What are emerging pathogens?

1. Infectious diseases whose incidence has increased in the past 2 decades or threatens to increase in the near future
2. New infections resulting from changes or evolution of existing organisms
3. Known infections spreading to new geographic areas or populations

Modified Definition from “Emerging Infectious Diseases”

What are emerging pathogens?

4. Old infections reemerging as a result of their appearing in new vehicles
5. Previously unrecognized as potential foodborne infections

‘6.’ Organisms on which to keep a watchful eye

Factors in the Emergence of Pathogens

- Microbial adaptation and change
- Human susceptibility to infection
- Climate and weather
- Changing ecosystems
- Human demographics and behaviour
- Economic development and land use
- International travel and commerce
- Technology and industry
- Breakdown of public health measures
- Poverty and social inequality
- War and famine
- Lack of political will
- Intent to harm

Morens et al., 2004
I. Infectious diseases whose incidence has increased in the past 2 decades or threatens to increase in the near future

Emerging Pathogens

1. Infectious diseases whose incidence has increased in the past 2 decades or threatens to increase in the near future

Foodborne Viruses

<table>
<thead>
<tr>
<th>Virus</th>
<th>Family</th>
<th>Culturable</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatitis A</td>
<td>Picornaviridae</td>
<td>Yes 1</td>
<td>Hepatitis</td>
</tr>
<tr>
<td>Hepatitis E</td>
<td>Hepeviridae</td>
<td>No</td>
<td>Hepatitis</td>
</tr>
<tr>
<td>Norovirus</td>
<td>Caliciviridae</td>
<td>No</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Sapovirus</td>
<td>Caliciviridae</td>
<td>No</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Reoviridae</td>
<td>Yes</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Astrovirus</td>
<td>Astroviridae</td>
<td>Yes 1</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Adenovirus</td>
<td>Adenoviridae</td>
<td>Yes 1</td>
<td>Respiratory, eye and GI infection</td>
</tr>
<tr>
<td>Enterovirus</td>
<td>Picornaviridae</td>
<td>Yes 1</td>
<td>Poliomyelitis, meningitis and encephalitis</td>
</tr>
</tbody>
</table>

1 Not all strains within the genus are culturable; wild-type strains are often difficult to culture


Role of Noroviruses in Sporadic Gastroenteritis

- Leading cause of epidemic gastroenteritis in all age groups, causing >90% of non-bacterial and ≈50% of all-cause epidemic gastroenteritis worldwide
- The second most common cause of severe childhood gastroenteritis, following rotavirus
- Global burden estimate: >1 million hospitalizations and 200,000 deaths / year among children <5 years of age
- GII.4 NoV appear to be the most prevalent strain; may be the primary target for vaccine development
- Found in retail meat samples (Mattison et al., 2007)
Acute gastroenteritis in children/infants

Global burden estimate: 138 million infections, over 600,000 deaths each year

Rotaviruses

- Acute gastroenteritis in children/infants
- Faecal-oral transmission, highly infective
- Global burden estimate: 138 million infections, over 600,000 deaths each year
- Severe disease preventable by live attenuated oral vaccines
- Vaccination programs being evaluated in Europe
- Found in raw retail meats; 18% of retail poultry, beef or pork in Canada were positive for group A rotaviruses

Hepatitis E

- Asia, Africa, Mexico; drinking water
- 20% mortality rate in pregnant women; 1-3% in the rest of the population
- Increase in UK non-travel related cases, target population men around age 55; same for other countries?
- In US, low prevalence of anti-HEV (<2%) found in healthy populations

Hepatitis E virus in pig livers

Reports of HEV have been increasing in Germany since 2002

In 2005, large waterborne HEV outbreak occurred in Hyderabad, India with 1611 cases of illness

Cross-species infection of HEV is probable

Pigs may be reservoir; undercooked raw meat may partially explain occurrence of autochthonous HEV in industrialized countries

People working with swine are at a higher risk of HEV infection
Emerging Pathogens

2. New infections resulting from changes or evolution of existing organisms

What are verotoxigenic \textit{E. coli}?

