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# The Economic Benefits of Genomics Research:

# New Assays for Foodborne Pathogens

Presentation for:

The Society for Benefit-Cost Analysis

Research Funded by:

Health Canada

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March 18, 2016

# The Genomics Research & Development Initiative

- Genomics:
  - The study of the structure and function of genomes – the complete set of DNA within the single cell of an organism.
  - Emerged with development of DNA sequencing techniques in the 1970s.
- Government of Canada's Genomics R&D Initiative (GRDI):
  - Multi-million dollar program established in 1999.
  - Provides cross-agency coordination of Federal genomics research.
- Goals:
  - Protect and improve human health.
  - Develop new treatments for chronic and infectious diseases.
  - Protect the environment.
  - Promote sustainable agriculture and sustainable management of natural resources.
  - Support the health and economic welfare of all Canadians.

# Challenge: Documenting the Benefits of GRDI

- As goals suggest, GRDI encompasses wide range of research, many agencies.
- Participants have generally found it difficult to quantify/value long-term implications of emerging science.
- Continued support for GRDI hinges on demonstration of practical benefits.
- Health Canada's approach: portfolio of case studies.
- Pilot case – potential benefits of new bioassays for two foodborne pathogens:
  - *Campylobacter* – the leading cause of bacterial gastroenteritis in Canada; can also lead to chronic disability (Guillain-Barré syndrome).
  - *Listeria* – the cause of listeriosis, a less common but often fatal condition that, in congenital cases, can lead to death or lifelong disability.

# Benefits Analysis: Conceptual Overview

- Practical implications of new bioassays:
  - Will improve accuracy and speed with which food safety agencies can detect and trace sources of pathogens.
  - Improved response should reduce exposure to contaminated foods, thereby reducing incidence of infection.
- Approach to characterizing benefits:
  - Estimate baseline annual morbidity and mortality costs attributable to each pathogen.
  - Consult food safety experts re: the potential impact of the new assays on disease incidence (percent reduction).
  - Estimate annual benefits assuming pro-rata reduction in baseline morbidity and mortality costs.
- Limitations:
  - Approach focuses solely on public health benefits.
  - Ignores potential cost savings/consumer welfare benefits associated with reductions in unnecessary product recalls.

# Benefits Analysis: Methodology

- Builds on USDA Economic Research Service's analysis of the costs associated with 14 foodborne pathogens in the U.S., based on work of Hoffmann, Batz, and Morris (2012):
  - Draws on disease outcome trees for both listeriosis and campylobacteriosis provided by Batz et al. (2014).
  - Estimates baseline morbidity costs using a standard estimate of the value of a statistical life.
  - Values non-fatal cases using a cost-of-illness approach, including both direct medical costs and productivity losses.
- When possible, GRDI analysis relies on Canadian sources to estimate baseline morbidity and mortality costs.
- When necessary, analysis builds on U.S. data, adjusted to reflect conditions in Canada.
- All economic values reported in 2014 Canadian dollars.

# Baseline Incidence of Disease

- Source: Public Health Agency of Canada, National Notifiable Diseases Registry.
- Begin with mean of five most recent years for which data are available (2008-2012).
- Scale upward to account for under-reporting and under-diagnosis (Thomas et al., 2013).
  - Campylobacteriosis multiplier: 27.2.
  - Listeriosis multiplier: 1.7.
- Scale downward to focus on share of cases from foodborne sources that are domestically acquired.
- Results:
  - Campylobacteriosis: 132,000 cases per year.
  - Listeriosis: 200 cases per year.

