VIRUSES AND PRIONS TRANSMITTED VIA FOOD AND WATER

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Introduction

• Viruses transmitted via food and water are, with one exception, human enteric viruses.
• Only a few primate species other than humans are infected by these viruses.
• Enteric viruses infect perorally and are shed in feces.
• Replication occurs only in susceptible cells; no DNA is involved in the replicative cycles of the RNA viruses.
• Prions are a newly recognized class of infectious agents that cause fatal neurological illnesses.

Major groups of human enteric viruses.

<table>
<thead>
<tr>
<th>Size (nm)</th>
<th>NA strands</th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>25–35</td>
<td>single</td>
<td>astro-</td>
<td>parvo-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>calici-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>picorna-</td>
<td></td>
</tr>
<tr>
<td>70–85</td>
<td>double</td>
<td>reo-</td>
<td>adeno-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rota-</td>
<td></td>
</tr>
</tbody>
</table>

Causes of foodborne outbreaks, U.S., '98–’02

<table>
<thead>
<tr>
<th>Rank</th>
<th>Agent</th>
<th>Cases</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Norovirus</td>
<td>27,121</td>
<td>21.2</td>
</tr>
<tr>
<td>2</td>
<td>Salmonella</td>
<td>16,821</td>
<td>13.1</td>
</tr>
<tr>
<td>3</td>
<td>Clostridium perfringens</td>
<td>6,274</td>
<td>5.2</td>
</tr>
<tr>
<td>4</td>
<td>Escherichia coli</td>
<td>4,864</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>Shigella</td>
<td>3,677</td>
<td>2.9</td>
</tr>
<tr>
<td>6</td>
<td>Staphylococcus aureus</td>
<td>2,766</td>
<td>2.2</td>
</tr>
<tr>
<td>7</td>
<td>Campylobacter</td>
<td>1,440</td>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
<td>Hepatitis A virus</td>
<td>981</td>
<td>0.8</td>
</tr>
<tr>
<td>9</td>
<td>Vibrio parahaemolyticus</td>
<td>613</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>Bacillus cereus</td>
<td>571</td>
<td>0.4</td>
</tr>
</tbody>
</table>

(from Lynch et al., 2006)
Noroviruses: Norwalk-like gastroenteritis viruses

- CDC (U.S., '98–'02): 657 outbreaks, 27,171 illnesses, 0 deaths; **est. 9.2 million foodborne/yr**; CAST: 181,000 cases/year, 0 deaths, $890/case
- History and naming
  - Norwalk, Ohio, gastroenteritis outbreak, 1972
  - Small round structured viruses (SRSV), “Norwalk-like”
  - Calicivirus group — small (~30 nm), single-stranded RNA, protein coat has “dimples”
- The disease — vomiting and diarrhea; less common than rotavirus in infants
  - Virus from ill or convalescent person via feces or vomitus
  - Colonization of intestines — incubation: 1–2 days
  - Severe diarrhea & vomiting — 12–60 hr (usually 24–48), **virus shedding up to 7 days**
  - Antibody is not protective
- Transmission/Control
  - Routes — person-to-person, or via water, “undercooked” shellfish, or food handled by an infected person
  - Prevention — sanitation, cooking
- Diagnosis
  - Virus in feces: ELISA for antigen; RT-PCR for viral nucleic acid; serogroups
  - Antibody production

Hepatitis A virus

- CDC (U.S., '98–'02): 60 outbreaks, 981 cases, 0 deaths; est. ~11,000 cases/yr; CAST: 4,800–35,000 cases/year, ≤14 deaths, $5030/case; no FoodNet coverage
- Picornavirus: ca. 28 nm diameter, single (+) strand RNA; coat protein comprises 60 copies of each of four structural polypeptides; virus is relatively resistant to heat and to drying
- History — Viral hepatitis recognized ca. time of World War II; fecal-oral transmission of “infectious hepatitis” (now hepatitis A) recognized much later; 5–6 hepatitis viruses now known, but only hepatitis A is known to be transmitted via food and water **in North America**
- The disease
  - Virus in feces of infected person
  - Entry via intestines
  - Liver colonized; infected cells destroyed by host's immune response; incubation 15–50 days (average 28–30); virus shed in feces 1–2 weeks before onset
  - Illness: fever, malaise, anorexia, nausea, abdominal discomfort—jaundice (?); usually complete recovery after a few weeks, with permanent immunity
- Transmission/Control
  - Routes — person-to-person, or via water (drinking, irrigation?), “undercooked” shellfish, or food handled by an infected person
  - Prevention — sanitation, cooking, **vaccination** (U.S., 1995)
  - Food as a vehicle
Other gastroenteritis viruses
- Astroviruses — occasionally foodborne, some replicate in cell culture
- Rotaviruses — more often infant diarrhea than foodborne disease
- Adenoviruses — serotypes 40 & 41, not known to be foodborne
- Coronaviruses — questionable cause of human diarrhea, foodborne once?

