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Large Animal VETERINARY Rounds®

JULY/AUGUST 2008
Volume 8, Issue 6

AS PRESENTED IN THE ROUNDS OF THE DEPARTMENT OF LARGE ANIMAL CLINICAL SCIENCES OF THE WESTERN COLLEGE OF VETERINARY MEDICINE, UNIVERSITY OF SASKATCHEWAN

Foodborne Zoonoses: Challenges for the Veterinary Profession

By Tasha Epp, DVM, PhD

"Animals have always shaped the destiny of man." – KF Meyer, DVM, MD

Worldwide, foodborne illness remains a constant public health issue, despite improvements in animal husbandry, as well as in food processing, preparation, and preservation. Veterinary medicine and public health both have a role to play in the surveillance, prevention, and control of this continuing problem. This issue of *Large Animal Veterinary Rounds* reviews the current knowledge of foodborne hazards and highlights several recent emerging pathogens. The factors that contribute to the emergence of these pathogens are discussed, emphasizing the role of the veterinary profession in prevention and control of pathogens in food

Humans have always been exposed to zoonotic pathogens, essentially, for as long as they have coexisted with animals. The first zoonotic transmission would likely have occurred as hunters killed, skinned, butchered, and ate wild animals. Pathogens would certainly have included micro- and macroparasites transmitted through the consumption of meat, but also through the various uses of the skin, bones, blood, and organs. Likely pathogens included *Bacillis anthracis* (anthrax), *Brucella, Taenia,* and *Trichinella*, although at that time, it is unlikely that the source of human disease was related back to their animal hosts.[1]

When humans began to settle and domesticate animals, they unknowingly domesticated the animal pathogens as well. In some instances, this new relationship probably brought about new opportunities for cross-species transmission, including animal to human. Some pathogens required continuing contact with susceptible human hosts for transmission, while others made the genetic leap to allow human-to-human spread.[1]

Foodborne illness in the 21st Century

Food is an integral part of human life and the composition of diets is largely governed by social status, economics, and culture. Many pathogens effectively use food as a vehicle of transmission. In developed countries, foodborne illness remains a major health problem, despite control measures to ensure a safe food supply. Canadian public health experts estimate that between 11 million and 13 million cases of bacterial foodborne illness occur every year.[2] In developing countries, the World Health Organization states that diarrhea of food- and waterborne origins is the leading cause of illness and death.[3]

Over 250 different foodborne diseases have been described; the majority of these diseases are caused by biological pathogens, with the remainder caused by chemicals and toxins.[4] Biological hazards include bacteria, viruses, parasites, and prions. Some of these are classified as strictly human pathogens that use food as a vehicle for transmission, while others are zoonotic. Factors contributing to the emergence of foodborne pathogens are multifaceted. They can be categorized as follows:

- human demographics and behaviours
- food-production industry and technology
- international travel and trade

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Table 1: Information on selected zoonotic bacterial foodborne pathogens, with specific reference to Canada[6]					
Pathogen	**Reservoir(s)***	**Food products**	**Human outbreaks/ case clusters reported†**	**Human cases ($\times 10^3$)**	**Provinces with most cases per 100,000**
Campylobacter jejuni	**Poultry**	Poultry, raw milk, untreated water	5	3.2	Saskatchewan (19.1 per 100,000)
Escherichi coli O157	**Cattle**	Ground beef, raw milk, lettuce, untreated water, apple juice	31	3.1	Prince Edward Island (15.9 per 100,000)
Salmonella enteriditis	**Poultry,** mammals, reptiles	Eggs, poultry, meat, fresh produce, other raw foods	3	4.1	Northwest Territories, Yukon, Nunavut (9.6 per 100,000)
Listeria monocytogenes	**Soil,** forage, water	Ready-to-eat foods (soft cheeses, deli foods, etc)	NA‡	NA	NA
Vibrio species	**Water,** seafood	Seafood (raw, undercooked, contaminated)	1 (*V parahaemolyticus*)	0.08	British Columbia (0.3 per 100,000)

* Primary reservoir is in bold.
† There is no national reporting system for outbreaks. This compilation of sources is not exhaustive.
‡ NA = Not available; no surveillance data available for this pathogen.

- microbial adaptation
- economics, political stability, and any breakdown in public-health measures.[5]

Despite major efforts aimed at creating a "safe" food supply, many well-known pathogens, as well as newly emerging pathogens, continue to cause high numbers of food-related illness every year. Since the list of pathogens is too long for one article, the following discussion covers only a few pathogens in detail, highlighting the factors that have contributed to their emergence.