# Listeria: Distribution of Disease Outcomes

| HEALTH OUTCOME | PERCENT OF CASES | NUMBER OF CASES |
|---|---|---|
| NON-CONGENITAL | 82.3% | 167 |
| DID NOT VISIT PHYSICIAN – RECOVERED | 8.6% | 17 |
| HOSPITALIZED - PREGNANT | 12.4% | 25 |
| POST-HOSPITALIZATION RECOVERY – PREGNANT | 12.4% | 25 |
| HOSPITALIZED – ADULT MODERATE | 2.1% | 4 |
| POST-HOSPITALIZATION RECOVERY – ADULT MODERATE | 2.1% | 4 |
| HOSPITALIZED – ADULT SEVERE (ICU) | 59.3% | 120 |
| HOSPITALIZED – ADULT SEVERE (POST ICU) | 43.8% | 89 |
| POST-HOSPITALIZATION RECOVERY – ADULT SEVERE | 43.8% | 89 |
| HOSPITALIZED - DIED | 15.5% | 31 |
| CONGENITAL | 17.7% | 36 |
| NEWBORN HOSPITALIZED – FULL RECOVERY | 11.9% | 24 |
| NEWBORN HOSPITALIZED – MILD DISABILITY | 0.4% | 1 |
| NEWBORN HOSPITALIZED – MODERATE DISABILITY | 1.3% | 3 |
| NEWBORN HOSPITALIZED – SEVERE DISABILITY | 0.4% | 1 |
| NEONATAL DEATH | 0.5% | 1 |
| STILLBIRTHS AND MISCARRIAGES | 3.2% | 6 |
| TOTAL - DOMESTICALLY ACQUIRED, FOODBORNE | 100.0% | 202 |

# Analysis of Short-term Medical Costs

- To avoid double-counting, COI analysis considers only non-fatal cases.
- Sources of unit cost estimates for medical care:
  - Outpatient facility visits (cost/visit) – World Health Organization estimates for Canada.
  - Emergency department visits (cost/visit) – Canadian Institute for Health Information (CIHI).
  - Standard hospitalization (cost/day): CIHI.
  - Intensive care (cost/day): 3x standard hospitalization cost (USDA).
  - Neo-natal intensive care (cost/day): 4x standard hospitalization cost (USDA).

# Listeria: Annual Short-term Medical Costs

| HEALTH OUTCOME | HOSPITALIZATIONS | | |
|---|---|---|---|
| | STAY (DAYS) | COST PER DAY | ANNUAL COST ($MM) |
| NON-CONGENITAL | | | |
| HOSPITALIZED - PREGNANT | 7 | $1,057 | $2.8 |
| HOSPITALIZED - ADULT MODERATE | | | |
| HOSPITALIZED - ADULT SEVERE (ICU) | | $3,171 | |
| HOSPITALIZED - ADULT SEVERE (POST ICU) | | $1,057 | |
| CONGENITAL | | | |
| NEWBORN HOSPITALIZED - FULL RECOVERY | 21 | $1,057 | $0.9 |
| NEWBORN HOSPITALIZED - MILD DISABILITY | | $4,229 | |
| NEWBORN HOSPITALIZED - MODERATE DISABILITY | | | |
| NEWBORN HOSPITALIZED - SEVERE DISABILITY | | | |
| TOTAL | | | $3.8 |

# Analysis of Long-term Medical & Education Costs

- Congenital exposure to *Listeria* can lead to long-term disability, with associated medical and special education costs.
- Analysis relies on estimates from Buzby et al. (1996) to estimate costs for mild, moderate, and severe disability.
  - Mild: $2,000 per year for 20 years.
  - Moderate: $5,000 per year for 20 years.
  - Severe: $20,000 per year for 25 years (1988 $US).
- Present value of long-term cost per case is calculated at discount rates of 3% and 8%.
- Annual costs are calculated by applying PV per case figures to the estimated incidence of cases that lead to mild, moderate, or severe disability.

# Listeria: Long-term Medical and Education Costs

| HEALTH OUTCOME | 8% DISCOUNT RATE | | 3% DISCOUNT RATE | |
|---|---|---|---|---|
| | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) |
| NEWBORN HOSPITALIZED - MILD DISABILITY | $37,715 | $0.0 | $57,150 | $0.0 |
| NEWBORN HOSPITALIZED - MODERATE DISABILITY | $94,288 | $0.2 | $142,875 | $0.4 |
| NEWBORN HOSPITALIZED - SEVERE DISABILITY | $410,059 | $0.3 | $668,906 | $0.6 |
| TOTAL | NA | $0.6 | NA | $1.0 |

# Analysis of Short-term Productivity Losses

- Short-term: patient is able to return to work within a year.
- Value of lost work day: $211 (Statistics Canada).
- Total Lost Work Days = f(Incidence, Duration, Severity, Proportion employed):
  - Incidence = Number of cases for given health outcome.
  - Duration = Average length of illness (days) for given outcome.
  - Severity = Work days missed per day of illness.
  - Proportion of patients employed = 46 percent.
- Limitation:
  - Analysis assigns no value to losses in productivity for those not classified as employed (e.g., homemakers).
  - Results therefore likely to understate true productivity losses.

