# *Campylobacter* infections, a significant issue of veterinary urban hygiene: dog-related risk factors

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**Summary**
*Campylobacter* spp. are ubiquitous bacteria and campylobacteriosis is the most frequently reported zoonotic disease in humans in Europe, since 2005. Handling or consuming contaminated/undercooked meat (especially poultry) are the most important sources of human campylobacteriosis. However, in recent years, the role of dogs as a source of infection for humans has been amply demonstrated. Approximately 6% of human campylobacteriosis cases are due to contact with pets. This review analyses the current literature related to risk factors at the dog-human interface.

## *Infezioni da* Campylobacter*, un argomento rilevante in Igiene Urbana Veterinaria: fattori di rischio nella relazione uomo-cane*

**Parole chiave**
*Campylobacter*,
Campylobatteriosi,
Cane,
Fattori di rischio,
Zoonosi.

**Riassunto**
Il genere *Campylobacter* comprende batteri ubiquitari. Dal 2005 le campylobatteriosi sono state le zoonosi più frequentemente registrate in medicina umana in Europa. La manipolazione e il consumo di carni crude (soprattutto pollame), rappresentano la fonte principale di infezione ma, negli ultimi anni, il ruolo dei cani nella trasmissione di questi batteri è stato ampiamente dimostrato. Circa il 6% delle campylobatteriosi registrate in medicina umana sono dovute al contatto con animali domestici. Questa rassegna analizza i fattori di rischio correlati al rapporto uomo/cane.

## Introduction

The members of *Campylobacter* genus are ubiquitous bacteria, frequently found in the alimentary tracts of wild and domestic birds and mammals, commonly contaminating the environment, including water. The genus *Campylobacter* belongs to the family *Campylobacteraceae* and includes 34 species that are known as human and animal pathogens (Newell 2001)[1].

*Campylobacter* spp. are gram-negative spiral, rod-shaped, or curved bacteria (0.2-0.8 µm × 0.5-5 µm), non-spore-forming, catalase and oxidase positive with a single polar flagellum, bipolar flagella, or no flagellum, depending on the species (Lengerh *et al.* 2013, Bolton 2015). *Campylobacter gracilis* has not flagella, while *Campylobacter showae* has multiple flagella, and all other *Campylobacter* species have a single polar flagellum at 1 or both ends of the cell (Bolton 2015).

Generally, the optimum growth temperature is 37°C. Thermophilic *Campylobacter* species (*Campylobacter jejuni*, *Campylobacter coli*, *Campylobacter lari*, *Campylobacter upsaliensis*, and *Campylobacter elveticus*) do not grow below 30°C and have an optimum growth temperature at 42°C. Visible colonies of *C. jejuni* usually appear within 48 to 72 hours (Hindiyeh *et al.* 2000).

[1] LPSN-2015 List of Prokaryotic names with Standing in Nomenclature www.bacterio.net/campylobacter.html.

Most *Campylobacter* species grow under microaerobic conditions (but some can also grow aerobically or anaerobically), and have a respiratory type of metabolism. However, several species (*Campylobacter concisus*, *Campylobacter curvus*, *Campylobacter rectus*, *Campylobacter mucosalis*, *Campylobacter showae*, *Campylobacter gracilis*, and, to a certain extent, *Campylobacter hyointestinalis*) require hydrogen or formate as an electron donor for microaerobic growth. In addition, certain species prefer anaerobic conditions for growth. *Campylobacter* is sensitive to many external conditions, like low water activity, UV light, salt, and heat. In contrast to *Salmonella*, *Campylobacter* does not multiply outside a warm-blooded host (*e.g.,* on meat samples), given the absence of microaerobic conditions and the non-permissive temperatures (EFSA 2011).

Campylobacteriosis identifies infectious diseases caused by members of the genus *Campylobacter* and mostly characterised by acute enteritis, extraintestinal infections, and post-infectious complications. Currently, the high global prevalence and the socioeconomic burden associated with *Campylobacter* infection pose major challenges for public health in the 21st century.