Pathogens

Parasitic

Parasites are a group of pathogens that are able to thrive under a variety of conditions, from the far north to the tropics. This group can include helminths (roundworms, tapeworms, and flukes) and protozoa; in this area, control measures appear to have worked. Part of this success can be attributed to the more limited transmission opportunities and specific life cycles exhibited by many parasites. To date, very few parasitic pathogens are present in the North American domestic food supply. Yet, in 2006, in spite of this knowledge and various control measures, *Cryptosporidium, Giardia,* and *Cyclospora* infections, combined, were the third leading cause of enteric disease in Canadians.[6]

The last reported case of *Trichinella* in Canadian pork was in 1996, in a pig reared outdoors, while the last case of human trichinosis associated with the consumption of pork was in 1980.[7] Today, cases of human trichinosis are attributed to the consumption of walrus or bear meat, specifically in northern communities or from hunting-related events. *Trichinella native* is the genotype associated with northern Canadian cases; it has an annual estimated incidence rate of 11 cases per 100,000 indigenous people.[8] Recently, a laboratory-based program specific for testing the presence of *Trichinella* in native diets was initiated in Nunavut in an attempt to curtail the growing public health risk.

Taenia species, which are reportable diseases in Canadian livestock, are rare occurrences in Canadian slaughtered animals. Despite our safe domestic food supply, *Taenia*-associated diseases still sporadically occur in humans in North America; usually, they are found specifically in immigrants or individuals who have contracted the disease in another country. In a study of seizure patients in the Niagara region, 3 individuals were identified to have neurocysticercosis: 1 from Somalia, 1 from Mexico, and 1 of Hispanic background.[9]

Toxoplasmosis, a protozoan that is commonly associated with eating undercooked pork, presently has a low prevalence in Canadian pork; even if present, proper cooking prevents zoonotic transmission. In 1996, as indicated by a seroprevalence study, the prevalence in individuals <30 years old was 4.6% for those born in Canada and 23.1% for those born outside of Canada.[10] A recent survey of overseas travelers, immigrants, and visitors to Canada revealed that approximately 3% harboured *Taenia* tapeworms, 1.3% had neurocysticercosis, and 1.0% had toxoplasmosis.[11] This emphasizes the need for Canadians to be diligent about the sources of food they consume, particularly if they consume uninspected food (eg, hunted or bush meat) or food outside of Canadian boundaries.

Bacterial

Many bacterial pathogens have been recognized as zoonoses for a long time, while others have a relatively short history. For example, the association between *Escherichia coli* and gastrointestinal (GI) disease was suspected in the 1880s, but was not demonstrated until 1947.[4] Many bacteria are considered normal gut flora in 1 or more of our domesticated livestock or wildlife species (Table 1), making eradication unachievable. Information is available only on those pathogens under surveillance.

In the latter half of the previous century, several bacteria were controlled or even eradicated from domestic animal populations, making their transmission to people unlikely. In Canada, one of those success stories was the successful eradication of *Brucella abortus* from the domestic cattle herd since mid-1980. This pathogen was transmissible to people through direct contact with sick animals, as well as through unpasteurized milk or milk products such as soft cheeses. A nationwide veterinary-driven eradication program involved the meat inspection system, implementation of milk pasteurization, and individual farm control. Despite this success, *B abortus* still exists in wildlife within Canada (eg, bison in Wood Buffalo National Park) and the potential for reintroduction to domestic herds continues.

In the last decade, there have been several newly identified bacterial pathogens. The *Vibrio* family of bacteria, which includes *V cholerae, V parahaemolyticus,* and *V vulnificus*, is a natural resident of estuarine and marine environments.[4] *V parahaemolyticus* was first identified in Japanese sardines in 1950, while *V vulnificus* was first identified in the 1970s, but was not associated with the eating of raw shellfish until the 1980s. *Vibrio* species are found worldwide along the coasts in waters of 15°C or above.[12] The organisms asymptomatically contaminate shellfish, mollusks, and fin fish, but do not affect the taste, smell, or appearance.