# Listeria: Short-Term Productivity Losses

| HEALTH OUTCOME | DURATION OF ILLNESS (DAYS) | WORK DAYS AFFECTED | ANNUAL PRODUCTIVITY LOSS ($MM) |
|---|---|---|---|
| DID NOT VISIT PHYSICIAN – RECOVERED | 3 | 0.8 | $0.0 |
| HOSPITALIZED - PREGNANT | 7 | 5.0 | $0.0 |
| POST-HOSPITALIZATION RECOVERY – PREGNANT | 21 | 14.9 | $0.0 |
| HOSPITALIZED – ADULT MODERATE | 7 | 5.0 | $0.0 |
| POST-HOSPITALIZATION RECOVERY – ADULT MODERATE | 21 | 14.9 | $0.0 |
| HOSPITALIZED – ADULT SEVERE (ICU) | 7 | 5.0 | $0.0 |
| HOSPITALIZED – ADULT SEVERE (POST ICU) | 7 | 5.0 | $0.0 |
| POST-HOSPITALIZATION RECOVERY – ADULT SEVERE | 42 | 29.8 | $0.3 |
| TOTAL | | | $0.4 |

# Listeria: Long-Term Productivity Losses

- Analysis focuses on infants born with intellectual disabilities due to exposure *in utero*.
- Impact on long-term productivity varies with degree of disability (Buzby et al., 1996):
  - Mild disability: loss of $10,660 per year.
  - Moderate disability: loss of $36,718. per year.
  - Severe disability: loss of $39,482 per year (2014 CAD).
- Present value of losses calculated assuming they occur over a period of 50 years, between the ages of 15 and 64.
- Limitation:
  - Analysis assigns value to losses in productivity only for the share of victims we assume would be employed outside the home.
  - Results therefore likely to understate true productivity losses.

# Listeria: Long-Term Productivity Losses

| HEALTH OUTCOME | 8% DISCOUNT RATE | | 3% DISCOUNT RATE | |
|---|---|---|---|---|
| | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) |
| NEWBORN HOSPITALIZED - MILD DISABILITY | $83,705 | $0.0 | $176,051 | $0.1 |
| NEWBORN HOSPITALIZED - MODERATE DISABILITY | $288,318 | $0.4 | $606,397 | $1.6 |
| NEWBORN HOSPITALIZED - SEVERE DISABILITY | $310,019 | $0.1 | $652,040 | $0.6 |
| TOTAL | NA | $0.5 | NA | $2.3 |

# Listeria: Annual Mortality Costs

- Analysis of mortality costs employs value of statistical life (VSL) estimate of $7.3 million (2014 CAD), based on recommendation provided by Government of Canada's Policy Research Initiative (Chestnut and De Civita, 2009).
- VSL estimate applied to deaths stemming from:
  - Congenital exposure (neonatal fatalities, miscarriages, stillbirths).
  - Non-congenital exposure.

| IMPACT | NON-CONGENITAL LISTERIOSIS | CONGENITAL LISTERIOSIS | TOTAL |
|---|---|---|---|
| PREMATURE DEATHS | 31 | 7 | 38 |
| MORTALITY COSTS ($MM) | $229.3 | $54.7 | $284.0 |

# Baseline Annual Morbidity and Mortality Costs

| COST MEASURE | CAMPYLOBACTER ($MM) | LISTERIA ($MM) |
|---|---|---|
| 8% DISCOUNT RATE | | |
| MEDICAL COSTS | $32.3 | $3.8 |
| LONG-TERM CARE AND SPECIAL EDUCATION | N/A | $0.6 |
| PRODUCTIVITY LOSSES | $28.5 | $0.9 |
| PREMATURE DEATH | $200.0 | $284.0 |
| TOTAL | $260.8 | $289.3 |
| 3% DISCOUNT RATE | | |
| MEDICAL COSTS | $32.3 | $3.8 |
| LONG-TERM CARE AND SPECIAL EDUCATION | N/A | $1.0 |
| PRODUCTIVITY LOSSES | $48.4 | $2.7 |
| PREMATURE DEATH | $200.0 | $284.0 |
| TOTAL | $280.7 | $291.4 |

