Estimating the total health-related impact of foodborne illness in Ontario, using Monte Carlo simulation to characterize uncertainty

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Health-related impacts

- **Health-related**: associated with health impacts BUT not necessarily borne by the health care system

- **Included:** lost time, doctor's visits, hospitalizations, mortality (value of a statistical life), certain chronic sequelae (eg Guillain-Barre syndrome from Campylobacter)

- **<u>Not</u> included:** certain chronic sequelae (eg. reactive arthritis), lost sales, recalls, political impacts

Purpose of health-related impact estimates

- To rank risks from foodborne hazards and pathogen-food combinations, to ensure Ministry resources are allocated based on risk

- Estimates now being incorporated into impact component of Food Safety Universe Database

How estimates are made

1. Estimate the *total* number of foodborne illnesses for each pathogen, accounting for underreporting

2. Estimate the **number** and **cost** of lost work days, Dr.'s visits, hospitalizations, mortality, and certain chronic sequelae associated with each pathogen

3. Quantify uncertainty associated with estimates by using distributions (as opposed to point estimates) to describe input variables, and performing Monte Carlo simulation in the @risk software package

Groups of pathogens examined

1. Reportable: All diagnosed cases required to be reported through the Ontario Reportable Disease Information System (RDIS) of the Ontario Ministry of Health and Long Term Care (e.g., Listeria, VTEC, *Salmonella*, Hepatitis A)

2. Non-reportable: Only outbreak-associated cases involving these organisms are required to be reported through the RDIS database (e.g., *S. aureus*, *C. perfringens*, Norwalk viruses)

3. Unknown: include organisms that cause disease but have not yet been formally recognized as causes of disease (e.g., *E. coli* O157:H7 prior to 1982)

Estimating *total* number of cases: reportable pathogens

- 11 reportable pathogens or diseases, that may be foodborne, were examined:
  - *Campylobacter*, *Salmonella*, VTEC, *Listeria*, *Yersinia*, *Shigella*, Hepatitis A, *Cryptosporidium*, *Giardia*, botulism, typhoid
- Reported cases (MOHLTC: 1997-2001) were used as a base with the following adjustments:
  - travel-associated cases removed
  - non-foodborne cases removed
  - under-reporting accounted for

Estimating *total* number of cases: reportable pathogens

- Travel associated cases removed
  - illness acquired outside of Ontario
  - average for 7 pathogens **~25%** (e.g., *Salmonella*: 25%, *Shigella*: 69%, VTEC: 8% travel association)

- Non-foodborne cases removed
  - other transmission sources include: waterborne, person-person, animal contact
  - Examples of foodborne transmission rates: *Salmonella* - 80%; VTEC - 60%; Hepatitis A - 36%

Estimating *total* number of cases: reportable pathogens

- Under-reporting:
  - 1) people with mild illnesses often don't seek medical attention
  - 2) doctors may not order diagnostic tests on patients
  - 3) diagnostic testing may fail to determine the responsible pathogen

- Ontario specific rates estimated using U.S. (CDC) rates as a base (except for VTEC for which an Ontario specific rate was available)

- Assumption: *actual* foodborne illness rates are similar in the U.S. and Ontario. Since incidence of *reported* cases is higher in Ontario compared with U.S., Ontario under-reporting rates were estimated to be lower than U.S. rates

Under-reporting rates

Pathogen/disease	ON rate	CDC rate
GI without bloody diarrhea		
Campylobacter	**17X** (10X-31X)	38X
Salmonella	**17X** (10X-31X)	38X
Yersinia	**17X** (10X-31X)	38X
GI with bloody diarrhea		
VTEC[1]	**7X** (5X-12X)	20X
Shigella	**9X** (5X-16X)	20X
Severe illness		
Listeria	**1.5X** (1X-2X)	2X
Botulism	**1.5X** (1X-2X)	2X

1. Based on an Ontario study

Total case estimates: reportable pathogens

Pathogen	Reported cases[1]	Estimated Total foodborne cases	
Campylobacter	4,882	**54,000**	(35,000-77,000)
Salmonella	2,612	**29,000**	(19,000-42,000)
Yersinia	348	**4,300**	(2,700-6,000)
VTEC	431	**1,800**	(1,300-2,400)
Shigella	310	**457**	(289-656)
Hepatitis A	268	**80**	(57-107)
Listeria	38	**17**	(13-22)

