to disease</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status of community:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion in community who are vaccinated or have acquired immunity due to previous exposure to disease</td>
<td><strong>Low</strong></td>
<td>High risk of outbreak occurring&lt;br&gt;Outbreak will have high attack rate&lt;br&gt;Very high risk for individual X</td>
</tr>
<tr>
<td>Proportion in community who are vaccinated or have acquired immunity due to previous exposure to disease</td>
<td><strong>High</strong></td>
<td>Low risk of outbreak occurring&lt;br&gt;Any outbreak is likely to feature a low attack rate&lt;br&gt;Low risk for individual X overall (but high should an outbreak occur)</td>
</tr>
</tbody>
</table>

- **Most vaccines reduce "c", others "p"**
  - Some prevent not only transmission, but also progression to disease and death
- **In order to protect the entire community (i.e. avert an outbreak), we must reach the herd immunity threshold coverage**
  - We can't rely on routine EPI to do this (it would take too long): need mass vaccination campaigns!
  - However, we should move to re-establish EPI services in the post-emergency phase
Insufficient vaccination coverage

- **Sudden mass displacement into camps:**
  - The herd immunity threshold changes as a function of the settlement pattern
  - In camps it is higher, due to overcrowding!!!
    - i.e. a coverage of 85% for measles might be sufficient in a village, but, as soon as people move to a camp, it is no longer enough: 95-100% is needed
    - This risk is immediate (days after displacement)
    - **Must** do preventive measles mass vaccination campaign as soon as camp is established (children 6-59m, or up to 14y old)

- **Protracted "entrapment" crises:**
  - Vaccination coverage decreases gradually due to disruption in EPI health services
  - Unvaccinated newborns are constantly being added to the susceptible pool: eventually, coverage dips below the herd immunity threshold, and outbreaks start to occur (DRC is a good case study)
  - This risk manifests itself over months
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- **Poor water, sanitation and hygiene conditions**
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Poor water, sanitation and hygiene

- Hands
- Flies
- Food
- Water
- Mouth
- Faecal matter
Poor water, sanitation and hygiene

- Exclusively affect “c” = higher transmission rate

- Faecal-oral diseases

- Vector-borne disease
  - Stagnant water

- Refer to water and sanitation lecture on Thursday
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Exposure to / proliferation of disease vectors

- "People have been displaced into a large overcrowded camp, so we should expect an epidemic of malaria."

- "There has been massive flooding this week, and we are already seeing a huge increase in malaria cases."

- "There has been massive flooding this week, and this is an area of possible dengue transmission. We can stop an epidemic if we give out bednets as soon as possible."
Exposure to / proliferation of disease vectors

- Do conditions allow for transmission?
- Could the crisis result in:
  - Vector proliferation?
  - Reduced latency period in vector? (but mainly temperature-dependent)
  - Sudden exposure to transmission of previously unexposed people? (esp. malaria, if displaced move to transmission area)
- What are the most appropriate prevention interventions?
  - Is the vector day-biting (e.g. dengue) or night-biting (malaria)? If night-biting, should use bednets or IRS; otherwise, larval control
  - Are bednets, IRS or other tools more appropriate given shelter conditions?
  - Is there a vaccine? (e.g. yellow fever, Japanese encephalitis)
- When would an outbreak start?
  - Depends on [latency period in vectors + latency period in humans]
- May need entomological advice
Understanding risk factors

- Overcrowding
- Inadequate shelter
- Insufficient nutrient intake
- Insufficient vaccination coverage
- Poor water, sanitation and hygiene conditions
- High exposure to and/or proliferation of disease vectors
- Lack of and/or delay in treatment
Lack of and/or delay in treatment

- **Main effect: increase in CFR**
  - For most infectious diseases, exponential increase in CFR as a function of delay in treatment
  - Two parameters:
    - Coverage of treatment
    - Effectiveness of treatment

- **Possible effect: increase in transmission rate**
  - Higher “d”
  - However, impact on transmission dependent on coverage and proportion of asymptomatic cases
## Different risk factors = different effects

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Increased transmission</th>
<th>Increased progression to disease</th>
<th>Increased case-fatality (CFR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased malnutrition</td>
<td>Nearly all diseases (malnutrition lecture)</td>
<td>Nearly all diseases (malnutrition lecture)</td>
<td>Nearly all diseases (malnutrition lecture)</td>
</tr>
<tr>
<td>Displacement into overcrowded camps</td>
<td>Air-droplet diseases (maybe not bacterial ARI)</td>
<td>Faecal-oral diseases</td>
<td></td>
</tr>
<tr>
<td>Poor shelter</td>
<td>Vector-borne diseases</td>
<td>ARI</td>
<td></td>
</tr>
<tr>
<td>Insufficient vaccination coverage</td>
<td>EPI vaccines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor water, sanitation and hygiene conditions</td>
<td>Faecal-oral diseases (lecture on watsan)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vector proliferation and/or increased human-vector contact</td>
<td>Vector-borne diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of and/or delay in treatment</td>
<td></td>
<td>All diseases (lecture on health system)</td>
<td></td>
</tr>
</tbody>
</table>