# Listeria: Potential Benefits of New Assay

- Estimated reduction in time required to complete testing process, from research scientist at Health Canada: 75 percent.
- Analysis treats this as a high-end estimate of potential impact on disease incidence.
- Also considers reductions of 25 and 50 percent.

| METRIC | PERCENT REDUCTION IN DISEASE INCIDENCE | | |
|---|---|---|---|
| | 25% | 50% | 75% |
| Annual Cases Avoided | 50 | 100 | 150 |
| Annual Benefits (8%) | $72 Million | $145 Million | $217 Million |
| Annual Benefits (3%) | $73 Million | $146 Million | $219 Million |
| Present Value over 20 Years (8%) | $0.71 Billion | $1.42 Billion | $2.13 Billion |
| Present Value over 20 Years (3%) | $1.08 Billion | $2.17 Billion | $3.25 Billion |

# Breakeven Analysis

- Given uncertain impact of new assays, analysis also incorporates a breakeven calculation.
- Breakeven analysis identifies the annual reduction in the incidence of disease necessary for the benefits of each new bioassay to equal the costs of its development.
- Results suggest even a small impact on disease incidence would yield a positive return on the government's investment.

| DISCOUNT RATE | BASELINE PUBLIC HEALTH COSTS (PRESENT VALUE, 20 YEARS) | GRDI PROGRAM COSTS (PRESENT VALUE) | BREAKEVEN REDUCTION IN ANNUAL INCIDENCE OF DISEASE |
|---|---|---|---|
| **CAMPYLOBACTER** | | | |
| 8% | $2.56 billion | $1.1 million | 0.044% |
| 3% | $4.18 billion | $1.1 million | 0.025% |
| **LISTERIA** | | | |
| 8% | $2.84 billion | $1.4 million | 0.048% |
| 3% | $4.30 billion | $1.3 million | 0.032% |

# Appendix A: Results of Campylobacter Case Study

- Distribution of disease outcomes.
- Annual short-term medical costs.
- Short-term productivity losses.
- Long-term productivity losses.
- Annual mortality costs.
- Potential benefits of new assay.

# Campylobacter: Distribution of Disease Outcomes

| HEALTH OUTCOME | PERCENT OF CASES | NUMBER OF CASES |
|---|---|---|
| ACUTE ILLNESS - DOMESTICALLY ACQUIRED, FOODBORNE | 100.0% | 131,604 |
| DID NOT VISIT PHYSICIAN – RECOVERED | 93.6% | 123,181 |
| VISITED PHYSICIAN – RECOVERED | 5.4% | 7,107 |
| HOSPITALIZED | 1.0% | 1,316 |
| POST-HOSPITALIZATION RECOVERY | 1.0% | 1,303 |
| HOSPITALIZED - DIED | 0.01% | 13 |
| CHRONIC ILLNESS (GUILLAIN-BARRÉ SYNDROME) | 0.2% | 316 |
| HOSPITALIZED – ICU | 95.5% | 302 |
| HOSPITALIZED – POST ICU | 95.5% | 302 |
| POST-HOSPITALIZATION RECOVERY | 75.6% | 239 |
| CHRONIC – DO NOT RESUME WORK | 19.9% | 63 |
| DIED | 4.5% | 14 |

# Campylobacter: Annual Short-term Medical Costs

| HEALTH OUTCOME | OUTPATIENT FACILITY VISITS | | | EMERGENCY DEPARTMENT VISITS | | | HOSPITALIZATIONS | | | TOTAL ($MM) |
|---|---|---|---|---|---|---|---|---|---|---|
| | VISITS PER CASE | COST PER VISIT | ANNUAL COST ($MM) | VISITS PER CASE | COST PER VISIT | ANNUAL COST ($MM) | STAY (DAYS) | COST PER DAY | ANNUAL COST ($MM) | |
| ACUTE ILLNESS (CAMPYLOBACTERIOSIS) | | | | | | | | | | |
| DID NOT VISIT PHYSICIAN - RECOVERED | 0 | $136 | $2.0 | 0 | $192 | $0.2 | 0 | $1,022 | $8.0 | $10.2 |
| VISITED PHYSICIAN - RECOVERED | 1.7 | | | 0.1 | | | 0 | | | |
| HOSPITALIZED | 0.9 | | | 0.3 | | | 6 | | | |
| POST-HOSPITALIZATION RECOVERY | 1.0 | | | 0 | | | 0 | | | |
| CHRONIC ILLNESS (GUILLAIN-BARRÉ SYNDROME) | | | | | | | | | | |
| HOSPITALIZED - ICU | N/A | | | | | | 18.4 | $3,067 | $22.1 | $22.1 |
| HOSPITALIZED - POST ICU | N/A | | | | | | 16.4 | $1,022 | | |
| TOTAL | | | | | | | | | $30.1 | $32.3 |