## Campylobacteriosis in humans

Since 2005, campylobacteriosis has been the most frequently reported zoonotic disease in humans in Europe, with the annual number of notified cases increasing in recent years (EFSA 2012, Tam *et al.* 2003). However, considering the high number of campylobacteriosis cases, the severity in terms of reported fatalities is low (0.05%) (EFSA 2015).

Campylobacteriosis in humans is caused by thermotolerant *Campylobacter* spp., although other species including the non-thermophilic *C. fetus*, are also known to cause human infection.

The most commonly associated species with human infection are *C. jejuni*, followed by *C. coli*, *C. lari*, and *C. upsaliensis* (Wieland *et al.* 2005, Leonard *et al.* 2011, EFSA 2012). The infective dose of these bacteria is generally low. However, recent studies highlighted the potential limitations of routine culture methods. While selective temperature and media are well established for *C. jejuni* or *C. coli*, they are not for other species and so the infective doses for these species are likely underestimated (Koziel *et al.* 2014). At the same time, the high concentration of antibiotics used in *Campylobacter* selective media to suppress commensal gastrointestinal flora may also inhibit the growth of less common species (Maher *et al.* 2003).

Developments in molecular diagnostics have revealed that infections caused by non-thermophilic *Campylobacter* have higher prevalence than previously thought. Bullman (Bullmann *et al.* 2012) reported that approximately half of the species detected by polymerase chain reaction (PCR) were non-*C. jejuni*/*C. coli*, with *C. ureolyticus* being the second most common. In the same study, the less common species *C. lari*, *C. fetus*, *C. upsaliensis*, and *C. hyointestinalis*, collectively account for 10% (Chaban *et al.* 2010, Hald *et al.* 2004). Lastovica and Engel (Lastovica and Engel 2001) reported that *C. upsaliensis* is the third most prevalent *Campylobacter* species isolated from the diarrhoeic stools of paediatric patients representing 23% of the 4,260 *Campylobacters* isolated during a period of 10 years. The most significant reservoir of *C. upsaliensis* is the canine species (Hald *et al.* 2003, Carbonero *et al.* 2012).

The most common sources of human campylobacteriosis are handling or consumption of contaminated/undercooked meat (especially poultry), handling or consumption of contaminated or unpasteurised milk and dairy products, drinking contaminated water, person-to-person contact, direct contact with carrier farm animals, direct contact with pets and insect as flies (Saeed *et al.* 1993, Adak *et al.* 2005, Mazick *et al.* 2006, Strother *et al.* 2005).

The majority of *Campylobacter* infection cases are sporadic, and outbreaks are not common, although reported cases have the highest peak in Summer (Tenkate and Stafford 2001).

After ingestion, *C. jejuni* colonises the lower gastroenteric tract (ileum, jejunum, and colon), sometimes without symptoms. Colonization requires motility, adhesion, invasion, and toxin production (Bolton 2015).

In most symptomatic cases, campylobacteriosis is manifest as mild and self-limiting gastroenteritis characterised by 1-3 days of low fever, vomiting, myalgia, and headaches, followed by 3-7 days of abdominal pain with watery or bloody diarrhoea. Acute infection sometime begins with a high fever, peaking during the first days of illness. Excretion ends within 10-14 days (Newell 2001) and severe complications are uncommon (Altekruse *et al.* 2003, Blaser 1997, Bolton 2015).

Campylobacteriosis does not require antimicrobial treatment. However, in some cases such as septicaemia, or other invasive forms of the disease, antibacterial therapy may be needed. Chronic infections or extra-intestinal infections may occur with fatal bacteraemia, hepatitis, pancreatitis, meningitis, recurrent colitis, acute cholecystitis and cystitis, cardiovascular complication, abscesses and complications of the reproductive system (Goossens *et al.* 1987, Manfredi *et al.* 1999, Acke *et al.* 2009, Keithlin *et al.* 2014). Epidemiological studies indicate that a prior exposure with subsequent host-immunological response may significantly affect the clinical outcome of the infection, as naturally acquired immune responses appear to protect from disease but not necessarily from colonization (Newell 2001). For this reason, immune-compromised individuals, elderly people, and children are at higher risk of acquiring campylobacteriosis, and usually show more severe infections (Molina *et al.*1995).