V parahaemolyticus is an opportunistic pathogen that is most commonly associated with eating raw or undercooked oysters. Humans present mainly with GI symptoms (eg, diarrhea) and for immunocompetent individuals, the disease usually resolves in 2-3 days. Humans can be infected with *V vulnificus* through ingestion of contaminated seafood, but also through contamination of an open wound with seawater. Once infected, humans quickly develop neurological signs, septicemia, or less commonly, GI signs. The majority of these cases have other underlying medical conditions, such as liver failure, diabetes, or immunosuppression. In the United States (US), 95% of all seafood-related deaths are attributed to this pathogen.[4]

Control and prevention focus on the harvesting and preparation of shellfish. Harvesting offshore or in cooler months can decrease the amount of contamination; however, due to market pressure, the current trend is for much of the harvest to occur during the summer months.[13] In addition, climate change may be contributing to the emergence of this pathogen as a cause of food-borne illness. Proper cooking, storage, and handling of shellfish will prevent human cases, even with contaminated seafood.

Between 2001 and 2006, 140 cases of *Vibrio*-related infections were confirmed in British Columbia (BC), the majority due to *V parahaemolyticus*.[14] Most cases had their onset during July to September, when ocean temperatures were above 15°C. For locally acquired cases, the source of infection was consumption of raw shellfish, particularly oysters harvested from waters in BC or Washington state that had been served in restaurants, self-harvested, or bought from markets.

Viral

Very few viral pathogens of animal origin cause foodborne illness in humans. It is more common for human viral pathogens to use food or water as a vehicle for transmission. For example, Norwalk-like viruses are transmitted via the consumption of raw or undercooked shellfish that have been harvested from sewage-contaminated waters or by the contaminated water itself.

Hepatitis E is a newly identified pathogen (recognized as a distinct entity since the 1980s); thus far, a limited number of human cases have been attributed to foodborne outbreaks. The primary vehicle of transmission to humans is water, but the reservoirs for the 2 genotypes of zoonotic virus include pigs, wild boar, deer, monkeys, poultry, as well as humans. Since 2001, in Japan, several cases of acute infectious hepatitis have been attributed to the consumption of raw pork liver, raw deer meat, and raw wild boar liver.[15] In a Japanese survey of retail pork liver from stores in the area of a human outbreak, the virus was identified in 1.9% of specimens tested. In addition, the liver isolates and human isolates were similar, as revealed by nucleotide sequencing.[15] With any viral pathogen, proper cooking will render the food safe; however, consumption of raw meat or organs will likely continue in certain cultures despite outbreaks of foodborne illness.

Prions

The occurrence of variant Creutzfeldt-Jakob disease (vCJD) and its relationship to bovine spongiform encephalopathy (BSE) has resulted in political upheavals and increased surveillance. An economic decision to incorporate cheap animal-based protein sources into the diets of herbivore species, a change in the rendering process, and the global trade in those protein sources allowed for a worldwide epidemic to hit the cattle industry and the human population.[16,17]

In Britain, which was the hardest hit nation for animal-related cases, the number of human-associated illness reached 163 cases in just over 10 years. In Canada to date, there have been 12 BSE-infected animals identified, but no domestically-acquired cases of vCJD.[17] For control measures, specified risk material elimination practices and animal protein feed bans have been implemented that have the potential to eradicate the disease from the domestic food supply, as well as continuing to protect humans from exposure.

Antimicrobial residues

Preventing antimicrobial residues in meat is standard; however, even after the end of the withdrawal period, the microbes and, particularly, the antimicrobial-selected resistant microbes are still present in the animal products. Resistance patterns are more commonly observed where antimicrobials are in wide use or in intensive-use situations such as high-density livestock operations or hospitals.[18] Antimicrobial populations and their resistance patterns can spread from animals to humans through two routes: directly via zoonotic infections or indirectly through exchange of resistance patterns within bacterial populations. Once resistant bacteria are established, they can create scenarios where the number, severity, and duration of human illnesses are increased and treatments become ineffective or more expensive.

Fluoroquinolone-resistance patterns in *Campylobacter* isolates in the US emphasize the vigilance that is needed for both veterinarians and physicians. An increase in the number of human cases of domestically-acquired campylobacteriosis was linked with the licensing of fluoroquinolones for use in poultry in the US.[18] In fact, via deoxyribonucleic acid (DNA) fingerprinting, identical resistant *C jejuni* were identified in both retail poultry products and human clinical cases, thereby establishing a direct effect on humans through the food chain.

Nonanimal foods

Foods of animal origin have traditionally provided the greatest risk to humans for microbial and parasitic pathogen transmission. Now, a new area of concern is emerging, that of nonanimal food stuffs. With the intensification of production systems and resulting environmental contamination, nonanimal food stuffs are routinely making the news as the source of foodborne outbreaks. In the last year, consumer warnings on potentially-contaminated produce have included lettuce, spinach, tomatoes, and various fruits.

