CAMPYLOBACTER JEJUNI - Foodborne Gastroenteritis

Course # DL-994

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Approved for 3.0 CE
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Level of Difficulty: Intermediate

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**COURSE NAME** CAMPYLOBACTER JEJUNI FOODBORNE GASTROENTERITIS  
**COURSE #** DL-994

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1. Overall, I was satisfied with the quality of this Distance Learning course.  
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OUTLINE
A. Introduction
B. History of Campylobacter jejuni Gastroenteritis
C. Transmission of Campylobacter jejuni
D. Illness/Symptoms
E. Complications of Campylobacter Gastroenteritis
F. Microbiology of Campylobacter jejuni
G. Pathogenic Mechanisms of Campylobacter jejuni
H. Diagnosis and Identification of Campylobacter Infection
I. Treatment
J. Prevention of Campylobacter Infection
K. Conclusion
L. References

COURSE OBJECTIVES
After completing this course the participant will be able to:
1. outline the history of Campylobacter gastroenteritis
2. discuss the incidence of Campylobacter infection in the U.S.
3. explain the pathogenicity factors of Campylobacter
4. outline the clinical features of Campylobacter gastroenteritis
5. explain how the organism is identified
6. state methods to prevent Campylobacter gastroenteritis
7. outline methods of treatment of Campylobacter gastroenteritis

A. INTRODUCTION
Foodborne infections are an important public health problem in the United States. In 2013, the Centers for Disease Control and Prevention (CDC) estimated that foodborne infections from viral and bacterial sources caused 84 million illnesses, 275,000 hospitalizations, and 4,800 deaths in the U.S. (2). Most foodborne infections are self-limiting, and the symptoms are usually gone in 5-7 days. However, many foodborne infections can cause serious sequelae (diseases resulting from a previous disease).

One of the more commonly reported bacterial causes of foodborne infection in the United States and throughout the world is Campylobacter jejuni (1,2). In many industrialized nations, Campylobacter jejuni is the most frequently identified pathogen associated with acute diarrhea. Worldwide, the economic loss due to C. jejuni infection is likely to be well in excess of US $2 billion per year (1,2). Adding to the human and economic costs of C. jejuni are the chronic sequelae associated with this infection.
In 2013, the incidence of various pathogens in 19,056 laboratory-confirmed cases of foodborne illnesses reported by the CDC was as follows: *Salmonella*, 7,277 cases; *Campylobacter*, 6,621 cases; *Shigella*, 2,309 cases; *Cryptosporidium*, 1,186 cases; *E. coli* O157, 555 cases; *Yersinia*, 171 cases; *Listeria*, 123 cases; *Vibrio*, 242 cases, and *Cyclospora*, 14 cases (1,2,3). The true incidence of many of these infections is actually much higher because many infections are not reported. For example, it is believed that only one person in eight with *Campylobacter* infection seeks medical care, or has the illness confirmed by a laboratory so that the illness is reported to the health department (4). Further, the reporting practices can vary from state to state, so it is likely that many foodborne agents are not reported to the health department, and thus to the CDC. Taking these facts into account, the CDC estimates that a more realistic estimate of the incidence of *Campylobacter jejuni* infection is about 2.4 million cases each year in the United States (1,2).

The infection due to *Campylobacter jejuni* is called campylobacteriosis, or *Campylobacter jejuni* gastroenteritis. This infection occurs primarily in infants, elderly people, and patients with underlying disease, but not entirely. Anyone who has ingested the organism from contaminated food or water is at risk of acquiring the disease. Immunocompromised individuals are at higher risk of acquiring campylobacteriosis, and the infection is usually more severe in these individuals. Campylobacteriosis is usually a self-limited disease, and antimicrobial therapy is not generally indicated. However, treatment can decrease the duration and the severity of illness if it is initiated early in the course of infection on very sick patients. Complications are rare; however, previous *C. jejuni* infection can result in serious sequelae, such as reactive arthritis, meningitis, recurrent colitis, acute cholecystitis, hemolytic uremic syndrome, pancreatitis, cystitis, and Guillain-Barré syndrome (4,5).

*C. jejuni* normally inhabits the intestinal tract of a wide range of animal hosts, notably poultry, other birds, cattle, swine, and sheep. It is from these sources that the organism can subsequently be passed into the food or water chain. *Campylobacter jejuni* gastroenteritis in humans is generally acquired through the ingestion of food — poultry, beef, pork, or unpasteurized milk and milk products — although infection can also be acquired through a contaminated water supply, causing large outbreaks. Undercooked chicken is the most common source of infection. In some rare instances, *C. jejuni* may be acquired person-to-person via the oral-fecal route.

The gastroenteritis associated with *Campylobacter jejuni* ranges from mild disease to severe diarrheal disease. Most people who become ill with *C. jejuni* get diarrhea (often bloody diarrhea), cramping, abdominal pain, and fever within two to five days after exposure to the organism, with symptoms typically lasting one week (4,5). Often the illness can be accompanied by nausea and vomiting. Some infected persons have no symptoms. In persons with compromised immune systems, *C. jejuni* can occasionally spread to the bloodstream or cause infection in other parts of the body, such as the appendix, abdominal cavity, central nervous system, gallbladder, or urinary tract, and cause a life-threatening infection. Some individuals may develop secondary sequelae. Death can occur in severe cases, but tends to occur in patients with other existing illnesses, such as HIV, cancer, or liver disease (4,5).

This Distance Learning Course will review the history of gastroenteritis due to *Campylobacter jejuni* and discuss where the organism is normally found, how the organism is spread, the clinical symptoms of the disease, how the organism is isolated and identified by the clinical laboratory, treatment of the disease, and steps people can take to reduce the risk of infection.

**B. HISTORY OF CAMPYLOBACTER JEJUNI GASTROENTERITIS**
Awareness of the health implications of *Campylobacter* spp. causing gastrointestinal infections began more than a century ago when the organism was first seen by Dr. Theodor Escherich in Germany in 1886 (4). Dr. Escherich, for whom the organism *Escherichia coli* was named, observed under a microscope some spiral and gull-wing-shaped organisms with darting motion in stool samples of children with diarrhea. Dr. Escherich, however, was not able to isolate and grow these organisms. In the 1960s, veterinarians developed a filtration-culture system and recovered a spiral, S-shaped or gull-wing-shaped organism causing diarrhea in animals. They were not able to characterize the organisms, but were able to grow them under microaerobic (reduced oxygen) conditions.

In 1972, *Campylobacter jejuni* was first isolated from human diarrheal stool specimens by a clinical microbiologist in Belgium using the same filtration technique that had been initially used in veterinary medicine (4). It was not until later in the 1970s, with the development of improved media and the discovery of optimal temperature and reduced atmospheric requirements, that *Campylobacter* finally was recognized as a significant cause of bacterial gastroenteritis. Due to its unusual growth and atmospheric requirements, the organism had escaped notice as a human pathogen for many years, all the while causing many undiagnosed cases of gastroenteritis.