*Campylobacter* plays an important role, and is particularly acute, during weaning. Consequently, campylobacteriosis contributes significantly to malnutrition in infants in developing countries (WHO 2001). In these countries, *Campylobacter* spp. are among the most common causes of diarrhoea in travellers (Acheson and Allos 2001). Long term effects, or chronic consequences, such as Guillain-Barré syndrome (GBS), reactive arthritis (ReA), Reiter's syndrome (RS), post-infectious irritable bowel syndrome (IBS), and inflammatory bowel disease (IBD), *e.g.* including Crohn's disease and ulcerative colitis, may also be associated with *Campylobacter* infection (Peterson 1994, Kittl *et al.* 2013, Keithlin *et al.* 2014). Guillain-Barré syndrome was considered the most common cause of flaccid paralysis since the eradication of polio in developed countries (Nachamkin *et al.* 1998).

## Campylobacter *in dogs*

Dogs have been identified as asymptomatic carriers of *Campylobacter* species and their role as a source of infection for humans has been demonstrated (Skirrow 1991, Siemer *et al.* 2004, Karenlanpi *et al.* 2007, Koene *et al.* 2004). It has been reported that approximately 6% of human campylobacteriosis cases are due to contact with pets (Tenkate and Stafford 2001, Rossi *et al.* 2008).

The role of *Campylobacter* as an enteric pathogen in dogs is unclear. Some studies found no significant relationship between diarrhoea and *Campylobacter* spp. infection (Sandberg *et al.* 2002, Workman *et al.* 2005, Acke *et al.* 2006), suggesting that the organism is a commensal. At the same time, other studies report an association between infection and clinical signs (Guest *et al.* 2007, Chaban *et al.* 2010), particularly in younger dogs (Parson *et al.* 2010, Burnens *et al.* 1992). Lesions described are characteristic but not pathognomonic. The colon may be congested and oedematous, mild to severe haemorrhagic colitis, and oedematous mesenteric lymph nodes may be present (Marks *et al.* 2011). Chaban and colleagues (Chaban *et al.* 2010) report that there is a notable increase in species richness detectable in the dog population. Cases of perinatal death associated with *C. jejuni* infection of foetus-placental organs are reported (Sahin *et al.* 2014).

Colonization with *Campylobacter* may predispose dogs to infection with parvovirus, or with a secondary infection, and may increase the severity of the primary infection (Workman *et al.* 2005, Olson and Sandstedt 1987).

Dogs can carry a wide range of *Campylobacter* species. Some studies report *C. jejuni* as the most common species, although others indicate *C. upsaliensis* as predominant (Table I), which has dogs as main reservoir. Simultaneous presence of multiple species with various pathogenicity characteristics can also occur. Koene and colleagues (Koene *et al.* 2004) describe multiple *Campylobacter* species in 26% of the positive-testing stools.

All consulted studies show that dogs should be regarded as potential sources of exposure for humans. The prevalence of dogs carrying *Campylobacter* spp. varies widely (Table I), depending on the sampled population, on the design of the study, and on the detection method. The main factors affecting prevalence and recorded in literature are: environment, age, presence of diarrhoea or enteric disease, high-density housing (*e.g.,* kennels), food, contact with other animals, walking outdoors, and season.