Other viruses and food
- Human enteroviruses (polioviruses, coxsackieviruses, echoviruses)
- Hepatitis E virus — water, food?
- Tick-borne encephalitis virus — milk & milk products, Slovakia
- Industry alarms
- “Non-problems” — hepatitis B, C, & D; herpes, HIV, hantavirus

Detection & monitoring: cytopathic effects in cell culture, plaques
- Diagnosis
- Detection of viruses in food
  - Sample processing — liquefaction, clarification, concentration
  - Test methods — probes, PCR, antigen capture
- Indicators — bacteria, viruses, phages

Prevention
- Food vehicles
  - Shellfish (bivalve mollusks)
  - Other food vehicles
- Sanitation (handwashing)
- Depuration of shellfish — not very successful
- Cooking, inactivation

PRIONS

Transmissible spongiform encephalopathies (TSEs)
- Accumulation of abnormal prions in brain leads to spongiform degeneration
- All are fatal
- Some are “contagious”

Prions are
- Low MW peptides found in CNS & some other organs
- Normal folding (“PrP$^C$”) depends on amino acid sequence.
- Abnormal (various causes, *PrP$^{Sc}$) produces a protease-resistant molecule
“Old” TSEs
- Scrapie in sheep
- Creutzfeldt-Jakob disease (CJD), sporadic, etc., in humans
- Transmissible mink encephalopathy
- Chronic wasting disease (deer, elk)

“New” TSEs
- Bovine spongiform encephalopathy (BSE) — “mad cow disease”
- Feline spongiform encephalopathy
- New variant CJD (vCJD) in humans

BSE in cattle, UK
- April 1985 to December 2004, 184,131 confirmed cases of BSE (3–5-yr incubation)
- Control by not feeding rendered bovine meat-and-bone meal (MBM) to cattle — slow enforcement
- Slaughter of affected herds
- Enormous research effort
- No BSE prions found in red meat (voluntary muscle) or milk
- Vertical transmission (cow-to-calf) “unlikely"
- Carcass disposal precautions

BSE in cattle elsewhere
- Some cattle, much beef, and a lot of MBM exported from UK to other countries
- Now ca. 30 countries have BSE (few thousand cases), all in Europe except Japan, Israel (occupied West Bank territories), Oman, Canada, and US, so far; 152 cases worldwide in 2006

Inter-species transmission
- Ca. 1994, TSE in cats (UK), including zoo species
- In 1995, something resembling CJD began occurring in young people in the UK — “new variant CJD" or “vCJD" (>10-yr incubation?)
- vCJD differs in more than age distribution of victims

Impact of vCJD
- ~165 people in UK, ~37 in the rest of the world affected by 04/07 (almost all deceased)
- Even in UK, <CJD rate (28 vs 50 in peak year, 2000; 5 vs 57 in 2006)
- Far less than deaths from other foodborne diseases
- HUGE public reaction
- Specified bovine offals banned from the food chain, most BSE countries
- Cattle >30 months old not eaten in UK, carcasses incinerated — discontinued, 2006
- Slaughter cattle >30 (24 in some countries) months old tested in other BSE countries
- Genetic susceptibility — all “primary” vCJD patients tested have been homozygous for methionine at codon 129 of their prion gene (40% of population)
• Restrictions on blood donation and use (3 from transfusions in UK)

Sporadic CJD and vCJD in the UK, 1990–2006

BSE in Canada, spring 2003
  • One cow, no trace
  • Exports to U.S. (& other countries) cut off — now largely restored
  • Case total now at 9

BSE in US (Washington), December 2003
  • One cow, possible “downer”
  • Huge interstate recall of meat
  • Media orgy
  • Embargoes on US beef

US control measures
  • Ban on feeding mammalian meat and bone meal (MBM, product of rendering) to food-source ruminants
  • Restrictions on blood donation
  • Scrutiny of biologicals
  • Slaughter of downer cattle prohibited
• Risk materials, from animals >30 months old, prohibited from human food supply
• Other prohibitions pending
• More testing of downers, dead-on-farms, and suspects at slaughter; case total now 3
• Major over-reaction to minimal threat to human health

Drama in North America — chronic wasting disease
• Deer & elk, Colorado, Wyoming
• Other states (Wisconsin), Canadian provinces, farmed and wild animals
• Environmental transmission (feces?)
• Transmissible to humans??
• Processing carcasses — food safety?
• Now upstaged by BSE

Summary
• Human enteric viruses, fecal contamination
• Cooking or other means of inactivation (depuration)
• Detection vs. indicator systems for monitoring
• Prion diseases are here in North America.
• Threat to human health is minimal.
• Measures being imposed may well lessen overall food safety.

Bibliography


http://www.fda.gov/cber/bse/bse.htm (has many links)