During the 1970s, the use of commercial selective growth media and commercial environmental systems permitted more laboratories to test stool specimens for the presence of *Campylobacter* spp. Further studies during the 1970s and 1980s increased our knowledge of *C. jejuni* and other species of *Campylobacter*, including their natural habitat, role in disease, and pathogenic mechanisms.

The family *Campylobacteraceae* consists of 17 species in the genus *Campylobacter*. They vary widely in their normal habitat, including poultry, wild birds, farm animals, domestic pets, as well as marine mammals. However, only a few *Campylobacter* species cause human gastrointestinal disease. *Campylobacter* enteritis is typically caused by *Campylobacter jejuni* 95% of the time, *Campylobacter coli* 4% of the time, and other lesser known *Campylobacter* species, such as *C. upsaliensis* or *C. lari*, about 1% of the time (4,5). Since *C. jejuni* is much more commonly isolated than *C. coli* from clinical fecal specimens, and since *C. jejuni* and *C. coli* cause identical clinical symptoms and are treated in the same manner, this course will only describe gastroenteritis due to *Campylobacter jejuni*. Most clinical laboratories currently do not routinely distinguish between these two organisms.

With the development of newer methods and improved selective media, *C. jejuni* rose from relative obscurity to become the most common bacterial pathogen recovered from diarrheic stools in the U.S. For many years, *Campylobacter jejuni* infection became either the leading or the second leading cause of bacterial gastroenteritis reported in the U.S. (see Table 1). In 1996, for example, almost 24% of laboratory-confirmed cases of bacterial gastroenteritis reported by the CDC and by FoodNet (6), a component of the CDC, were caused by *Campylobacter jejuni*. In 2013, however, 14% of laboratory-confirmed cases were caused by *C. jejuni*, and 16% of laboratory-confirmed cases were caused by *Salmonella* species. The prevalence of shigellosis during this period was 4% and *Escherichia coli* O157 infection 1% (1,2,3).

Around 2000, the CDC started seeing a decrease in the isolation rate of *C. jejuni*, while the incidence of *Salmonella* spp. and a few other foodborne bacterial agents remained about the same (Table 1). While there was a drop in the incidence of *C. jejuni* since 2000, the number of human *Campylobacter* cases in the U.S. is still estimated to be 2.1 to 2.5 million per year, or 0.8% of the population (1,2). It is believed that the actual incidence is substantially greater than the reported incidence due to under-diagnosis and under-reporting (1,2).
In 2013, FoodNet had a surveillance area that included 48 million persons, or 15.8% of the United States population. From this cohort, FoodNet obtained information about 18,499 laboratory-confirmed infections caused by nine organisms: *Campylobacter*, *Cryptosporidium*, *Cyclospora*, *E. coli* O157:H7, *Listeria*, *Salmonella*, *Shigella*, *Vibrio*, and *Yersinia*. Most infections were due to *Salmonella* (42%), followed by *Campylobacter* (37%) (2,3,6).

Since the peak of *Campylobacter* infection in 1998, the incidence of infection has declined about 30% according to current estimates (See Table 1). In 2008, the incidence of diagnosed *Campylobacter* infections was 12.6 per 100,000 people, lower than that of salmonellosis at 16.2 per 100,000 people (1,2,3). Even though there has been a decline in the incidence of *C. jejuni* infection in the U.S., *C. jejuni* is estimated to be responsible for 12% of the diarrhea cases worldwide (1,4). An unusual fact is that the reported incidence of *C. jejuni* gastroenteritis varies substantially by state in the United States. For example, in 2013 California had the highest rate of *Campylobacter* infection among all the U.S. states under surveillance by FoodNet (see Table 2). It is believed that the different incidence rates reflect regional differences in exposure to the organism, or to different food consumption habits (2). The overall recent decline in the reported incidence of *Campylobacter* infection in the U.S. may be due to new food-processing regulations and techniques, as well as other food safety efforts regulated by the FDA (4).

The incidence of *Campylobacter* infection in many developing countries, such as Mexico and Thailand, is much higher than that in the United States. Travelers to developing countries are at risk for developing *Campylobacter* infection with isolation rates of as high as 39% reported from various studies (4,5). The frequency of *C. jejuni* infection is much higher in Japan than in the U.S. In 2008, the incidence in England was quite high, 40,000 cases, or 80 per 100,000 people (4,5).

While *Campylobacter* does not receive the notoriety of foodborne pathogens like *E. coli* O157:H7 and *Salmonella* spp., *Campylobacter* infection is very common. It can cause serious complications, and is costly to the health care system. Current estimates are that each case of campylobacteriosis in the U.S. costs $920 on average due to medical and productivity (lost wages) expenses, with an annual total cost for all cases of approximately $1 billion (1,2).

**C. TRANSMISSION OF CAMPYLOBACTER JEJUNI**

The *Campylobacter jejuni* organism is zoonotic—an organism normally found in animals as a part of their normal microbial flora, but capable of causing disease in humans. A variety of animals serve as reservoirs for *C. jejuni*, such as poultry, wild birds, pigs, sheep, cattle, and domestic pets. This section explains how *C. jejuni* is transmitted from animals and discusses the incidence of campylobacteriosis.

**Case Study 1:** (MMWR 47:129-131)

On Aug. 29, 1996 the Jackson County Health Department (JCHD) in southwestern Oklahoma notified the Oklahoma State Department of Health (OSDH) of a cluster of *Campylobacter jejuni* infections that occurred during August 16-20 among persons who had eaten lunch at a local restaurant on August 15. A case was defined as illness in a person who had lunch at the restaurant on August 15 and had onset of diarrhea or vomiting during August 16-20. Of 25 persons available for interview who had eaten lunch at the restaurant on Aug. 15, a total of 14 had an illness that met the case definition. Stool specimens were collected from 10 patients; all yielded *C. jejuni*. To identify risk factors for illness, OSDH conducted a case-control study of 14 patients and 11 controls (persons who had eaten lunch with patients at the implicated restaurant on Aug. 15 but did not become ill). All 14 patients and four controls reported eating lettuce. Eleven patients and three controls had eaten lasagna. Both lettuce and lasagna were
statistically associated with illness. Lettuce consumption accounted for all cases, and lasagna consumption accounted for 79% of cases.

Health department staff visited the restaurant to obtain information about menu items, to observe food preparation, and to inspect the kitchen. Inspection indicated that the countertop surface area was too small to separate raw poultry and other foods adequately during preparation. The cook reported cutting up raw chicken for the dinner meals before preparing salads, lasagna, and sandwiches as luncheon menu items. The lettuce or lasagna was probably contaminated with C. jejuni from raw chicken through unwashed or inadequately washed hands, cooking utensils, or the counter top. JCHD recommended that the restaurant enlarge its food-preparation table and install a disposable hand towel dispenser and that food handlers wash hands and cooking utensils between use while preparing different foods.