## *Risk factors at the dog-human interface*

Dogs are the most popular companion animals in many countries. Ownership of dogs is beneficial to the owner's psychological and physical health, promoting a less sedentary lifestyle, emotional protection, and social interaction (McNicholas *et al.* 2005). They increasingly participate in animal-assisted therapy. For this reason the high prevalence of *Campylobacter* infection, recorded in many studies is an important topic of public health (Table I); especially as there is evidence of increased risk of *Campylobacter* infections associated with dog ownership (Tenkate and Stafford 2001, Parsons *et al.* 2010). The genotyping of isolates has aided the identification of contamination sources and the tracing of the transmission routes, *e.g.* the environment, reservoirs, and human beings, thus increasing the understanding of the epidemiology of this disease (Keller *et al.* 2007). Mughini Gras and colleagues (Mughini Gras *et al.* 2013) hypothesise the following scenarios: humans and pets become infected from the same source; humans become infected from dogs; dogs become infected from humans.

### Environment

Poor hygiene conditions may represent an important source of *Campylobacter*. It can resist in the environment, especially when protected from

**Table I.** *Prevalence of* Campylobacter *infections in the relevant literature according to species isolated, type of sample, population sampled, country, and detection methods.*

| Bibliography | Population | Samples | Total dogs | Prevalence | Detection | Species | Identification method | Geography |
|---|---|---|---|---|---|---|---|---|
| Lopez *et al.* 2002 | Household dogs | Faecal samples | 380 | 17% | Culture | *C. jejuni* 12% | Phenotypic test | Argentine |
| Workman *et al.* 2005 | Household dogs | Rectal swabs | 130 | 46.9% | Culture | *C. jejuni* 26%<br>*C. coli* 4%<br>*C. upsaliensis* 2% | PCR | Barbados |
| Chaban *et al.* 2010 | Healthy household dogs | Faecal samples | 70 | 56% | PCR | *C. upsaliensis* 43%<br>*C. yointestinalis* 13%<br>*C. jejuni* 7%<br>*C. showae* 6%<br>*C. coli* 0% | PCR | Canada |
| | Diarrhoeic household dogs | Faecal samples | 65 | 97 % | PCR | *C. upsaliensis* 85%<br>*C. jejuni* 46%<br>*C. showae* 28%<br>*C. coli* 25%<br>*C. yointestinalis* 18% | PCR | |
| Leonard *et al.* 2011 | Dogs from veterinary clinics | Faecal swabs | 240 | 22% | Culture | *C. upsaliensis* 19%<br>*C. jejuni* 3% | PCR | |
| Hald and Madsen 1997 | Healthy puppies aged between 11 and 17 weeks | Rectal swabs | 72 | 29% | Culture | *C. jejuni* 22%<br>*C. upsaliensis* 5%<br>*C. coli* 1% | Phenotypic test | Denmark |
| Acke *et al.* 2009 | Household dogs | Rectal swabs | 147 | 41% | Culture | *C. upsaliensis* 10%<br>*C. jejuni* 30%<br>*C. coli* 1% | PCR | Ireland |
| Giacomelli *et al.* 2015 | Household dogs | Rectal swabs | 100 | 11% | Culture | *C. jejuni* 5%<br>*C. upsaliensis* 5%<br>*C. coli* 1% | PCR | Italy |
| | Shelter-housed dogs | Rectal swabs | 50 | 26% | Culture | *C. jejuni* 16%<br>*C. upsaliensis* 2%<br>*C. hyointestinalis* 6%<br>*C. lari* 2% | PCR | Italy |
| Mohan 2015 | Faecal samples from walk way area | Faecal samples | 498 | 13% | Culture | *C. jejuni* 5% | PCR | New Zealand |
| Salihu *et al.* 2010 | Household dogs | Rectal swabs | 141 | 28% | Culture | *C. upsaliensis* 21%<br>*C. jejuni* 6% | Phenotypic test | Nigeria |
| Sandberg *et al.* 2002 | Household dogs | Rectal swabs | 529 | 23% | Culture | *C. upsaliensis* 20%<br>*C. jejuni* 3% | Phenotypic test | Norway |
| | Diarrhoeic household dogs | Rectal swabs | 66 | 27% | Culture | *C. upsaliensis* 23%<br>*C. jejuni* 3% | Phenotypic test | |
| Engvall *et al.* 2003 | Household dogs | Faecal samples | 91 | 56% | Culture | *C. upsaliensis* 43%<br>*C. jejuni* 11%<br>*C. coli* 2%<br>*C. helveticus* 2%<br>*C. lari* 1% | PCR | Sweden |
| Holmberg *et al.* 2015 | Healthy dogs under the age of two | Rectal swabs | 180 | 37% | Culture | *C. upsaliensis* 29%<br>*C. jejuni* 4% | PCR | |
| Parson *et al.* 2010 | Dogs from veterinary clinics | Faecal samples | 249 | 38% | Culture | *C. upsaliensis* 37% | PCR | UK |
| Westgarth *et al.* 2009 | Household dogs | Faecal samples | 183 | 26% | Culture and direct PCR | *C. upsaliensis* 25% | PCR | UK |