- A diverse group of \textit{E. coli}
  - All produce exotoxins, called verotoxins (VT), Shiga toxins (STX), Shiga-like toxins (SLT)
- VTEC vary in their ability to cause disease
  - Virulent VTEC such as \textit{E. coli} O157:H7 cause:
    - Diarrhea; Bloody diarrhea (hemorrhagic colitis)
    - Hemolytic uremic syndrome (HUS)
  - Children and the elderly are most susceptible
  - Most infections (80%) are sporadic
- Over 400 VTEC serotypes isolated from humans
  - >90% of known infections are caused by fewer than 10 serogroups

R. Johnson, 2006

Non-O157 \textit{E. coli} outbreaks in North America

<table>
<thead>
<tr>
<th>Year</th>
<th>Serogroup</th>
<th>Location</th>
<th># of cases</th>
<th>Vehicle of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>O111:NM</td>
<td>Quebec</td>
<td>2</td>
<td>Ground beef</td>
</tr>
<tr>
<td>2005</td>
<td>O111</td>
<td>NY, N. Carolina</td>
<td>212</td>
<td>Unpasteurized apple cider</td>
</tr>
<tr>
<td>1999</td>
<td>O111:NM</td>
<td>Texas</td>
<td>58</td>
<td>Salad</td>
</tr>
<tr>
<td>2006</td>
<td>O121:NM</td>
<td>Utah</td>
<td>4</td>
<td>Lettuce</td>
</tr>
<tr>
<td>1999</td>
<td>O121</td>
<td>Connecticut</td>
<td>11</td>
<td>Lake water</td>
</tr>
<tr>
<td>2001</td>
<td>O26</td>
<td>Minnesota</td>
<td>4</td>
<td>Lake water</td>
</tr>
<tr>
<td>2000</td>
<td>O103</td>
<td>Washington</td>
<td>18</td>
<td>Punch</td>
</tr>
<tr>
<td>2005</td>
<td>O45</td>
<td>New York</td>
<td>52</td>
<td>Infected food handler</td>
</tr>
</tbody>
</table>


Review

Emergence, Distribution, and Molecular and Phenotypic Characteristics of \textit{Salmonella enterica} Serotype 4,5,12:i:-

Andrew I. Moseley; Kyle D. Sayer; Louis D. Perkins; and Martin Winstone

Abstract

\textit{Salmonella} serotypes represent one of the most common causes of hospitalised foodborne disease around the world. The \textit{Salmonella} enterica species contains more than 2,500 serotypes, and understanding of new human pathogen \textit{Salmonella} enterica and serotype differences presents a public health threat. \textit{Salmonella} enterica and serotype differences are major public health threats. \textit{Salmonella} enterica and serotype differences have been identified with the mid-20th-century emergence of new human pathogen \textit{Salmonella} enterica and serotype differences. The use of this positive and negative approach has increased understanding of the molecular and phenotypic differences among human pathogens of the \textit{Salmonella} enterica species.
Emerging Pathogens

3. Known infections spreading to new geographic areas or populations

Vibrio cholerae

- The Latin American epidemic strain found off the coast of southern US in 1991 may have been introduced when a cargo ship discharged contaminated ballast water
- Likely a similar mechanism led to the introduction of cholera for the first time this century into Peru in 1991 from Asia and Africa
- Serogroups O1, non-O1 and O139 (which emerged in Bengal, India in 1992) are foodborne illness threats
- Seven distinct pandemics have occurred since 1817
- Able to directly take up DNA present in the environment