Poultry—particularly chickens and turkeys—and waterfowl are the most important sources of Campylobacter jejuni infection in humans. Any raw poultry—chicken, turkey, duck, goose, or game fowl—may contain Campylobacter jejuni, including organic and “free range” products. Most chicken flocks are infected with Campylobacter, but show no signs of illness. In mature poultry the organism is usually nonpathogenic, but some strains of C. jejuni can cause enteritis and death in newly hatched chicks or poults (young fowl). The intestines of poultry are easily colonized (the organism establishes itself without a detectable host immune response) with C. jejuni. Day-old chicks can be colonized with as few as 35 organisms. Most chickens in commercial operations are colonized by 4 weeks (5). Once chicks and poults become colonized, they can continue to excrete C. jejuni in their feces throughout their lifetime and spread the organism from bird to bird. Laid eggs can be contaminated with C. jejuni from chicken feces. Once C. jejuni has been introduced into the environment of the chicken, rapid transmission within the flock occurs. Unchlorinated water is a major source of transmission among chickens. Once the organism is established within the flock, it can be very difficult to eliminate (4,5).

When an infected bird is slaughtered, Campylobacter organisms can be transferred from the intestines to the meat. It is estimated that over half of all commercial chicken and turkey flocks harbor C. jejuni (1,2). A 1998 FDA study identified Campylobacter contamination in 63% of more than 1,000 chickens obtained in grocery stores (1,2). In 2005, Campylobacter was present on 47% of raw chicken breasts tested through the FDA Retail Food program (1,2). Another study reported an isolation rate of 98% for retail chicken meat, with bacterial counts often exceeding 10^3 per 100 grams. Skin, giblets, and the liver have particularly high levels of contamination. When fecal samples from chicken carcasses chosen at random from butcher shops were tested for Campylobacter, 83% of the samples yielded more than 10^6 colony forming units per gram of feces (4,5).

Interestingly, one study from the CDC (2) found that the risk associated with eating commercially prepared chicken was greater than that associated with eating home-prepared chicken. The reasons might be higher contamination levels or inadequate cooking procedures. Minimal cooking of food will destroy C. jejuni organisms, which are not very resistant to heat. One way humans infect themselves is by cutting raw poultry meat on a cutting board, then using the unwashed cutting board or utensil to prepare vegetables or other raw or lightly cooked foods. The infectious dose (number of organisms necessary to cause disease) is very small; fewer than 500 Campylobacter organisms can cause illness in humans (4,5). One drop from raw contaminated chicken meat can infect a person. However, in contrast to other agents of foodborne gastroenteritis, including Salmonella spp., Campylobacter does not multiply in food (1,2,3).

For humans, waterfowl are just as important a source of Campylobacter jejuni as chickens and turkeys. Wild birds, including migratory birds—cranes, ducks, geese, and
seagulls—and domestic bird species can all harbor *C. jejuni* in their intestines, which offer a suitable biological niche for the survival and dissemination of the organism, often in water sources. *C. jejuni* organisms have been found in the water supply adjacent to fields of migratory birds. Often these organisms may survive for months in the water after the birds have migrated elsewhere.

Cattle are yet another source of human campylobacteriosis. *C. jejuni* is a commensal (symbiotic) organism in the intestinal tract of most cattle. Young animals are more often colonized than older animals, and feedlot cattle are more likely than grazing animals to carry *Campylobacter jejuni*.

**Case Study 2** (MMWR 57:1377-1379)

On October 26, 2007, a family health clinic nurse informed the Kansas Department of Health and Environment (KDHE) that *Campylobacter jejuni* had been isolated from two ill persons from different families who were members of a closed community in a rural Kansas county. This community was an insular religious group of about 150 consisting primarily of agricultural workers who practiced small-scale and traditional farming. On October 20, members held a community fair celebrating their pioneer heritage. During the fair, unpasteurized cheese was made at an activity station by adding rennet extract to unpasteurized milk donated by a local dairy, producing soft cheese in 5-6 hours with little additional processing. The cheese was served at a banquet that evening along with buffalo stew, chili, and potluck meals brought from community members’ homes. By October 29, seventeen additional members of the community had reported gastrointestinal illness and visited the clinic within a week. All nineteen persons reported consuming the fresh cheese that was made on October 20. Eating fresh cheese at the fair was the only exposure associated with illness. Of 101 persons who ate the cheese, 67 became ill (66%). Among the ill persons, 66 (97%) reported watery diarrhea, 18 (27%) reported bloody diarrhea, and 16 (24%) reported vomiting and diarrhea. Two patients were hospitalized. No deaths were reported. One case of secondary transmission occurred in a person who did not consume the fresh cheese, but became ill on October 29, six days after her child became ill.

As part of the investigation a questionnaire was distributed at a community meeting on Nov. 4 to collect information regarding demographics, illness status and characteristics, food history, and other possible exposures. 130 of 150 community members completed the questionnaire. 68 met the case definition (diarrhea and vomiting onset occurring between Oct. 21-29). Consuming fresh cheese produced from unpasteurized milk was significantly associated with illness. Cultures of stool specimens collected from three persons who met the case definition all yielded *C. jejuni*.

Unpasteurized (raw) milk can become contaminated if the cow has an infection with *Campylobacter* in her udder, or if the milk is contaminated with manure. As shown in the case study, raw milk may be made into cheese or other milk products that may contain *C. jejuni*. One study showed 12% of raw milk samples from dairy farms in eastern Tennessee were contaminated with *C. jejuni*. Consumption of raw milk was implicated as the source of infection in 30 of the 80 outbreaks of human campylobacteriosis reported to the CDC between 1973 and 1992 (1,2). Milk-borne outbreaks, while common in the 1980s and 1990s, are less frequently reported now. It is believed that improvements in the production of milk, such as control of *Campylobacter* contamination on the farm, strict animal hygiene, as well as many food safety measures have reduced campylobacteriosis outbreaks from milk.

Another common route of transmission for *C. jejuni* is through waterborne sources. Large outbreaks of campylobacteriosis throughout the world have been associated with unchlorinated drinking water (4,5). Surface water and mountain streams, if used as drinking water, can be contaminated with infected feces from cows, wild birds, or other animals (4).
The incidence of *Campylobacter* infections is usually sporadic—a single event following ingestion of improperly handled or cooked food, primarily poultry products. Undercooked poultry is responsible for >50% of cases investigated by the CDC, and consuming undercooked poultry from a restaurant is usually the source of the infection (1). Campylobacteriosis can occur in large outbreaks, when a number of people become ill at one time, sometimes as many as >1,000 illnesses from the same source.

There is a marked seasonality with sporadic rates of *C. jejuni* infection in the United States: the highest rates of infection increase during the late spring and peak in June, July, or August (see Fig 1 Number of U.S. Cases by Month, 2013). The rise in the number of cases during the summer may be due to higher levels of poultry contamination during warmer weather, and/or to summer food-consumption patterns, including barbecuing and eating outdoors, which may result in food that is undercooked or cross-contaminated. An interesting finding from the CDC showed that the risk for illness associated with recent chicken consumption was much lower for persons who regularly ate chicken than in those who did not, suggesting that partial immunologic protection may follow regular chicken consumption (4,5).