dryness. These bacteria can survive on dry surfaces for at least 7 days (Ullman and Kischkel 1981). Most surface water sources are contaminated by animal manure, containing *Campylobacter*. In slurries and dirty water, *Campylobacter* can survive for up to 3 months (Nicholson *et al.* 2005).

Some studies have shown the presence of *Campylobacter* on flies. The common houseflies (*Musca domestica*) and other flies thrive in excreta and other filth. They could act as mechanical vectors, by carrying bacteria on the hairs and surface of their bodies, or on their feet. In this respect, it is worth noting that fly control has shown to be effective in preventing childhood diarrhoea (Wright 1983, Ekdahl *et al.* 2005). *Campylobacter* spp. has been isolated from sewage contaminated water (Bolton *et al.* 1987), contaminated soil (Brown *et al.* 2004), and aquatic sediments (Jones *et al.* 1990).

### Age

The majority of studies found that younger dogs were more likely to be carriers of *Campylobacter* spp. and to shed the organism more commonly than older dogs (Sandberg *et al.* 2002). This suggests an age predisposition and age- immunity development (Sandberg *et al.* 2002, Workman *et al.* 2005, Acke *et al.* 2006, Parsons *et al.* 2010). In a study conducted in Barbados (Workman *et al.* 2005) over 70% of *Campylobacter*-positive dogs were under 1 year old, and 32.8% were younger than 9 week old (Workman *et al.* 2005).

### Diarrhoea and enteric disease

As previously written, this topic is controversial, but the precautionary approach requires counting the presence of diarrhoea among the risk factors.

### High-density housing

The prevalence in dogs living in groups (for example in kennels or shelter) is higher than in household dogs (Workman *et al.* 2005, Acke *et al.* 2006). This is probably due to the stress, increased prevalence of gastrointestinal disease, close contact with other animals, and dietary variation (Table I).

### Contact with other animals

The contact of dogs with other animal species could be a factor of great importance. Natural reservoirs for *Campylobacter* spp. include chicken and other poultry, wild birds, pigs, cats, sheep, cows (Workman *et al.* 2005), and exotic pets, such as turtles (Harvey and Greenwood, 1985), and hamsters (Fox *et al.* 1983). The high prevalence (39.3%) reported by Workman and colleagues (Workman *et al.* 2005) in wild birds is of particular interest, as dogs can easily meet bird faeces in parks.

### Food

Homemade cooked food or leftover food in the dog's diet (or added to the dog's diet) may increase the odds of *Campylobacter* carriage (Leonard *et al.* 2011). Westgarth and colleagues (Westgarth *et al.* 2009) report that feeding dogs with leftover human food in its bowl greatly increases the risk of infection; whereas feeding dogs directly from a person's plate reduces the risk of its being positive. It is possible that owners would be more likely to put 'spoiled', undercooked or contaminated food in the dog's bowl, whereas food from a plate would be less likely to be contaminated. It is also possible that the food may become contaminated while it is waiting to be fed to the dog. Raw food, especially meat, is generally considered to be a source of *Campylobacter* species (Westgarth *et al.* 2009).

A rapid change of diet can predispose to enteric dismicrobism, which could favour the onset of acute diarrhoea. In this condition, pathogens, like silent *Campylobacter* spp., could take over, multiply, and exacerbate the gastroenteric symptoms.