Source: Pruzzo et al., 2008; Pazzani et al., 2006; Medlorn et al., 2005

Vibrio vulnificus

- Source: Pruzzo et al., 2008

Recent Foodborne Outbreaks of Cyclosporiasis in North America

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th># of cases</th>
<th>Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta GA</td>
<td>May 2000</td>
<td>21</td>
<td>raspberries (Guatemala)</td>
</tr>
<tr>
<td>Vancouver BC</td>
<td>May 2001</td>
<td>17</td>
<td>Thai basil</td>
</tr>
<tr>
<td>Vermont</td>
<td>Jan 2002</td>
<td>22</td>
<td>raspberries (Chile?)</td>
</tr>
<tr>
<td>Vancouver BC</td>
<td>Jun-Jul 2003</td>
<td>10</td>
<td>cilantro?</td>
</tr>
<tr>
<td>Texas/Illinois</td>
<td>Feb 2004</td>
<td>95</td>
<td>basil/mesclun?</td>
</tr>
<tr>
<td>Vancouver BC</td>
<td>May-Jun 2004</td>
<td>9</td>
<td>cilantro?</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Jun-Jul 2004</td>
<td>&lt;100</td>
<td>snow peas (Guatemala)</td>
</tr>
<tr>
<td>Florida</td>
<td>Mar-Apr 2005</td>
<td>293</td>
<td>basil (Peru)</td>
</tr>
<tr>
<td>Ontario</td>
<td>Apr 2005</td>
<td>40</td>
<td>basil</td>
</tr>
<tr>
<td>Quebec</td>
<td>Jun 2005</td>
<td>220</td>
<td>basil</td>
</tr>
<tr>
<td>Vancouver BC</td>
<td>Jun-Jul 2006</td>
<td>14</td>
<td>basil / garlic?</td>
</tr>
<tr>
<td>BC</td>
<td>May-Jul 2007</td>
<td>23</td>
<td>fresh herbs?</td>
</tr>
</tbody>
</table>

Source: Dixon, 2008

Emerging Pathogens

4. Older pathogens reemerging as a result of their appearing in new vehicles
Adult Colonization Botulism

- Three cases reported in Ontario from Nov 2006 to Feb 2007
- All three patients had Crohn’s disease – risk factor?
- One case linked to consumption of peanut butter
- Only 10 cases documented worldwide from 1973 to 2007

Health Canada, 2009; Manuscript in preparation

Salmonella Outbreaks in Low-Moisture Products

<table>
<thead>
<tr>
<th>Year</th>
<th>Product</th>
<th>Serotype</th>
<th>Country</th>
<th>Cases</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>Raw almonds</td>
<td>Enteritidis</td>
<td>US/Canada</td>
<td>158</td>
<td>Eurosurveillance vol12 issue 3-6</td>
</tr>
<tr>
<td>2001</td>
<td>Chocolate</td>
<td>Oranienburg</td>
<td>Multiple</td>
<td>400+</td>
<td>BMC Infect Dis. 2005 Feb 3-5/7</td>
</tr>
<tr>
<td>2002</td>
<td>Tahini, Halva</td>
<td>Montevideo</td>
<td>Australia</td>
<td>35</td>
<td>Eurosurveillance Vol17 issue 18</td>
</tr>
<tr>
<td>2003-04</td>
<td>Raw almonds</td>
<td>Enteritidis</td>
<td>US/Canada</td>
<td>28</td>
<td>MMWR 52(52);558-561</td>
</tr>
<tr>
<td>2005</td>
<td>Chocolate</td>
<td>Montevideo</td>
<td>UK</td>
<td>377</td>
<td>Food Production Daily 25/Aug/05</td>
</tr>
<tr>
<td>2006-07</td>
<td>Peanut butter</td>
<td>Tennessee</td>
<td>US</td>
<td>628</td>
<td>MMWR 06(27);231-234</td>
</tr>
<tr>
<td>2007</td>
<td>Children’s snack</td>
<td>Wandsworth/Typetum</td>
<td>US</td>
<td>637</td>
<td>CDC, July 18, 2007</td>
</tr>
<tr>
<td>2008</td>
<td>Infant formula</td>
<td>Give</td>
<td>France</td>
<td>61</td>
<td>Eurosurveillance Vol13 issue 39</td>
</tr>
<tr>
<td>2008-09</td>
<td>Peanut butter</td>
<td>Typetum</td>
<td>US</td>
<td>657</td>
<td>CDC, March 17, 2001</td>
</tr>
</tbody>
</table>