Sporadic infection of *C. jejuni* can also occur in travelers, particularly to developing countries and has been reported to be a common cause of travelers’ diarrhea (1). Other sporadic infections have been associated with some person-to-person contact via the fecal-oral route. This has been noted from infected individuals who have very frequent episodes of diarrhea, and also from infected infants who are still in diapers. Because the infectious dose is small, campylobacteriosis can easily be spread from person to person, particularly if individuals do not properly wash their hands (4,5).

Other sporadic infection occurs from acquiring the organism from domestic pets. Animals, particularly puppies, which have diarrhea due to *C. jejuni* may infect their owners or others who have contact with the stool from an ill dog. Studies of other sporadic *Campylobacter* infections have found such risk factors as contact with domesticated animals and contact with farm animals (1,2).

The incidence of sporadic infection follows primarily a bimodal (2-peak) age distribution, with the highest incidence in infants and young children, followed by a second peak in young adults 20 to 40 years old. In the United States, infants and young adults have the highest *Campylobacter* rate of infection (1,2,4). Infants and young children have a rate of infection of approximately 14 per 100,000 person years. As children get older, isolation rates decline to approximately 4 per 100,000 person years for young adolescents. A notable feature of the epidemiology of human campylobacteriosis is the high isolation rate among young adults (age 20 to 40), approximately 8 per 100,000 person years. The high isolation peak in infants and young children is attributed in part to susceptibility on first exposure to the organism, and to the low threshold in seeking medical care for infected infants. The high rate of infection during early adulthood, more pronounced among men, is thought to reflect poor food-handling practices. Some recent studies, however, are now beginning to show a third peak with a high isolation rate among the elderly (>65). The reason for this recent change in age distribution is unknown, but suspected factors include underlying chronic diseases and the decrease in immune status seen in the elderly.

D. ILLNESS/SYMPTOMS

The average incubation period for campylobacteriosis is three days (but ranges from one to seven days) after ingestion of *C. jejuni* contaminated food or water. The disease generally starts in one of two ways, as explained below; however, a spectrum of illness may be seen with *C. jejuni* infection. Some patients may be asymptomatic or have mild symptoms; others may
have a severe life-threatening illness with various complications. The majority of cases are mild, do not require hospitalization, and are usually self-limited. Approximately one-tenth of patients with laboratory-confirmed cases require hospital treatment as a result of their illness (4,5). Although *Campylobacter* does not commonly cause death, it has been estimated that approximately 124 persons with *Campylobacter* infections die each year (1,2). Death is more common when other diseases (e.g., cancer, liver disease, and immuno-deficiency diseases) are present.

In one type of campylobacteriosis, the first symptoms are usually abdominal pain, cramps, nausea, vomiting, and watery or bloody diarrhea. Approximately half of the patients with laboratory-confirmed campylobacteriosis report a history of bloody diarrhea (4,5). The diarrhea may be as many as 10 watery bowel movements per day, accompanied by a fever as high as 40°C. These patients exhibit a severe inflammatory response, with leukocytes and red blood cells in their stool. In most people, the illness usually lasts 7-10 days; however, severe cases may persist for up to three weeks. Symptom relapses are not uncommon, occurring in about 10-25% of untreated cases.

In the second type of campylobacteriosis, which occurs in about one-third of cases, a prodromal period (early symptoms indicating the start of disease) of headache, myalgia and malaise without gastrointestinal symptoms occurs. This influenza-like prodrome can be characterized by high fever that is accompanied by rigors, generalized aches, dizziness, and delirium. The fever and generalized aches may last for one day (rarely two or three days) before the onset of gastrointestinal symptoms previously described. Patients presenting with these types of prodromal symptoms tend to have more severe disease than those presenting with diarrhea alone.

Extraintestinal infections have been reported either following or concurrent with *Campylobacter* enteritis, including bacteremia and such focal infections as meningitis, appendicitis, cholecystitis (gallbladder infection), septic arthritis, and abscess formation. Bacteremia has been reported to occur at a rate of 1.5 per 1,000 intestinal infections, with the highest rate occurring in the elderly or immunocompromised patients (4). Immunocompromised patients may also have persistent diarrheal illness that may be difficult to treat and can become life-threatening. The severity and persistence of infection in patients with AIDS and hypogammaglobulinemia indicates that both cell-mediated (release of macrophages and T-lymphocytes) and humoral (secretion of antibodies) immunity are important in preventing and eliminating *C. jejuni* infection (4). Even after recovery, patients may excrete the organism for several weeks. Once infected, patients may experience long-term immunity to reinfection with serologically similar strains. However, some individuals who have had *C. jejuni* infection may develop late sequelae as described in the following section.

**E. COMPLICATIONS OF CAMPYLOBACTER GASTROENTERITIS**

Although *Campylobacter* gastroenteritis is generally self-limiting, in some rare instances life-threatening complications have been associated with *C. jejuni* infection, such as: reactive arthritis (Reiter’s Syndrome), hemolytic uremic syndrome, and Guillain-Barré Syndrome (1,4,5). Usually, these complications occur a week or two after the diarrhea has stopped.

Reactive arthritis, or Reiter’s Syndrome, is an autoimmune response that produces an inflammation (arthritis) in different joints in response to *C. jejuni* infection. It most commonly affects large weight-bearing joints such as the knees and the lower back, but other joints can also be inflamed. Patients can also have inflammation of the eyes and urethritis. This is a complication strongly associated with a particular genetic make-up; persons who have the human lymphocyte antigen B27 (HLA-B27) are most susceptible. In approximately 1% of patients with
campylobacteriosis, the onset of pain and joint swelling occurs an average of two weeks after the onset of diarrhea and lasts from a few weeks to nearly a year. Pain and incapacitation can last for months or become chronic.

Another rare complication associated with previous *C. jejuni* infection is due to the cholera-like enterotoxin that some rare strains of *C. jejuni* produce. These patients often have had prior severe clinical symptoms of *Campylobacter* infection, including very severe bloody diarrhea and exudative gastroenteritis. Patients that have cholera-like enterotoxin strains of *C. jejuni* can develop hemolytic uremic syndrome, a disease characterized by acute renal failure with a 5-10% mortality rate (4). The cholera-like enterotoxin produced by *C. jejuni* is similar to that produced by *E. coli* O157: H7.

Lastly, some patients may develop a rare but severe complication called Guillain-Barré syndrome (GBS), a disease that affects the nervous system of the body. Guillain-Barré syndrome is the most common cause of acute generalized paralysis in the Western world (4,5,7). This complication may occur in 1 in 1000 *Campylobacter* patients approximately 2 to 3 weeks after the initial symptoms develop (4,5,7). As many as 40% of GBS cases in this country may be triggered by a previous *Campylobacter* infection that occurred 1 to 3 weeks before the onset of neurological symptoms. *C. jejuni* is now the most recognized infection preceding the development of GBS (7).

Guillain-Barré syndrome is an acute autoimmune disease that causes demyelination (removal of the protective myelin sheath surrounding the nerve in the peripheral nervous system). The disorder results in paralysis that lasts several weeks to years and usually requires intensive care treatment and often respiratory care. Serotyping studies of *Campylobacter* have revealed that most cases of GBS in the United States occur after an infection with *Campylobacter jejuni* serotype O:19.