### Season

The season can affect the patterns of infection and shedding of *Campylobacter* spp. by dogs. Some authors reported a higher number of isolations during Summer and Autumn (Lopez 2002, Torre and Tello 1993, Mohan 2015). For example, Carbonero and colleagues (Carbonero *et al.* 2012) reported in a study performed in Cordoba (Spain) that *C. upsaliensis* peaks in Spring, while *C. jejuni* peaks in Summer. This agrees with other studies performed on other species, like cattle and sheep, where the highest prevalence rates were also found in Spring-Summer (Grove-White *et al.* 2010).

### Walking outdoors

Housed dogs have less chance of becoming infected. Dogs that escaped from home in the past, or that are free to access the external environment, have higher odds of being positive (Westgarth *et al.* 2009).

## *Antimicrobial resistance*

An important aspect, from a public health and urban hygiene point of view, is the frequent anti-microbial resistance of zoonotic agents. Increasing antimicrobial resistance in both medicine and agriculture, is recognized as a major emerging public health concern by various authors and national authorities, including the World Health Organization (WHO) (Moore *et al.* 2002, Di Giannatale *et al.* 2014, Ozbey and Tasdemi 2014, WHO 2001).

The growing number of household pets and their growing health care standards have led to an augmented number of geriatric animals accompanied by extensive medical histories, including antimicrobial drug administration. Companion animals may play an important role as a reservoir of resistant bacteria or resistance genes. Furthermore, human beings may be a reservoir of pathogens for their pets (Rutland *et al.* 2009).

The spread of antimicrobial-resistant bacteria can occur by direct contact (petting, licking, etc.) or indirectly, via the household environment, contamination of food, furnishings, etc. (Guardabassi *et al.* 2004).

Antimicrobial drugs exert a selection pressure not only on pathogenic bacteria, but also on commensal microorganisms of the intestinal tract of humans and animals. This may constitute a reservoir of resistant genes for potentially pathogenic bacteria (Guardabassi *et al.* 2004, da Costa *et al.* 2013).

Anti-microbial resistant enteric infections are highest in the developing world, where the use of anti-microbial drugs in humans and animals is largely unrestricted (Lengerh *et al.* 2013). In *Campylobacter* isolated from animals and food, the highest levels of resistance were reported for ciprofloxacin, nalidixic acid and tetracyclines (EFSA 2015).

The major issue of concern is the resistance to aminoglycosides such as gentamicin, macrolides, and quinolones which are the drugs of choice for serious campylobacteriosis in humans. In particular macrolides and quinolones are the antibiotics most frequently used in dogs (Marks *et al.* 2011).

Resistant *Campylobacter* infection in dogs may pose a hazard for owners, especially if they have increased susceptibility to infection.

## Laboratory diagnosis

Isolation of causative agent is conducted using selective media under microaerophilic conditions (Marks *et al.* 2011). Rectal swab specimens or fresh faeces should be collected (Fox 1990), paying particular attention to prevent faeces from drying. When swabs are used, a transport medium (like Amies, Cary Blair or Stuart) must be used (OIE 2008). Transport to the laboratory and subsequent processing should therefore be as rapid as possible. It should be conducted preferably by the same day of collection, and, in any case, no later than 2 days from the collection. No recommendation on the ideal temperature for transportation can be made, but it is clear that freezing or high temperatures can reduce viability. High temperatures (> 20°C), low temperatures, and fluctuations in temperature must be avoided. When the time between sampling and processing is longer than 48 hours, storage at 4°C (± 2°C) is advised (OIE 2008). Currently, 2 ISO International Organization for Standardization (ISO) procedures are available: a horizontal method for detection of thermo-tolerant *Campylobacter* in food and animal feeding stuffs (ISO 2006), and a procedure for the isolation of *Campylobacter* from water (ISO 2005).