Adapted from Scott, (2009) IAFP

Produce – “New” Vehicles

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli O157:H7</td>
<td>melons, tomatoes, melons, mango, fruit salad, snow peas</td>
</tr>
<tr>
<td>Salmonella</td>
<td>raspberries, basil, snow peas</td>
</tr>
<tr>
<td>Cyclospora</td>
<td>carrot juice, snow peas</td>
</tr>
<tr>
<td>C. botulinum</td>
<td>sugar snaps, baby corn, watercress, green onions</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>Norovirus</td>
</tr>
<tr>
<td>Shigella</td>
<td>fresh-cut fruit</td>
</tr>
</tbody>
</table>

L. Harris, 2006; Nuoti et al., 2004; Lofthol, et al., 2009

Emerging Pathogens

5. Previously unrecognized and potential foodborne infections

- C. difficile
- MRSA
- Ebola
- Chagas
**Clostridium difficile**

- Increasing prevalence of “outbreak strain” 027/NAP1 in various countries:
  - Hospitals; Outbreaks, severe disease
  - Animals – cattle, pigs
  - Food – retail ground meat (20% positive in Canada, 2005, similar to 027/NAP1), raw vegetables
- Animal isolates often indistinguishable from pathogenic human strains
- Animal reservoirs via food are possible sources of *C. difficile* infection

Rodríguez-Palacios et al., 2007; Weese, 2006

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**Clostridium difficile**

- Vulnerable populations – elderly, children, antibiotic use
- Antimicrobial resistant, heat-tolerant, disinfection-resistant
- Some of the community-acquired *C. difficile* infections do not appear to be linked to recent antibiotic therapy, increased age, co-morbidity or prior hospital admission
- Rate of community-acquired *C. difficile* is increasing; 3% of healthy adults and up to 80% of infants are carriers


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**MRSA as a foodborne pathogen?**

- High prevalence of methicillin resistant *Staphylococcus aureus* in pigs
- Toxin associated with *MRSA* and pig farming
- Risk factors: Community-acquired CDAD
- Disruption of normal colonic microflora
  - Usually limited or no antibiotic exposure
  - Minor use of fluoroquinolones
  - Chronic GI conditions
- Exposure to *C. difficile*
  - Home surfaces?
  - Family members
  - Pets?
  - Soil?
  - Foods?
- Host factors
  - Young children
  - Post-partum women
  - Use of PPIs
- Microbial factors
  - MRSA


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**Chagas’ Disease**

- Transmitted by the protozoan parasite *Trypanosoma cruzi*
- Worldwide incidence estimated at 200,000 cases per year
- WHO estimates that about 5-6 million people are infected in Andean and Central America
- Acute and chronic phases of infection occur
- Principally transmitted by infected insects which contaminate fruits under inadequate harvest, transport, storage and manufacturing conditions
- Where Chagas’ is endemic, it should now be considered a potential foodborne disease

J. Food Protect. (72):441-446; Pereira et al., 2009
The Unknown

- Unknown etiology for 80% of foodborne illnesses; 64% of deaths
- Detection methods, long incubation, toxins
- 1978 – new disease identified every 10-15 years
- 1988 – new disease identified every 8-9 years
- Today – new disease identified every 14-16 months

Organisms on which to keep a watchful eye

- Laribacter hongkongensis
- Plesiomonas shigeloides
- Cronobacter spp.
- Mycobacterium avium subsp. paratuberculosis
- Streptococcus zooepidemicus/S. suis
- Campylobacter concisus
- Hafnia alvei
- Escherichia albertii
- Helicobacter pullorum
- Enterocytozoon bieneusi

Sources: Mead et al., 1998; Cynthia Johnson, USDA, from Emerging Animal Health Issues Identification and Analysis Training Course, Ottawa, Sept 15, 2006
Concluding thoughts

- Continue to be evolutionary conflicts between rapidly evolving and adapting foodborne pathogens and their slowly evolving hosts
- Compounded by a backdrop of environmental and behavioural changes
- These changes provide new ecological niches into which evolving microbes can easily fit and prosper
- Must do more to try and keep one step ahead

Morens et al., 2004

Nothing microbes do, whether under the duress imposed by antimicrobials or from some less evident pressure, should surprise us. It’s their world; we only live in it.

-Sepkowitz. K.A.

Muchas gracias!
Thank you very much!