*C. jejuni* is thought to cause Guillain-Barré syndrome through a mechanism called molecular mimicry. At the molecular level, the O:19 serotype of *C. jejuni* contains a unique lipo-oligosaccharide in its cell membrane. When *C. jejuni* enters the human body, one of the body’s immune responses is to produce antibodies specific to the structure of that lipo-oligosaccharide. However, the human body itself contains compounds with exactly the same molecular structure—certain gangliosides (compounds found in the cell membrane of human nerve cells). Thus, the lipo-oligosaccharide structure of *C. jejuni* mimics the body’s ganglioside molecular structure, and the antibodies produced to attack the *C. jejuni* cell membrane also attack the human body’s nerve cell membrane. The result is nerve damage that leads to the paralysis characteristic of Guillain-Barré syndrome (4,5,7). Different strains of *Campylobacter* as well as a variety of host factors likely play an important role in determining who develops GBS. Approximately 20% of patients with GBS are left with some disability, and approximately 5% die because of respiratory failure.

**F. MICROBIOLOGY OF CAMPYLOBACTER JEJUNI**

*Campylobacter jejuni* are slender, curved, S-shaped, gull-winged, or spiral rods (see Figure 2) that are 0.2 to 0.9 µm wide and 0.5 to 5 µm long (compared to *E. coli*, which are typically 0.5 µm wide and 2 µm long). *Campylobacter* takes its name from the Greek kampylos, meaning curved or bent, and bacterium meaning rod. The species name *jejuni* comes from the sites where the organism does its damage, the jejunum and ileum.

*Campylobacter* species are gram-negative, non-spore-forming rods that may form spherical or coccoid-shaped cells in old cultures or cultures exposed to air for prolonged periods. Organisms are usually motile by means of a single polar flagellum at one or both ends. The organism is relatively fragile, and sensitive to environmental stresses (e.g., oxygen, drying,
freezing, heating, disinfectants, acidic conditions [pH \leq 5.0], and salinity). They are relatively slow-growing, fastidious, and in general, asaccharolytic (relatively inert biochemically to sugars), which makes biochemical identification of *Campylobacter* a challenge (4). (See section H for isolation and identification guidelines.) *Campylobacter jejuni* is a microaerobic organism, which means it has an atmospheric requirement of reduced levels of oxygen (3 to 5%) and a carbon dioxide level of 2 to 10%.

Survival of *C. jejuni* outside the gut of the normal host is poor, and replication does not occur readily. *C. jejuni* grows best at 42°C, the approximate body temperature of the chicken. Thus, the thermophilic (heat-loving) characteristics of *Campylobacter jejuni* are adaptations for growth in its normal habitat – the intestines of warm-blooded birds and mammals. The thermophilic *Campylobacter* include *Campylobacter jejuni*, *C. coli*, *C. lari*, and *C. upsaliensis*. *C. jejuni* accounts for more than 95% of all the human *Campylobacter* infections.

**G. PATHOGENIC MECHANISMS OF CAMPYLOBACTER JEJUNI**

Until recently, investigators have understood very little about the pathogenic mechanisms of *Campylobacter jejuni*. The lack of knowledge concerning the pathogenic mechanisms has limited our means of preventing humans from obtaining the organism from contaminated food or water. Since *C. jejuni* is commensal in poultry, cattle and many other animals, but pathogenic in humans, it was presumed that interactions with human cells permitted the organism to express virulence factors. However, the virulence factors were not understood. Within the last 10 years, information regarding the molecular virulence mechanisms of *C. jejuni* made it clear that *C. jejuni* is a unique pathogen capable of exhibiting various virulence mechanisms depending upon its host.

Studies suggest that *Campylobacter* penetrates the mucus of the small bowel (jejunum, and ileum) of humans using flagellar motility and the corkscrew motion facilitated by its spiral shape. It first colonizes and then multiplies in the intestinal mucus layer. *C. jejuni* is able to invade through the epithelial surface to the underlying tissue and secrete proteins mainly via its flagellar apparatus. Once established, it elaborates other virulence factors and toxins to cause inflammation and epithelial damage with leakage of fluid.

Some strains of *C. jejuni* produce a classic cholera-like enterotoxin similar to that elaborated in *Shigella* spp. and *E. coli* O157:H7. The enterotoxin from these *C. jejuni* strains can produce profuse watery diarrhea, often bloody, and edematous enteritis. In a small number of cases, the infection caused by these enterotoxin-producing *C. jejuni* strains may be associated with hemolytic uremic syndrome and thrombocytopenic purpura through a poorly understood mechanism (4).

One special virulence factor is the ability of *Campylobacter jejuni* to execute N-linked glycosylation of more than 30 human proteins to permit colonization, adherence, and invasion. N-linked glycosylation is an enzymatic process that links saccharides (sugars) to produce glycans (polysaccharides). The N-linked glycosylation process generally occurs in eukaryotic cells (humans), where it is important in the formation of cell membranes, but not in prokaryotic cells (bacteria). Many of the glycosylated substances produced by *C. jejuni* are therefore able to short-circuit host defense mechanisms and mimic host cell substances so that the body is slow to generate a humoral (antibody) response against the organism.

Motility is another factor that allows *C. jejuni* to colonize or infect human intestinal mucosa and produce disease. Previous work (5) indicates that motility contributes significantly to the colonization of animals by *C. jejuni*, and subsequently to the development of disease in susceptible hosts. The flagellum of *C. jejuni* not only facilitates motility into invading tissues,
but also has the ability to secrete discrete *Campylobacter* invasive antigens (proteins). Both the motility and its invasive antigens aid in the pathogenesis of *C. jejuni*.

Yet another *C. jejuni* virulence factor is its ability to bind to human cells through the generation of adhesins (surface-exposed molecules that facilitate a pathogen’s attachment to host cell receptors), particularly binding to host target cells associated with the intestinal mucus-filled crypts that are important in colonization. Still another virulence factor is cytolethal distending toxin (CDT). CDT is a bacterial protein that hijacks the control of eukaryotic cells and causes cell death of lymphocytes. The cytolethal distending toxin of *C. jejuni* seems to be important for human cell cycle control, and has been recognized as a major pathogenicity-associated factor (4,5).

Finally, another virulence factor is lipopolysaccharide (LPS). Lipopolysaccharide is a major component of the outer membrane in gram-negative bacteria and acts as an endotoxin. It is thought to permit invasion of the organism into the intestinal epithelial cells. The LPS elicits a strong immune response, causing human cell damage that leads to the production of an exudate.

The pathogenesis of *C. jejuni* infection certainly involves both host and pathogen-specific factors. The health and age of the host, and *C. jejuni*-specific antibodies produced from previous exposure, all influence the clinical outcome.

H. DIAGNOSIS AND IDENTIFICATION OF *CAMPYLOBACTER* INFECTION

Since many agents of foodborne infection cause similar clinical symptoms including bloody diarrhea, the diagnosis of *Campylobacter jejuni* is dependent upon either isolating the organism from fresh stool, or performing various immunological or molecular tests on a clinical specimen to determine either the presence of the organism, antibody, or DNA segments (see Table 3 and Table 4). *Campylobacter jejuni* should be routinely sought in all stools submitted to the laboratory for culture. The culture request should not be based upon clinical symptoms, travel, or food history since *Campylobacter jejuni* infection may occur under various conditions.