1. Average 1997-2001. Includes illnesses from all modes of transmission, as well as travel associated cases.

Estimating *total* number of cases: non-reportable and unknown pathogens

- Insufficient Ontario case data, therefore estimates made based on extrapolation from U.S. (CDC) food-borne estimates accounting for population as well as certain other differences between the jurisdictions

Pathogen	U.S. est.	Ontario est.
Norwalk viruses	9,000,000	**216,000**
C. perfringens	250,000	**7,700**
Staphylococcus	185,000	**5,700**
Unknown pathogens	62,000,00	**1,600,000**

Health-related economic impact

- Total case estimates for each pathogen were used as a basis to estimate the associated number of:
  - lost work days
  - doctor's visits
  - hospitalizations
  - certain types of chronic sequelae cases
  - mortality

- Estimated costs associated with each of these events was then used to determine the health-related economic impact incurred by each pathogen.

Cost of health related impacts

- Lost time: **$495*/day**
- Doctors visit: **$75/visit**
- Hospitalization: **$770/day**
- Chronic sequelae: **$1.68M** (avg. case)
- Mortality: **$9.7M** (value of a statistical life)

* all dollar values are CDN

Health-related impact estimates

Pathogen	Total food-borne case estimate	Annual health-related economic impact (Millions of $Cdn)
Campylobacter	54,000	**128** (85 -182)
VTEC	1,800	**115** (74 -167)
Salmonella	29,000	**106** (84 -128)
Listeria	17	**53** (39 - 69)
C. perfringens	7,670	**8** (4 -13)
S. aureus	5,711	**6** (3 - 9)
Norwalk virus	216,000	**212** (123 - 329)

Health-related economic impact of pathogen-food combinations

- North American surveillance data analyzed to determine fraction of outbreaks/cases associating specific pathogens with specific foods
- For example, it was determined that ~50% of outbreaks involving ground beef are linked to VTEC, ~20% of poultry outbreaks are linked to Salmonella, and ~ 50% of Listeria outbreaks are linked to RTE meats
- A formula was also applied to account for the average size of outbreaks

Health-related economic impact of pathogen-food combinations

Notable pathogen-food combinations	Annual Economic Impact (Millions of $ Cdn)
Campylobacter/chicken	**$ 65**
Norwalk virus/salad	**$ 58**
VTEC/ground beef	**$ 54**
Listeria/RTE meats	**$ 24**
Salmonella/chicken	**$ 18**
VTEC/lettuce	**$ 12**
VTEC/unpasteurized cider	**$ 10**
Salmonella/sprouts	**$ 7**
Salmonella/cheese	**$ 5**
Listeria/smoked fish	**$ 4**

Health-related impact of food commodities

Commodity	Economic impact
Horticultural, incl. non-deli salad	$**146M**
Poultry	$**104M**
Beef	$**83M**
Deli salads	$**59M**
RTE meats	$**57M**
Fish/seafood	$**36M**
Eggs/egg products	$**31M**
Dairy, excl. raw milk	$**28M**
Pork	$**13M**

Quantifying uncertainty using Monte-Carlo simulation

- Apply probability distributions to input variables, as opposed to point estimates
  - for instance, underreporting rate of Campylobacter is described by a triangular probably distribution with a minimum value of 10, maximum value of 31 and probable value of 17
- In Monte Carlo simulation, different values from the distributions of each variable are randomly selected by the computer to make any given calculation
- The simulation is repeated thousands of times, with different values being selected from the prob. distributions each time, creating a final estimate described by a probability distribution
- Adv.: improved confidence over simply using best and worst case scenarios

Conclusions

- The health-related economic impact estimate is useful as a comprehensive measure of the impact of individual pathogens, because it accounts for both the frequency and the severity of illnesses associated with a given pathogen.

- Ranking pathogens in this way, and accounting for uncertainty in the estimates, helps decision makers in government to evaluate resource allocation and risk management options in order maximize societal benefit.