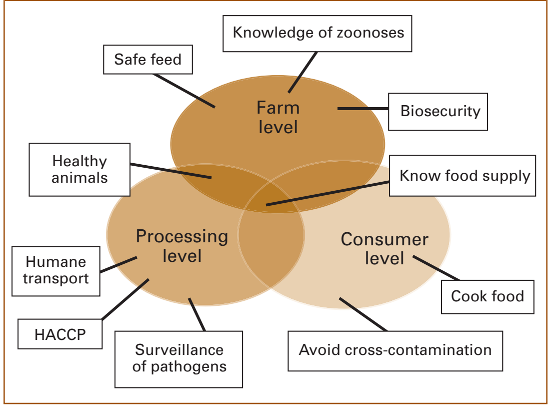
For example, the recent *E coli* O157:H7 outbreak due to bagged spinach in September 2006 was traced back to contaminated products from 4 locations in California, but eventually involved 26 states and Canada, evidence of the integrated nature of every aspect of the food chain.[19] One of the spinach-production locations was located within 1 mile of a cattle farm that had evidence of the outbreak strain in the feces of the cattle. In addition, this area was frequented by feral swine that would have had access to areas in which cattle grazed, the spinach field itself, and the local waterways. *E coli* O157 was cultured from cattle and feral swine feces, surface water and sediment, as well as pasture soil. It was hypothesized that feral swine played a significant role in the spinach contamination, either directly though contamination of the fields or indirectly though contamination of waterways.

Role of the veterinary profession

Humans become infected by handling or eating raw or undercooked contaminated animal products, eating raw vegetables that have been washed or irrigated with contaminated water, drinking contaminated water or raw milk, or in some cases after direct contact with or immersion in contaminated water.[4,12] Generally, control measures focus on 1 of 3 areas:

- reduction of the pathogen in the reservoir (eg, increased biosecurity, vaccination, etc.)
- prevention of contamination during processing
- education of consumers on safe food-handling practices

Figure 1: List of control measures applicable at each level of the food chain.



HACCP = hazard analysis and critical control point

The goal is to interrupt the transmission pathway that essentially can be tailored to each specific pathogen.

The profession of veterinary medicine was originally given the task of halting the spread of agricultural diseases affecting food-producing animals, as well as controlling the slaughter of animals for food consumption. Now and in the future, controlling food- and waterborne diseases will require a holistic approach, essentially from farm to fork (Figure 1), using safe, reliable, measurable, practical to implement, and economical control measures.[20]

Preharvest interventions

The first step in the control of zoonoses is at the farm. Biosecurity protocols for new animals, feed, equipment, or visitors can be tailored and imposed at the farm level. Implementation of practices such as including commercial competitive exclusion products in poultry diets or vaccinations for specific pathogens are effective.[21] In all circumstances, knowing the risks and understanding the control measures specific to each pathogen are the keys to proper implementation and eventual success. This offers a prime opportunity for the veterinary profession to play an integral role in foodborne and waterborne disease prevention. With proper instruction on the lifecycles of common pathogens, food producers can instigate control measures specific to their operations that can limit the exposure to certain pathogens or the propagation and transmission of endemic pathogens.

Another important emerging area for veterinarian involvement is that of welfare-sensitive, organic, or naturally-raised livestock. Many modern farming practices were developed in order to control disease transmission. For example, raising pigs indoors without access to rodents, waste food, and refuse was an effective measure to control parasitic diseases such as *Taenia, Trichinella,* and *Toxoplasma*. However, as consumers demand "free-range," antibiotic-free animals or produce free of pesticides or commercial fertilizers, the risk of reintroducing old pathogens will increase. For example, organically-raised outdoor pigs present many challenges in the control of *Toxoplasma gondii* or even *Trichinella* spp.[22] This is an area where the veterinary profession can provide information and expertise to ensure healthy disease-free animals with all production methods.

The integrity of the food supply does not stop with individual animals, but extends to the interaction of animals with their environment. Thus, animal waste, dead stock, and outdated feedstuff or drugs are areas that must be addressed, since all animal waste or dead stock can be potential sources of infection for wildlife. Once diseases become established within wildlife, a permanent source of reinfection is established. Again, the veterinary profession is poised to play a role in educating food producers about proper waste management, lobbying for adequate regulations, collecting outdated antimicrobial products with subsequent proper disposal, or site planning in the development of new food-production operations to prevent water contamination due to waste or water runoff.