Collection and Transport of Specimens

For culture of *Campylobacter jejuni*, a fresh fecal specimen (less than 2 hr) should be submitted to the clinical laboratory from patients with symptoms of gastrointestinal infection. If a delay of more than two hours is anticipated, the stool sample should be collected using rayon-tipped swabs and placed in semi-solid modified Cary-Blair transport medium (4). Modified Cary-Blair medium contains reducing agents and appears to be the most suitable single transport medium for *Campylobacter* as well as for other enteric pathogens. Specimens received in the transport medium should be processed immediately, or stored at 4°C until processed. On hospitalized patients, the three-day rule (rejection of specimens collected >72 hr after admission) should be used as a criterion for acceptability of routine stool culture requests. Do not perform a culture on formed stools, since patients that have gastroenteritis due to *C. jejuni* or other enteric pathogens will not have a formed stool. In an acute infection, there are usually a very high number of organisms in the stool, so testing of a single stool sample usually has a high sensitivity for detection of *C. jejuni*.

Direct Gram Stain of Specimen

Although a direct Gram stain examination on stool samples is not normally considered part of the analysis for acute bacterial gastroenteritis, a direct examination can be useful since *Campylobacter jejuni* has a unique microscopic morphology, allowing early detection. *C. jejuni* are small, curved or seagull-winged, faintly staining, gram-negative rods (see Figure 2). Studies show a sensitivity ranging from 66 to 94% and specificity about 95% for detecting *C. jejuni* directly from a clinical specimen, so a Gram stain may be a rapid and sensitive method for presumptive diagnosis of *Campylobacter* enteritis (4).
Because of their thin morphology, *Campylobacter jejuni* are not easily visualized with the safranin counterstain commonly used in the traditional Gram stain procedure. Carbol fuchsin or 0.1% aqueous basic fuchsin should be used as the counterstain. This counterstain may also be helpful in identifying the unique morphology of *C. jejuni* from plating media. Some laboratories also find that a direct wet mount on the fecal specimen facilitates the observation of the thin, curved organisms with the darting, rapid motion characteristic of *C. jejuni*.

**Isolation Media**

To successfully recover *C. jejuni* from a clinical specimen, selective media and optimal environmental conditions are critical. There are a number of selective media recommended for the isolation of *C. jejuni* (see Table 3). These include blood-free media such as charcoal cefoperazone dextyholate agar (CCDA) and charcoal-based selective medium (CSM), as well as blood-containing media such as Campy-CVA and Skirrow medium. Some studies suggest that to achieve the highest yield of *C. jejuni* from stool samples, two different selective media, including either CCDA or CSM as one of the media, may increase the recovery of *C. jejuni* by as much as 10 to 15% over the use of a single medium (4). However, other studies found that a single medium, such as Campy-CVA, or a charcoal-based medium, such as CCDA, works as well as two media when incubated at 42°C under optimal microaerobic conditions (4). Many laboratories find that in the current age of cost effective clinical laboratory practice, only a single medium can be used because of budgetary constraints.

Antimicrobial agents, such as cephalothin, present in some selective medium formulations are inhibitory to some strains of *C. jejuni*; therefore, media containing cephalothin are no longer recommended for primary isolation. The addition of cefoperazone to the media has proved effective in inhibiting normal fecal flora while allowing detection of *Campylobacter jejuni*.

**Atmospheric Conditions**

*Campylobacter jejuni* require a microaerobic atmosphere that contains approximately 5% O₂, 10% CO₂, and 85% N₂ for optimal growth. Several manufacturers, such as Anaerocult, CampyGen, CampyPak, and others, produce microaerobic gas generator packs that are suitable for use in the clinical laboratory (see list in Table 5). The microaerobic generators are placed into jars or bags along with plating media, and are initiated by either opening their pouch or by adding water directly to the generator. Some laboratories perform manual gas-evacuation-replacement on jars with this gas mixture to achieve the optimal microaerobic atmosphere. Other laboratories use an automated gas-evacuation-replacement method, such as Anoxomat (Anoxomat, Mart Microbiology) on jars using this gas mixture to achieve microaerobic conditions. The concentration of gases (in particular the high concentration of oxygen) left in candle jars after burning the candle is ineffective for the isolation of *C. jejuni* and should not be used for routine laboratory isolation procedures.

**Temperature for Optimal Growth**

*Campylobacter jejuni* are thermophilic, so their optimal growth temperature is higher than the 35-37°C temperature commonly used in the laboratory. Occasionally, some rare growth of other species of *Campylobacter* may be observed at 37°C; however, the optimal temperature using *Campylobacter* selective media is 42°C for *C. jejuni*.

**Approach to Identification**

Depending on the medium used, the age of the medium and the moisture content, *Campylobacter jejuni* may have different colonial appearances. In general, *C. jejuni* produce gray, flat, irregular, and spreading colonies, often pinkish-beige and spread along the streak line in a puddle-appearing morphology. Some *C. jejuni* colonies are gray and slightly mucoid-looking; some colonies may exhibit a tailing effect along the streak line. Colonies may also
appear as round, convex, entire, glistening colonies 1-2 mm in diameter. Therefore, it is important for the microbiologist to perform many Gram stains on suspicious looking colonies to avoid confusion and possibly mis-detection of \textit{C. jejuni}. Spreading along the streak line is commonly seen, particularly on freshly prepared media, but as the moisture content decreases, the organisms may form round, convex, and glistening colonies with very little spreading. Thus, proper storage of media to ensure correct moisture content is important for optimal isolation and recognition of \textit{Campylobacter} spp. Visible colonies of \textit{C. jejuni} usually appear on culture medium within 48 to 72 hours. An enrichment medium is generally not recommended for recovery of \textit{C. jejuni}, because infected humans usually excrete $10^6$ to $10^9$ CFU of \textit{C. jejuni} per gram of stool.

Agar plates should be examined daily for characteristic \textit{C. jejuni} colonies for a total of three days. Perform a Gram stain and an oxidase test on suspicious looking colonies seen on selective media incubated at 42°C. However, keep in mind that the glucose in some media may cause weak or negative oxidase reactions due to protein sparing (the metabolism of carbohydrate first, in preference to the metabolism of a protein). Oxidase-positive colonies exhibiting a characteristic Gram stain and colonial morphology, isolated from selective media under microaerobic conditions, and incubated at 42°C can be reliably reported as \textit{Campylobacter} spp. Only further testing for hippurate hydrolysis is recommended. Hydrolysis of sodium hippurate is the definitive test for distinguishing \textit{C. jejuni} from other \textit{Campylobacter} species. \textit{C. coli} and \textit{C. jejuni} are biochemically similar, except that \textit{C. coli} lacks hippurate activity. Oxidase-positive, curved gram-negative rods that are hippurate hydrolysis positive should be reported as \textit{C. jejuni} without further workup. Plates should be incubated for a minimum of 72 hr before being reported as negative.