# Campylobacter: Short-Term Productivity Losses

| HEALTH OUTCOME | DURATION OF ILLNESS (DAYS) | NUMBER OF WORK DAYS AFFECTED | ANNUAL PRODUCTIVITY LOSS ($MM) |
|---|---|---|---|
| ACUTE ILLNESS | | | |
| DID NOT VISIT PHYSICIAN – RECOVERED | 2.0 | 0.5 | $5.9 |
| VISITED PHYSICIAN – RECOVERED | 5.0 | 1.7 | $1.1 |
| HOSPITALIZED | 6.0 | 4.3 | $0.5 |
| POST-HOSPITALIZATION RECOVERY | 3.0 | 2.1 | $0.3 |
| SUBTOTAL | | | $7.8 |
| CHRONIC ILLNESS (GUILLAIN-BARRÉ SYNDROME) | | | |
| HOSPITALIZED – ICU | 18.4 | 13.1 | $0.4 |
| HOSPITALIZED – POST ICU | 16.4 | 11.6 | $0.3 |
| POST-HOSPITALIZATION RECOVERY | 60.8 | 43.2 | $1.0 |
| SUBTOTAL | | | $1.7 |
| TOTAL | | | $9.5 |

# Campylobacter: Long-Term Productivity Losses

- Analysis focuses on patients who develop Guillain-Barré syndrome and cannot return to work.
- Average period of lost productivity: 47 years per patient.
- Average value of lost productivity:
  - $24,900 per patient annually.
  - Present value of $302,000 @ 8 percent discount rate.
  - Present value of $620,000 @ 3 percent discount rate.
- Limitation:
  - Analysis assigns value to losses in productivity only for the share of patients we assume would otherwise be employed outside the home.
  - Results therefore likely to understate true productivity losses.

# Campylobacter: Long-Term Productivity Losses

| HEALTH OUTCOME | 8% DISCOUNT RATE | | 3% DISCOUNT RATE | |
|---|---|---|---|---|
| | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) | PRESENT VALUE OF LIFETIME COST PER CASE | ANNUAL COST AT BASELINE INCIDENCE ($MM) |
| CHRONIC – DO NOT RESUME WORK | $302,237 | $18.9 | $620,128 | $38.9 |

# Campylobacter: Annual Mortality Costs

- Analysis of mortality costs employs value of statistical life (VSL) estimate of $7.3 million (2014 CAD), based on recommendation provided by Government of Canada's Policy Research Initiative (Chestnut and De Civita, 2009).
- For *Campylobacter*, analysis applies this value to deaths stemming from:
  - Guillain-Barré syndrome.
  - Acute campylobacteriosis.

| IMPACT | ACUTE CAMPYLOBACTERIOSIS | GUILLAIN-BARRÉ SYNDROME | TOTAL |
|---|---|---|---|
| PREMATURE DEATHS | 13 | 14 | 27 |
| MORTALITY COSTS ($MM) | $96.1 | $104.0 | $200.0 |

# Campylobacter: Potential Benefits of New Assay

- Direct estimate of potential reduction in disease incidence from research scientist at Canadian Food Inspection Agency:
  - Central estimate – 40 percent.
  - Potential range – 20 to 60 percent.

| METRIC | PERCENT REDUCTION IN DISEASE INCIDENCE | | |
|---|---|---|---|
| | 20% | 40% | 60% |
| Annual Cases Avoided | 26,000 | 53,000 | 79,000 |
| Annual Benefits (8%) | $52 Million | $104 Million | $156 Million |
| Annual Benefits (3%) | $56 Million | $112 Million | $168 Million |
| Present Value over 20 Years (8%) | $0.51 Billion | $1.02 Billion | $1.54 Billion |
| Present Value over 20 Years (3%) | $0.84 Billion | $1.67 Billion | $2.51 Billion |

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