Nearly all diseases (malnutrition lecture)
**Different risk factors = different effects**

- From the previous slide we can immediately see that:
  - Malnutrition is a critical modulator of all infectious disease dynamics
  - Living in overcrowded camps affects the risk of the two most important routes of transmission (air-droplet, faecal-oral)
  - Lack of treatment can undo gains in prevention

- Nightmare scenario = gradually declining vaccination coverage + sudden mass displacement into camps + nutritional crisis + no health services
  - i.e. the first 3-4 weeks of many emergencies!

- In addition, the local HIV burden plays a role similar to malnutrition
  - The higher the background HIV prevalence, the higher the transmission, disease progression and CFR of most infectious diseases
Infectious disease risk assessment

- "We don't have any good morbidity or mortality data, so how can we decide on interventions?"

- "We should decide on infectious disease priorities and implement interventions without a rigorous field epidemiological evaluation conducted during the first weeks of the crisis."
Infectious disease risk assessment

- Exercise to systematically assess and prioritise infectious disease threats in a given crisis
  - Done in the early days of the emergency (in the future, we should do it even before)
  - Purpose is to guide the deployment of health relief programmes that include both preventive and curative interventions against the most important infectious disease threats (either present or possible)
  - Not a review of all infectious diseases affecting the crisis setting: focus is on main problems humanitarian community needs to focus on during the relief response

- Risk assessments and risk profiles coordinated by WHO/DCE for most major crises
  - Convenes WHO Communicable Diseases Working Group on Emergencies
  - [www.who.int/diseasecontrol_emergencies/toolkits/en](www.who.int/diseasecontrol_emergencies/toolkits/en)
Infectious disease risk assessment

Pakistan Earthquake (2005):

Kenya violence (2008):

Communicable disease risk assessment and interventions

Post-election emergency: Kenya
February 2008

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### 1. COMMUNICABLE DISEASES RISK ASSESSMENT

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pakistan</th>
<th>Afghanistan</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALRI</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Crimean-Congo HF</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cholera</td>
<td>?</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Dengue</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hepatitis A &amp; E</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>++</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Japanese encephalitis</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Leishmaniasis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Malaria</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Measles</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Meningitis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pertussis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Poliomyelitis</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Rabies</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Typhoid fever</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Typhus</td>
<td>+</td>
<td>?</td>
<td>+</td>
</tr>
<tr>
<td>Shigellosis</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Tetanus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
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</tbody>
</table>

Key:  + : At risk  - : Not at risk  ? : No information available; potentially at risk
Infectious disease risk assessment

- In practice, the core will always look a bit like this:
  - Acute respiratory infections
  - Diarrhoeal diseases
    - Endemic
    - Epidemic:
      - Type 1 shigella
      - Cholera (unless there is strong evidence against local transmission)
      - Typhoid
      - Rotavirus
  - Malaria
    - Only in areas of possible transmission
    - Main variables: epidemic or endemic? *P. falciparum* transmission?
  - Measles
    - Especially in case of displacement to camps
What do children die of?

Infectious disease risk assessment

Another way to look at it:

- **Endemic diseases with very high burden**
  - ARI
  - Common diarrhoeal diseases
  - Malaria [high transmission areas]

- **Diseases that are either absent now or have low-moderate transmission, but that could become epidemic unless preventive action is taken**
  - Malaria [low transmission areas]
  - Measles
  - Meningitis [esp. in meningitis belt]
  - Epidemic diarrhoeal diseases (cholera, shigella, typhoid...) and other diseases transmitted through faecal-oral route (e.g. hepatitis)
  - "Regional" vector-borne diseases such as yellow fever, Dengue, Japanese encephalitis, lymphatic filariasis, African trypanosomiasis, etc.
  - Other crisis-specific problems (e.g. tetanus post tsunami)
Infectious disease risk assessment

- Which epidemic-prone diseases should we expect, and when?