Tests of susceptibility (inhibition) or resistance of \textit{Campylobacter} spp. to nalidixic acid and cephalothin have been used in the past as an aid for species identification of \textit{C. jejuni}. However, these disk identification assays can no longer be relied upon because of the increasing prevalence of fluoroquinolone and other antibiotic resistance among \textit{C. jejuni}. Susceptibility or resistance to nalidixic acid and cephalothin may yield inconsistent results and is not a reliable method for identifying \textit{C. jejuni}.

**Commercial Immunological Systems**

Several commercial immunological systems have been developed to aid in the identification of \textit{Campylobacter} spp. (see Table 4). Currently at least three latex agglutination tests are available in the U.S. for identifying \textit{Campylobacter} spp. However, evaluation of these tests has shown they do not permit confirmation of \textit{C. jejuni} (4). For example, the Campyslide, Dry Spot, and Microgen Campylobacter Rapid Test latex agglutination tests are reported by the manufacturer to identify many \textit{Campylobacter} spp., not just \textit{C. jejuni} (4). Therefore, latex agglutination tests may be useful for confirming the presence of \textit{Campylobacter} spp., but are not specific for \textit{C. jejuni}. Further, cross-reactivity with closely related taxa and other organisms may yield inconsistent results and is not a reliable method for identifying \textit{C. jejuni}.

Rapid immunoassays exist for the detection of \textit{Campylobacter} antigens in human stool (see Table 4). Some EIA tests use either a lateral flow or microwell technology to permit identification of specific \textit{Campylobacter} antigens common to \textit{C. jejuni} or \textit{C. coli}. Some immunoassays are rapid, yielding results within 20 minutes, and can be used directly from either Cary-Blair-preserved or non-preserved stool specimens. Other tests, such as the Premier CAMPY (Meridian Bioscience), are monoclonal antibody-based EIA tests for direct detection of \textit{C. jejuni} in stool. Another test, the ProSpectT \textit{Campylobacter} Microplate Assay (Alexon-Trend), is an antigen detection system that uses polyclonal antibodies in a microwell format for the direct detection of \textit{C. jejuni} directly from either preserved or non-preserved stool specimens. This test
can be completed in less than two hours, and antigens are detectable in stored samples at 4°C for several days.

In one study, the ProSpecT *Campylobacter* Microplate Assay, when compared with culture, had a sensitivity near 89% but good specificity of >97% (4,5). Although the ProSpecT *Campylobacter* Microplate Assay was less sensitive (89%) than culture, its high specificity (>97%) allows a confident positive result. A recent study has actually shown an improved sensitivity of detecting *C. jejuni* using some immunoenzymatic methods compared to bacterial culture (1). Therefore, a laboratory that does not perform *Campylobacter* culture can reliably substitute the ProSpecT *Campylobacter* Microplate Assay.

This rapid, nonculture immunoassay for detection of *Campylobacter* may be of interest to both the clinician and the microbiology laboratory. Theoretically, same-day results would allow triage of patients for earlier therapy. A sensitive enzyme immunoassay (EIA) would provide an option for *Campylobacter* detection without lengthy culture procedures. One such test is the Immunocard Stat Campy (Meridian Bioscience, Inc. Cinn.). However, the cost-effectiveness of rapid immunoassays requires evaluation because the direct cost of an EIA is $8 more than that of a culture.

A DNA probe (Accuprobe; Gen-Probe, Inc., San Diego, CA) directed against *Campylobacter tRNA* sequences identifies *C. jejuni*; however, studies have shown the probe hybridized with other *Campylobacter* spp. (4,5). The major obstacle in the development of a PCR assay for stools for the clinical laboratory is the lack of a simple and practical DNA extraction procedure on stool specimens that eliminates PCR inhibitors.

There are many other immunoenzymatic (EIA) and other DNA probe system techniques that are used to test food and environmental samples for *Campylobacter* species. However, the majority of these systems are not approved for clinical use.

**Epidemiological Typing**

Many typing systems have been devised to investigate the epidemiology of *Campylobacter* infections, and they vary in complexity and ability to discriminate among strains. Some of these typing methods include serotyping, biotyping, and multilocus enzyme electrophoresis. Molecular typing includes methods such as restriction endonuclease analysis, ribotyping, and many different DNA-based subtyping schemes, including pulsed-field gel electrophoresis (PFGE). Epidemiological typing methods to determine similar strain outbreaks of *C. jejuni* are labor intensive and expensive and are usually performed by research or public health laboratories.

**I. TREATMENT**

Almost all persons infected with *C. jejuni* recover without any specific antibiotic treatment because *C. jejuni* infection is generally self-limiting. Supportive measures, such as fluid and electrolyte replacement, are the principal therapies for most patients with campylobacteriosis. Patients should drink extra fluid for the duration of their diarrhea symptoms. Severely dehydrated patients should receive more rapid volume expansion with intravenous fluids (usually dextrose and electrolytes). Antimotility agents, such as loperamide, can lead to prolonged illness or intestinal perforation in any invasive diarrhea and should be avoided.

Antibiotic treatment is controversial, and has only a marginal benefit on the duration of symptoms, and should not be used routinely. However, antibiotic treatment may be given for patients who have high fever, bloody diarrhea, and more than eight stools in 24 hours, or who are immunosuppressed. In more severe cases of gastroenteritis, antibiotics are often begun before culture or serological results are known. Treatment with antibiotics, therefore, depends on the severity of symptoms.
Azithromycin (a macrolide) is currently the drug of choice for most *C. jejuni* infections because of its ease of administration, lack of serious toxicity, and high degree of efficacy (1,2). Another macrolide, erythromycin, was previously the drug of choice and we used successfully for a number of years. However, current studies have shown that when treatment is necessary, azithromycin used early after diseases onset effectively eradicated *C. jejuni* and was clinically superior to erythromycin (1,2).

Fluoroquinolone antibiotics (ciprofloxacin, norfloxacin, levofloxacin, gatifloxacin, or moxifloxacin) can be used if *C. jejuni* are susceptible, however, high rates of quinolone use in livestock means that quinolones are now largely ineffective because of a high rate of resistance. Although most clinical isolates of *C. jejuni* were susceptible in the past to fluoroquinolones, the increasing rate of antimicrobial-resistant strains to this group makes the use for campylobacteriosis more difficult. The rate of fluoroquinolones-resistant *C. jejuni* infection can be as high as 20% in many parts of the world primarily due to the relative unrestricted use of this group of antibiotics in animals (4,5).

Experimental evidence demonstrates that fluoroquinolone-susceptible *C. jejuni* readily become drug-resistant in chickens when these drugs are used in animal feed (4,5). Within two years of the 1995 approval of fluoroquinolones use for poultry in the U.S., the number of domestically acquired human cases of ciprofloxacin-resistant campylobacteriosis in the U.S. doubled (1,6). In a 1998 study conducted in Minnesota, 12 (20%) of 60 *C. jejuni* isolates obtained from chicken purchased in grocery stores were ciprofloxacin-resistant (3). Fluoroquinolone resistance of *Campylobacter* from food animals is now recognized as an emerging public health problem. The high rate of resistance of *C. jejuni* to fluoroquinolones provides a rationale for the prudent use of antibiotics given to food animals. Fortunately, the FDA withdrew approval of these agents for use in poultry in 2005. A study in 1999 found that most clinical isolates of *C. jejuni* from U.S. troops in Thailand were resistant to ciprofloxacin.

