Thermophilic Campylobacter are an important cause of human illness worldwide. Campylobacter reservoirs include a wide variety of wild birds, poultry, farm animals, domestic pets and natural water systems. In Australia, infection is mainly associated with foodborne transmission, though other routes of exposure including waterborne and direct zoonotic transmission are not uncommon. Most cases of infection appear to be sporadic in nature, with outbreaks rarely reported. Epidemiological and microbiological evidence suggests chicken meat is the principal source of infection among cases. A recent study estimated there are more than 50,000 cases of Campylobacter infection attributed to chicken meat each year in Australia. When outbreaks are detected, they are most often associated with the consumption of poultry, contaminated water and occasionally unpasteurised milk. The lack of recognised foodborne outbreaks of campylobacteriosis could be due to organism-related factors such as the inability of thermophilic Campylobacter to multiply on food left at room
temperature, their microaerophilic nature and their susceptibility to drying. However, it is likely that outbreaks of *Campylobacter* infection are also under-reported in developed countries due to the current lack of a suitable phenotypic or genotypic typing method for routine surveillance and outbreak detection. The future development of improved typing methods for detecting outbreaks should enable further sources and risk factors for *Campylobacter* infection to be determined.

*Campylobacter* is the leading cause of gastrointestinal illness in Australia among all the notified enteric pathogens. There are more than 15,000 cases of *Campylobacter* enteritis notified through surveillance systems in Australia each year; excluding cases from New South Wales where the disease is not notifiable. However, notified cases represent only a fraction of all cases of infection occurring in the community and after adjusting for under-reporting and incomplete population coverage, recent estimates indicate approximately 225,000 (1180/100,000 population) *Campylobacter* infections occur in Australia each year. The majority of infections are sporadic illnesses with community outbreaks infrequently reported, partly due to the lack of an efficient standardized typing system for routine surveillance. Most infections are caused by two species, *C. jejuni* and *C. coli*. Foodborne transmission appears to be the most common method of transmission of *Campylobacter* infection to humans causing an estimated 75% to 80% of sporadic infections. While the majority (98% to 99%) of cases of campylobacteriosis lead to a self-limiting episode of acute gastroenteritis, antimicrobial therapy may be indicated in prolonged or complicated illness. Occasionally, more severe disease outcomes occur, particularly in patients with immune deficiency, notably hypogammaglobulinaemia and AIDS. Chronic carriage of *Campylobacter* with recurrent enteritis and bacteraemia are typical problems among this group. Post-infectious complications associated with *Campylobacter* infection include Guillain-Barre syndrome, an autoimmune disorder of the peripheral nervous system causing acute flaccid paralysis (0.01–0.1%) and reactive arthritis (1–5%) at the retail level have been reported.

At the retail level, *Campylobacter* are more frequently isolated from poultry meat than from red meats. Prevalence studies conducted in Australia and overseas of raw poultry meat, in particular raw chilled chicken, often show frequencies in excess of 50%. Furthermore, contamination levels in excess of 10^5 organisms per carcass at retail level have been reported. Prevalence studies conducted at the retail level on raw red meats have generally shown the frequency of contamination to be considerably lower than that seen in raw poultry. Australian surveys of beef, pork and lamb have shown a prevalence range of 0% to 8%. The lower prevalence of *Campylobacter* seen in red meat as opposed to white meat is thought to be due to differences in slaughtering processes and the extended forced-air chilling of red meat carcasses (most chicken carcasses in Australia are subjected to immersion chilling). Offal, on the other hand, is not subjected to forced-air chilling and consequently the prevalence of *Campylobacter* contamination tends to be higher than for whole cut meats. A recent Australian retail study reported contamination frequencies of 13% and 23% for raw lamb kidneys and livers respectively. The prevalence of *Campylobacter* in poultry livers is considerably higher.

The intestinal tract of poultry, including laying hens, is a common reservoir for *Campylobacter*; however, shell eggs are not considered to be a high risk food for transmission as the organism does not survive well on the shell surface due to desiccation. At the retail level, *Campylobacter* have been detected on the surface of faecally contaminated eggs that are not of commercial quality, penetration studies indicate the organism does not penetrate readily through the egg shell membrane. A recent study also suggests that vertical transmission of *Campylobacter* through the egg yolk is likely to be rare.

**Sources of infection**

The intestinal tract of a wide range of wild and domestic birds and warm-blooded animals have been identified as major reservoirs of *Campylobacter* in the environment. Colonisation of the intestinal mucosa may be as a commensal or as an asymptomatic transient infection. Farm animals, in particular, are major reservoirs for this organism including beef cattle, dairy cows, sheep, pigs and poultry. Consequently, this organism is frequently found in foods of animal origin including raw meat and raw milk. The organism is ubiquitous in the environment, probably as a result of faecal contamination by birds and animals, and is often detected in natural water sources including coastal seawater, rivers, streams, lakes, ponds and groundwater.