<table>
<thead>
<tr>
<th>Main risk factor</th>
<th>Main epidemic diseases of concern</th>
<th>Timing after onset of risk factor (time window to act)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>Malaria</td>
<td>At least 1 month</td>
</tr>
<tr>
<td>Intense rainy season</td>
<td>Dengue</td>
<td></td>
</tr>
<tr>
<td>Temperature abnormalities</td>
<td>Rift Valley Fever</td>
<td></td>
</tr>
<tr>
<td>Movement of people from non-endemic into disease-endemic region</td>
<td>Malaria</td>
<td>At least 1 month</td>
</tr>
<tr>
<td>Dry season</td>
<td>Meningitis</td>
<td>About 2 weeks</td>
</tr>
<tr>
<td>Overcrowding</td>
<td>Measles</td>
<td>As little as 2 weeks</td>
</tr>
<tr>
<td></td>
<td>Meningitis</td>
<td></td>
</tr>
<tr>
<td>Insufficient water</td>
<td>Cholera</td>
<td>As little as 2 weeks</td>
</tr>
<tr>
<td>Contaminated water</td>
<td>Shigella (bloody dysentery)</td>
<td></td>
</tr>
<tr>
<td>Very poor sanitation</td>
<td>Rotavirus</td>
<td></td>
</tr>
<tr>
<td>Poor nutrient intake</td>
<td>Measles</td>
<td>Starting about 1–2 months</td>
</tr>
<tr>
<td></td>
<td>Cholera</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shigella (bloody dysentery)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rotavirus</td>
<td></td>
</tr>
<tr>
<td>Interruption of routine vaccination activities</td>
<td>Measles</td>
<td>A few months</td>
</tr>
</tbody>
</table>
Do not forget endemic diseases

- "There is currently an outbreak of pneumonia in the camps."

- "Shigella is an endemic pathogen in the DRC."

- "We have an excellent data collection system in place, and we can say for sure that there are no outbreaks occurring. Therefore, infectious diseases are under control."
Do not forget endemic diseases

Illustration of the greater incidence and lethality (CFR) of endemic diseases as a result of crisis

Under 5 years mortality rate (/10,000/day)
Do not forget endemic diseases

- You don't need an epidemic to cause disastrous excess mortality:
  - This can easily occur if a lot of people experience higher incidence and/or higher CFR of common endemic diseases!
  - Lethal mix of overcrowding, malnutrition, lack of access to treatment...
    - A few percentage points matter greatly

- We must not neglect treatable diseases like ARI, neonatal sepsis, salmonellosis, non-epidemic shigella, ascariasis...

- Even among epidemics, we must not neglect the "simple" ones
  - e.g. Angola 2005-2006: Marburg versus cholera
Do not forget endemic diseases

- Acute respiratory infections

Do not forget endemic diseases

- **In crises, ARI burden probably even higher**
  - Malnutrition, poor shelter, lack of treatment, measles and pertussis
  - Not sure how much overcrowding plays a role (most pneumonia is bacterial, colonization takes place in first 6 months)

- **Battery of interventions available (no excuse!)**
  - EPI vaccines
  - Vitamin A and zinc supplementation
  - Oral amoxicillin (option when IPD referral impossible)
  - Improvement of cooking/heating conditions
  - Breastfeeding promotion
  - *Haemophilus influenzae* B, pneumococcal conjugate vaccines
    - The humanitarian community is not quite up to date with the latest innovations in child health care (equity?)
Do not forget endemic diseases

- Neonatal deaths
  - Worldwide, about 40% of all under 5y deaths
    - Thus, about 15-20% of all-age deaths!
  - Pneumonia, diarrhoea, tetanus and sepsis account for about half of neonatal deaths

- In the emergency phase, need to minimise CFR through greater access to inpatient care
Infectious disease risk assessment

What about TB and HIV/AIDS?

Data on TB burden in crises are very scarce, but the burden is likely to be higher than normal

- **Immediate**: higher CFR (interruption/lack of treatment, poorer immune response due to poor nutrition and other stress factors)
- **Medium-term** (months): higher progression to disease (e.g. due to stress, malnutrition, etc.)
- **Long-term** (years): Possibly higher transmission, consequences may be felt much later in countries of return

Refer to TB lecture

For HIV/AIDS, similar problems of faster progression to disease as a result of crises

- Interruption of HAART
- No evidence that crises increase HIV transmission
- Refer to HIV/AIDS lecture
Conclusions

- Infectious diseases do not exhibit unexpected properties in crises, but crises exacerbate existing or bring about new risk factors
  - Higher transmission rate, probability of progression to disease and/or CFR
  - Excess morbidity and mortality

- Think of which processes a risk factor or intervention affect:
  - Transmission?
  - Progression to disease?
  - CFR?

- Humanitarian relief in the health sector aims to reduce excess morbidity and mortality by
  - Reducing R
  - Reducing CFR (independent of R)