Infective Doses and Pathogen Carriage

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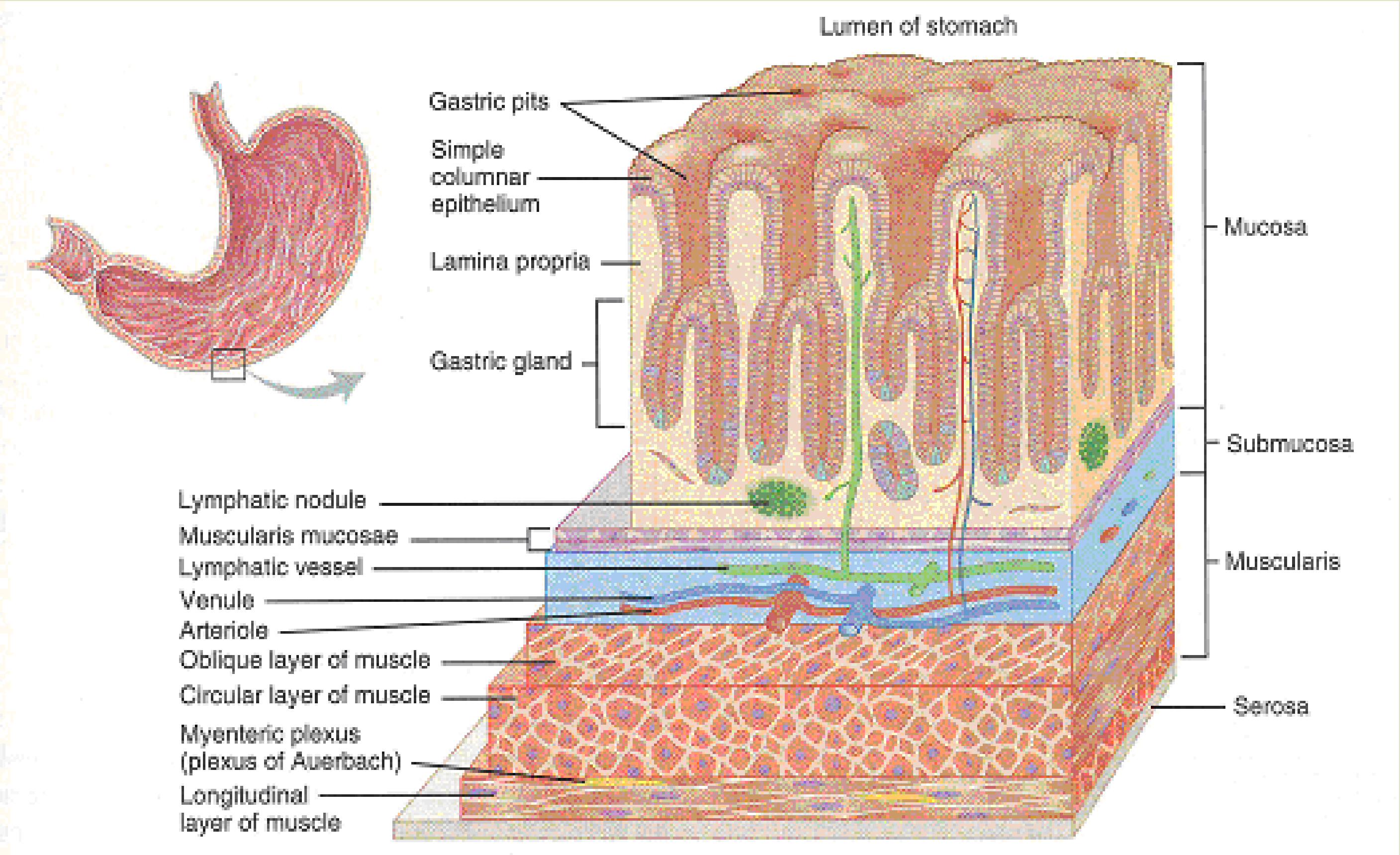
Overview:

- Introduction
- Sources of minimal dose data and influencing factors
- Characteristics of individual pathogens
- Carriage and shedding of pathogens in ill and asymptomatic individuals
- Public health implications
- Management implications
- Summary

Minimum Infectious Dose Data:

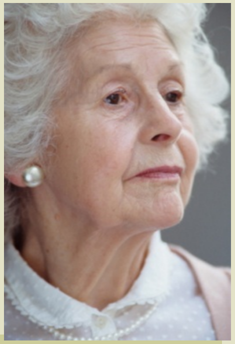
- Sources of minimum infectious dose data:
  - volunteer studies
  - counts from outbreak investigations
  - literature reviews provide infectious dose data for a defined population, in a particular food matrix
  - Japanese directive that restaurants and caterers must freeze food samples for 2 weeks
- Uncertainty associated with minimum infectious dose data
  - Varies by organism; can be strain dependent
  - Some pathogens appear able to infect at doses of 1-100 units, including viruses, parasites, and some bacteria
  - In theory one infectious unit can cause intestinal illness



Histology of the stomach. a three-dimensional view of layers of the stomach (Tortora and Grabowski, 1996)

- Gastric fluids can kill bacteria in 15 min with a pH < 3.0
- Reduced stomach acidity allows lower infectious doses
- Certain foods are protective against gastric fluids

Minimum Infectious Dose Data:



- Fat content of food matrix can protect pathogens from stomach acid: chocolate, tahini, hamburgers
- Immune status of the individual plays an important role
- Although impossible to determine the exact minimum infectious dose for individuals or even populations, low infectious doses can be expected for high-risk populations

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Minimum Infectious Dose Data:

- Pathogens with low infectious doses may be easily transmitted by foodhandlers
- Those with high infectious doses are less likely but temperature abuse can result in an outbreak
- Pathogens most likely to be transmitted by food workers are:
  - Norovirus, HAV, *Salmonella*, *Shigella* and *S. aureus*

- Pathogens of fecal, nose or throat, and skin origin are most likely to be transmitted by the hands, highlighting the need for effective hand hygiene and barriers preventing contact with RTE foods
- Multi-ingredient RTE items are more likely to be associated with food worker errors due to extensive handling

Hepatitis A:

- Infectious dose estimated at 10-100 virus particles

- San Diego naval training center: 166 cases
- Index case prepared salads, sliced cantaloupes and grapefruits while experiencing vomiting and diarrhea; he washed his hands after each episode. Allowed to return to work two days later and prepared coleslaw, although symptomatic for four more days (Hooper et al 1977)

- HAV vaccination for food handlers could reduce the risk but is costly and cost-effectiveness is not proven.
- Appropriate and regular hand hygiene, particularly after toilet visits, is the most effective measure for preventing HAV transmission.

Norovirus:

- Infectious dose estimated at 10-100 virus particles
- DNA viral load of genotype II is > 100 fold higher than that of genotype I; could account for the higher transmissibility of this genotype through the fecal-oral route
    - In 2006 in Michigan, genotype II was identified in 97% of 89 confirmed outbreaks
    - 2000-2004 predominant US genogroup was genotype II (79%)
- Contamination of hands, food, and contact surfaces through fecal transfer or aerosolization can easily infect other workers & patrons

Norovirus:

- Manufacturing company in Sweden
- Over 400 office workers ill who ate at canteen
  - Tomatoes from the salad buffet (RR 5.6, 95% CI 3.2–9.6) and hamburgers (RR 4.9, 95% CI 2.4–9.8) were the most likely vehicles
  - Norovirus GI.3 (Desert Shield) identified in stool samples from three office workers and from a food handler who prepared the tomatoes and hamburger ingredients before vomiting at the workplace
- The outbreak could have been prevented if the food items prepared by the food handler some hours before vomiting had not been served.

Rotavirus:

- Infectious dose estimated at 10-100 virus particles
- Infected individual can shed $>10^{12}$ rotavirus per g or ml of stool
- Virus remains infectious for many months

- 14 foodborne rotavirus outbreaks in New York in 1980s-1990s
  - thought due to excellent surveillance in area
  - likely many outbreaks in US not detected, misdiagnosed or included in multiple pathogen outbreaks

- Although adults tend to have immunity, studies show they can develop diarrhea when exposed
- Outbreak among college students in DC in 2000 associated with tuna & chicken salad sandwiches – infected cooks likely source

Salmonella:

- Although volunteer studies indicate a high infectious dose, outbreak investigations show $<10^1$ to 10^9 CFU
- An attack rate of 55% resulted from an average dose of 3.8 log CFU of *S*. Typhimurium in imitation ice cream
- Food worker associated outbreaks usually occur with egg-based mayonnaise salad items
- Following contamination of RTE foods and temperature abuse, levels could reach 10^1 to 10^3 CFU/g, sufficient to cause an outbreak
- Outbreaks with fatty foods caused by;
  - < 10 CFU *S*. Napoli per g of chocolate bars
  - 2.5 CFU *S*. Eastbourne in chocolate balls
  - 6-23 CFU *S*. Newport per g in hamburger

Shigella:

- *S. sonnei* < 500 CFU - many worker-associated outbreaks
- Festival 1988, Michigan: 3,175 cases
  - 563 staff responsible for set became infected but responded to treatment so organizers proceeded with the festival. Fifty volunteers, many of whom lacked training in proper food handling techniques, prepared the tofu salad identified as the vehicle of infection.

- Antibiotic-resistant, pandemic strain of *S. dysenteriae* infective dose was 200 CFU
- *S. flexneri* <140 CFU
- < 10 CFU for virulent strains

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Organisms Requiring a Large Infectious Dose:

- *Clostridium perfringens*
- Enteropathogenic *E. coli* (EPEC)
- Enterotoxigenic *E. coli* (ETEC)
- Enteroaggregative *E. coli* (EAEC)
- *Listeria monocytogenes*
- Some strains of *Salmonella*
- *Staphylococcus aureus*
- Streptococcus group D
- *Vibrio cholerae*
- *Vibrio parahaemolyticus*

No evidence directly implicating *C. perfringens* or *L. monocytogenes* in worker-related outbreaks

Clostridium perfringens:

- Inspection of a roast beef sandwich restaurant over 3 days found many pieces of equipment and preparation area contaminated with *C. perfringens* spores.
- All 9 stool specimens collected from 7 workers and 4/10 hand-rinse cultures were positive (Bryan & Kilpatrick, 1971)

- Outbreak opportunities only limited by preventing temperature abuse of cooked meat & poultry

Listeria monocytogenes:

- Implicated in large outbreaks associated with deli meats at both processing and retail
- Transfer has occurred from slicing machines
- There has been no direct link with fecal-oral route involving food workers although this pathogen has been found in stools.

Streptococcus pyogenes, S. aureus:

- Unique because they asymptomatically colonize nasopharynx & throat for long periods of time
- Outbreaks reflect the high nasal carriage in the population allowing frequent contamination of hands and food during preparation.
- Lesions on face or hands may be infected with *S. aureus*

- Infectious dose for *S. pyogenes* low at $<10^3$ CFU
- Outbreaks reported where workers sneezed on food that was then temperature abused

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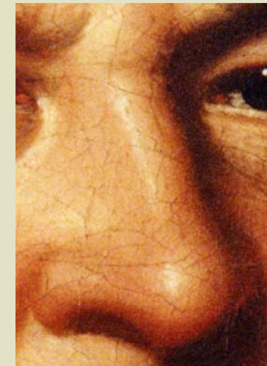
S. aureus:



- 67% of apparently healthy food workers had same phage type as the food in 131 *S. aureus* outbreaks in the US, 1977-1981

  (Holmberg & Blake 1984)
- Temperature abuse allows growth and production of enterotoxin at ≤ 1.0 µg, enough to produce symptoms
- Brazil 1998; 4000/8000 ill, 396 hospitalized, 16 deaths
  - Food prepared over 2 days and left at room temperature for a day

  (Do Carmo et al. 2004)
- Fewer outbreaks reported in last decade:
  - Better temperature control?
  - Less investigation due to short duration of illness?

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Campylobacter:

- Leading cause of diarrheal disease in developed countries
- Infectious dose low 500-800 CFU
- Rarely associated with food worker associated outbreaks
- Enters food service with poultry but dies rapidly in dry, warm conditions and will not grow in many foods
- Frequently associated with raw milk outbreaks
- 13% asymptomatic carriage in colonized individuals
- Shed ≥ 7 days after recovery
- Short duration immunity

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E. coli:

- Enteropathogenic, enterotoxigenic and enteroaggregative *E. coli* strains require large numbers to cause diarrhea (10^6 – 10^8)
  - not likely to be involved with food workers
  - endemic in developing countries where outbreaks may not yet be investigated and published

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Enteroinvasive & enterohemorrhagic *E. coli* strains:

- Assumed low infectious dose from outbreak data:
  - <100 or even < 10 CFU for O157:H7
- Relatively few asymptomatic carriers in the community :
  - 4/350 farm workers in an Italian study
  - enterohemorrhagic *E. coli* survives better and can grow in most RTE foods
  - extensive precautions in meat processing industry makes contamination rare but does occur in ground beef
- An outbreak in Belgium identified the same *E. coli* strains from ice cream, patients, and cattle. A worker who made the ice cream had contact with the animals (De Schrijver, et al. 2008)

Vibrio parahaemolyticus:

- Never linked to food worker outbreaks or person-to-person transmission
- New evidence indicates that some strains have infected persons with doses $\leq 10^{3}$ CFU (Gifford, 2008)
- Potentially food worker error could result in serious illness in susceptible individuals
  - Does not typically colonize humans
  - Occurs in select marine environments
  - Not a routine part of surveillance activities

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Vibrio cholerae:

- Toxigenic O1 serotypes infective dose is 10^3
- O139 serotypes infective dose is 10^4 organisms
- A non-O1 strain produces a heat-stable enterotoxin, NAG-ST that colonizes the gut at 10^6 CFU

- Food workers frequently implicated in cholera outbreaks: rice, shellfish, even cold meals served on airlines
- In each case poor hygiene & opportunities for pathogen growth were reported

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Yersinia enterocolitica and parasites:

- *Y. enterocolitica:*
  - high infective dose 10^6-10^9 CFU
  - more infective at lower temperatures:

    22°C rather than 37°C
  - has been associated with food worker outbreaks

- *Cryptosporidium*, *Cyclospora*, and *Giardia* all have very low infective doses and have been associated with food worker outbreaks

Carriage and Shedding of Pathogens:

- Postsymptomatic shedding may be of long duration for *Campylobacter*, *Salmonella*, *Shigella*, *V. cholerae*, *Yersinia*, enteric viruses and parasites
- Lasts the longest in children

- Asymptomatic cases may originate during outbreaks:
  - *E. coli* O157 outbreak: 14% of cases asymptomatically excreted the pathogen for up to 39 days
  - Yersiniosis outbreak in Belgium daycare: 81% of children were asymptomatic

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Carriage and Shedding of Pathogens:

- Persons with close contact to *Salmonella* index cases can have a high asymptomatic carriage rate
- Estimated that 200,000 individuals in US excreting *Salmonella* at any one time and many would be food workers (Buchwald & Blaser 1984)
- Long term carriers of *S.* typhi are rare but can excrete 10^{11} CFU/g feces and have been responsible for several outbreaks

Public Health Implications:

- The infective period for an individual depends on the organism:
  - Norovirus is thought to be shed within a short period before and after the illness stage
  - HAV has an incubation period of 15 - 50 days and is maximally infective during the latter half of the incubation period.
- Incubation periods range from hours (*S. aureus*) to many weeks (HAV)
- The longer the incubation period the more likely infected persons will excrete the pathogen
- The longer the individual has GI symptoms the more opportunities for fecal contamination
- GI symptoms may last days, weeks or even months

Public Health Implications:

- Workers will work when ill:
  - Michigan, 2006: restaurant outbreak with 364 GI cases because workers reported ill to work
  - Canadian study showed 50% of ill workers did not stay home

    (Thomas et al 2006)
- Sickness presenteeism is lost productivity occurring when employees come to work but perform below the normal output due to illness
- Accounted for four times more lost productive time than absenteeism

  (Stewart et al 2003)
- Failure to take time of resulted in longer absences:
  - health worsened
  - additional workers became infected raising total employee absence time

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Management Implications:

- Communication between food service managers and employees is vital
- Information about the risks of pathogen infection & transmission must be provided to all employees
- Workers need to be encouraged to report illness
- If a worker displays symptoms of an enteric infection the manager needs to be informed and allowed to make a decision concerning when the employee should be sent home and when to return to work
- Approximately 15% of food service workers receive paid sick days

Summary:

- Uncertainty associated with minimum infectious dose data
- The postsymptomatic excretion time for many enteric pathogens can be long posing a problem for managers & health authorities as they attempt to set reasonable policies
- Because workers may be asymptomatic the only solution is proper hygiene & creation of barriers against pathogen transmission to foods
- Handwashing does not eradicate the risk of transmission of illness to fellow workers and patrons, but will reduce pathogen load on hands and in food preparation environment

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QUESTIONS?