However, neither of these standard methods is optimal for the isolation of *Campylobacter*s from live animals (OIE 2008). Many media can be used in the recovery of *Campylobacter* spp., such as modified charcoal, cefoperazone or desoxycholate agar (mCCDA). The latter is the recommended medium, although alternative media may be used (OIE 2008).

A detailed description on *Campylobacter* spp. detection by culture and the variety of existing media has been provided by Corry and colleagues (Corry *et al.* 2003, Corry *et al.*1995). Isolation is enhanced by selective filtration of faeces to be cultured through a 0.45 µ filter (Goossens *et al.* 1991). Microaerobic atmospheres of 5-10% oxygen, 5-10% carbon dioxide are required for optimal growth (Corry *et al.* 1995, Vandamme 2000). Incubation is frequently carried out at 42°C to select for thermophilic *Campylobacter*, but a temperature of 37°C should be used to ensure isolation of variable or non-thermophilic species (Marks *et al.* 2011). *Campylobacter jejuni* and *C. coli* usually show growth on solid media within 24-48 hours at 42°C. As the additional number of positive samples obtained by prolonged incubation is very low, 48 hours of incubation is recommended for routine diagnosis (Bolton *et al.* 1988).

Biochemical and thermo-tolerance testing are used to differentiate *Campylobacter* spp. Hippurate hydrolysis test is the most common phenotypic test used in routine diagnostics (Engvall *et al.* 2002).

Several molecular techniques have been described to identify and differentiate *Campylobacter* spp. PCR, multiplex PCR, immuno-PCR, Realtime PCR, Random Amplified Polymorphic DNA (RAPD)-PCR, DNA microarrays, and probes are widely used (Wieland *et al.* 2005, Engvall *et al.* 2002, Dhama *et al.* 2013).

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometer (MALDI-TOF MS) has become commonly used in diagnostic laboratories for species identification (Bessede *et al.* 2011, Seng *et al.* 2010, Fagerquist *et al.* 2005).

Serological assays are not routinely in use for the detection of *C. jejuni* and *C. coli* colonization (OIE 2008). Unfortunately, no systematic studies have been conducted to ascertain the importance of antibody titers in dogs and cats as an indicator of infection in animals with or without diarrhoea (Fox *et al.* 1990).

## Conclusions

The "One Medicine" concept as described by Schwabe (Schwabe 1964) has seen unprecedented revival in the last decade and has evolved towards "One Health" conceptual thinking, which further emphasises epidemiology and public health (Zinsstag *et al.* 2009). Rabinowitz suggests that, as humans, we should change our "us versus them" perspective of the entire environment, including animals as determinants of 'risk to human health' towards a perspective of "shared risk" between humans and animals (Rabinowitz *et al.* 2008). Initially, "One Health" research focused on zoonoses from farm animals and wild animals. There are, however, numerous specific examples of human diseases for which small companion animals may play a significant role in the transmission or by acting as reservoirs of infection.

Measures to control human campylobacteriosis should focus on preventing transmission from dogs in addition to other sources, such as undercooked poultry, contact with livestock, raw milk and untreated surface water. The relationship established among companion animals, human beings, and the risk of zoonotic infection from pets varies with the given context (cultures, economics, religions, etc.). The most common factors that affect the odds of infection in dogs, as reported in the relevant literature, are: environment, age, presence of diarrhoea or enteric disease, high-density housing, food, contact whit others animals, walking outdoors, and season.

The awareness of the risk of *Campylobacter* spp. infection from dogs may be an important way to reduce the transmission from dogs to humans, in particularly infants, young children, and immune-compromised individuals. In this context, veterinarians bear a crucial role in protecting dogs and their families. In order to provide targeted education and recommendations to high-risk patients, veterinarian practitioners need to be aware of their clients' immune status and of the presence of high-risk household members or others who frequently enter in contact with dogs, including those outside of the home (*e.g.*, dogs involved in animal-assisted activities or therapy). To this end, communication between physicians and veterinarians must be improved. Further research in risk factors is also necessary to better understand the epidemiology of *Campylobacter* spp., as well as to develop a correct human-dog relationship and healthy lifestyles.

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