Transport of animals to slaughter facilities is another opportunity for prevention and control of disease transmission. Stress, overcrowding, poor ventilation, and uncomfortable conditions predispose latently infected animals to shed pathogens at a higher rate. This can result in contamination of the trucks, other animals in the trucks, the environment through which the trucks travel, and the slaughter facility to which the animals are transported. Currently, research is underway to provide a strong foundation for revising the regulations that govern the humane transport of animals. The education of both food producers and truck haulers to the effects of transport on pathogen spread would be invaluable. In addition, as consumers become more aware of the welfare issues associated with transport to slaughter, the strict adherence to Canadian standards will become vital to the industry.

Interventions at processing

Inspection services within the food-processing industry have greatly diminished the impact of diseased or disabled animals on a safe food supply. The implementation of hazard analysis and critical control point (HACCP) protocols in food processing aims to identify hazards, determine effective control points, and document successful control.[21] However, it is the transmission of unknown or unseen pathogens that still pose a threat. Therefore, good hygiene and tightly regulated animal-product processing can be considered the most important factor in food and thus consumer safety. The Canadian Food Inspection Agency (CFIA) is integral to the functioning of food inspection within Canada and the continuing support of the veterinary community will be integral to the future of the food-processing industry. In addition, the private veterinarian plays an important role in educating producers on what is an acceptable animal to send to slaughter.

Surveillance of diseases allows for an assessment of the risk posed by any one pathogen. Surveillance can occur at any level of the food chain and can alert providers to issues in food safety, as well as providing a mechanism to assess control measures. Unfortunately, in many instances the first indication of potential foodborne hazards is an outbreak of a foodborne illness in the public.[21] Recalls of products can be time consuming and are costly for the processor, often resulting in loss of consumer trust or even financial bankruptcy. With the global nature of the food supply, these events often cross state, provincial, or international boundaries. Most food products are no longer derived from a single local animal; instead, they are derived from multifarm, multinational products that are then shipped globally. Today, with the extensive trade of goods and the movement of people around the world, no individual country is immune to existing or emerging pathogens.[4,13] Surveillance of a multitude of pathogens is necessary to protect Canadian consumers, but also to ensure markets for international trade.

Postharvest interventions

The final step in the control process is the consumer. The majority of the public is far removed from the production and processing of their food supply; however, it would be naïve to think that they are not interested in ensuring that their meat and produce are ethically correct and biologically "safe" for consumption. No production or processing system in the world today will create zero-risk food. Therefore, public health agencies must continue to educate consumers on acceptable food handling, storage, and cooking procedures.

Conclusions

In the last century, significant strides have occurred in the quest for a "safe" food supply. No single control strategy can eliminate all of the risks for foodborne illness, but combined, the risks can be substantially minimized. Knowledge is the single most applicable control strategy available to both veterinarians and public health officials. It is recognized that significant challenges lie ahead, but veterinarians are poised to play a large role in the continued pursuit of food safety.

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Abstract of interest

Constraints to microbial food safety policy: opinions from stakeholder groups along the farm to fork continuum

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This exploratory qualitative study was conducted to identify constraints to microbial food safety policy in Canada and the USA from the perspective of stakeholder groups along the farm to fork continuum. Thirty-seven stakeholders participated in interviews or a focus group where semi-structured questions were used to facilitate discussion about constraints to policy development and implementation. An emergent grounded theory approach was used to determine themes and concepts that arose from the data (versus fitting the data to a hypothesis or a priori classification). Despite the plurality of stakeholders and the range of content expertise, participant perceptions emerged into five common themes, although, there were often disagreements as to the positive or negative attributes of specific concepts. The five themes included challenges related to measurement and objectives of microbial food safety policy goals, challenges arising from lack of knowledge, or problems with communication of knowledge coupled with current practices, beliefs and traditions; the complexity of the food system and the plurality of stakeholders; the economics of producing safe food and the limited resources to address the problem; and, issues related to decision-making and policy, including ownership of the problem and inappropriate inputs to the decision-making process. Responsibilities for food safety and for food policy failure were attributed to all stakeholders along the farm to fork continuum. While challenges regarding the biology of food safety were identified as constraints, a broader range of policy inputs encompassing social, economic and political considerations were also highlighted as critical to the development and implementation of effective food safety policy. Strategies to address these other inputs may require new, transdisciplinary approaches as an adjunct to the traditional science-based risk assessment model.

Zoonoses Public Health. 2007;54(5):177-84.

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Dr. Epp has stated that she has no disclosures to announce in association with the contents of this issue.

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This publication is made possible by an educational grant from

Schering-Plough Canada Inc.