**Risk factors for sporadic infection**

Risk factors for *Campylobacter* infection have generally been identified either through case-control studies of laboratory-confirmed sporadic infections or from investigation of disease outbreaks. The vast majority of case-control studies have been conducted in developed countries including the United States, Canada, the United Kingdom, Norway, Denmark and New Zealand. The majority of studies have demonstrated that poor handling and/or consumption of raw or undercooked chicken was the single most important risk factor for infection, being reported in no less than 20 case-control studies. Other meats identified as potential risk factors for sporadic
infection include pork and beef, though these foods are less frequently reported in case-control studies as risk factors than poultry. Raw milk is another regularly identified foodborne risk factor among case-control studies for sporadic infection, more so in those countries where raw milk consumption is relatively common.\(^{30,35,36}\)

The association between chicken consumption and Campylobacter infection has been extensively reported in the literature and this risk factor appears to be the major source of infections in Australia as well. A large multi-centre case-control study conducted by OzFoodNet among persons aged five years or older identified the consumption of undercooked chicken and offal as independent risk factors for infection.\(^{37}\) This study showed that almost one-third of Campylobacter infections that occur in Australia each year can be attributed to chicken meat, either through the consumption of undercooked chicken or from poor food handling of raw chicken and subsequent cross-contamination to cooked or ready-to-eat foods. The population attributable risk proportions from this study indicated that more than 50,000 cases of Campylobacter infection could be attributed to chicken meat annually in Australia among persons aged 5 years and older.\(^{38,39}\) Similarly, there are an estimated 3,500 cases of Campylobacter infection each year in Australia attributed to eating offal.

Consumption of chicken has not been identified as a risk factor for Campylobacter infection in children ≤4 years of age in Australia, despite three case-control studies which have examined risk factors for infection in this age group.\(^{40–42}\) Two studies conducted outside of Australia in other developed countries have also failed to identify chicken consumption as a risk factor for infection in this age group.\(^{43,44}\) Regardless of these findings, it is likely that foodborne transmission from chicken is a risk factor for infection in young children, albeit of less importance. Contact with pets such as puppies and young chickens have been identified as important risk factors for infection in young children.\(^{39,40}\)

**Outbreaks of Campylobacter infection**

Foodborne transmission is the predominant route of infection for outbreaks of Campylobacter. In Australia, 27 (82%) of the 33 Campylobacter outbreaks reported between 2001 and 2006 were foodborne or suspected foodborne, three (9%) were waterborne, one (3%) was due to person to person transmission and two (6%) outbreaks had unknown transmission routes. A food vehicle was confirmed for 16 (59%) of the 27 foodborne outbreaks; poultry (chicken or duck) was associated with 11 (41%) outbreaks, unpasteurised milk and salads were associated with two (7%) outbreaks each. Seven (44%) of the 16 outbreaks with identified food vehicles were attributed to consumption of the contaminated raw product (undercooked food) while four (25%) were attributed to consumption of a ready-to-eat food that was cross-contaminated from a raw food product. The contributing factors were unknown for the other five outbreaks. Although the sale of unpasteurised milk for consumption to the public is illegal in Australia, occasional outbreaks still occur. The two outbreaks reported above were associated with the consumption of raw milk during school excursions to dairy farms.

In recent years, both Australia and the United Kingdom have reported an increase in the number of outbreaks of Campylobacter associated with poultry liver dishes.\(^{45,46}\) Seven outbreaks associated with poultry liver have been recorded in the OzFoodNet outbreak register since 2001, with six (86%) of these occurring between 2008 and 2011. All seven outbreaks involved commercial food venues with either chicken (5) or duck (2) liver dishes prepared on site. Undercooking of the poultry liver dishes was the likely contributing factor for these outbreaks.

**Conclusion**

Foodborne campylobacteriosis is a major cause of bacterial enteritis in Australia. The incidence of disease in our community provide a strong argument for both government and industry to focus efforts into reducing contamination of chicken carcasses with Campylobacter either through improved on-farm control or interventions during processing. In addition, the figures justify the need for government to continue educating consumers and foodhandlers about the risks associated with the handling of raw chicken and the potential for cross-contamination in the kitchen. Improved surveillance and detection of Campylobacter outbreaks will increase our knowledge on the epidemiology of this organism and help inform prevention and control strategies.

**References**