**Susceptibility Testing Method**

A standardized broth microdilution test is the approved method recognized by the Clinical and Laboratory Standards Institute (CLSI) (formerly NCCLS) for susceptibility testing of *Campylobacter* spp. (4). CLSI has published quality control ranges for several antimicrobial agents and MIC breakpoints to determine susceptibility. See Performance Standards for Antimicrobial Susceptibility Testing, M100-S-24. 2014. Clinical and Laboratory Standards Institute, Wayne, PA.

**J. PREVENTION OF CAMPYLOBACTER INFECTION**

There are a number of ways to reduce one’s risk of acquiring campylobacteriosis. Since the majority of infections caused by *C. jejuni* are sporadic and are acquired by ingesting contaminated food or water, people can reduce their risk by practicing safe food eating habits and proper food handling practices. All foods derived from animal sources, particularly poultry, should be thoroughly cooked (see Table 6. Prevention of *Campylobacter* Infections from Food). Meat should be cooked throughout until no longer pink and any juices run clear. All poultry should be cooked to reach a minimum internal temperature of at least 165°F. Undercooked poultry served in a restaurant should be sent back for further cooking. One of the main risk factors for acquiring *Campylobacter* infection is eating improperly prepared poultry in restaurants (1,2).

Care must be taken during food preparation to prevent cross-contamination from raw poultry to other food items. One can reduce the risk of cross contamination by thoroughly cleaning knives, cutting boards, and counters. All surfaces and utensils that contact uncooked poultry should be washed between each use before using them with other foods that are to be
eaten without cooking. Remember that Campylobacter is found in nearly 50% of raw chicken. If possible, two cutting boards should be used—one for fresh produce, and the other for raw meat, poultry, and seafood. Good kitchen hygiene, including handwashing, is important to prevent Campylobacter infection. Some Campylobacter jejuni infections are caused by unpasteurized milk, so people should avoid drinking unpasteurized milk or eating unpasteurized milk products.

What are industries doing to prevent Campylobacter infection?

The FDA and the CDC are working with the poultry industry to lower the rate of Campylobacter jejuni found in the production of chickens for human consumption. Processing techniques whereby contamination from one chicken can be easily spread to others are being evaluated and changed. For example, the production of broiler chickens for consumers contains many steps, from evisceration of chickens to final product, and the potential for contamination exists at each step. Immersion in chillers, various rinsing stages, and manual handling of the chickens all have a very high potential for contamination. It has been shown that reduction in the manual handling of chicken carcasses by installation of advanced automated equipment can reduce C. jejuni contamination (1,2). In another study, automated forced-air chilling of chicken carcasses caused a 100-fold reduction in contamination of Campylobacter spp. (1,2). In other studies, turkey processing companies in Texas found that a scalding technique in which the carcass is immediately submerged in hot water (140°F) for a short period of time reduced C. jejuni counts to below detectable levels (1,2). Some European countries use irradiation as a final step to reduce the bacterial count of C. jejuni; however, irradiation is not well accepted by American consumers.

The FDA and the CDC are also looking at various steps farms can take to reduce contamination of Campylobacter in poultry, cattle, and in other farm animals. Studies indicate that strict hygiene reduces Campylobacter intestinal carriage in food-producing animals (1,2). In field studies, poultry flocks that drank chlorinated water and were not crowded had lower intestinal colonization rates than poultry in opposite conditions (1,2). Experimentally, treatment of chicks with commensal bacteria and immunization of older birds also reduced C. jejuni colonization (1,2). This has not been introduced in poultry farms so far. However, because intestinal colonization with Campylobacter spp. occurs so readily in poultry flocks, even strict measures may not totally eliminate intestinal carriage in poultry.

What is the government doing to prevent campylobacteriosis?

Various U.S. agencies, such as the Emerging Infections Program, the Food Safety and Inspections Service, the United States Department of Agriculture, the Center for Food Safety and Applied Nutrition of the FDA, and the CDC are actively involved in preventing foodborne diseases with Campylobacter jejuni (1,6). The Foodborne Disease Active Surveillance Network (FoodNet) of CDC’s Emerging Infections Program collects data from 10 U.S. states on diseases caused by enteric pathogens transmitted commonly through food. FoodNet provides uniform reporting from a panel of sentinel sites, giving an accurate measure of the incidence of diagnosed infections (6).

In addition to monitoring the incidence and trends of human Campylobacter infection in active laboratory and population-based surveillance, FoodNet also conducts studies to identify risk factors for infection. The U.S. Department of Agriculture conducts research on how to prevent the infection in chickens. The Food and Drug Administration has produced the Model Food Code (www.fda.gov/food/foodsafety) for restaurants; adherence to the code will decrease the risk of Campylobacter infection.

An important step in reducing many food outbreaks of Campylobacter jejuni is making sure the public health department and the CDC are aware of the incidence of infection. Physicians who diagnose campylobacteriosis and clinical laboratories that identify this organism
should report their findings to the local health department. If many cases occur at the same time, it may indicate that many people were exposed to a common contaminated food item or water source. Identifying and controlling the source will prevent continuation of the outbreak. Public education is an important aspect of the control process.

**When will a vaccine be available?**

Researchers at the U.S. Naval Medical Research Center are in the early stages of developing a vaccine against *Campylobacter jejuni* to prevent infection in humans. A group working with a Canadian scientist successfully protected monkeys against *C. jejuni* infection in studies performed in 2009. Studies in 2013 have shown that the oral-killed whole cell vaccine appears to be safe and effective in animal models and is currently being tested in phase I volunteer studies. If the vaccine becomes a reality, it would be a significant step forward in reducing foodborne illness in the U.S. and internationally.

Other vaccine studies are underway to study an oral immunization against *Campylobacter jejuni* in chickens. These studies still need to be evaluated before the vaccine becomes commercially available.

**K. CONCLUSIONS**

*C. jejuni*, first identified as a human diarrheal pathogen in 1973, has become one the most frequently diagnosed bacterial causes of human gastroenteritis in the U.S. It is estimated that *Campylobacter* infects over 2 million people each year, and many cases go undiagnosed. For many years it was the most frequent bacterial cause of gastroenteritis, but now the organism is generally ranked as second to *Salmonella* spp. The change in incidence may possibly be due to public awareness, and changes and improvements in commercial food handling policies.

*Campylobacter jejuni* are curved or spiral, motile, non–spore-forming, Gram-negative rods normally found in poultry, other birds, cattle, swine, sheep, and domestic pets as non-pathogenic (commensal) organisms. *C. jejuni* is microaerobic, requiring a reduced oxygen atmosphere for growth, and thermophilic, growing best at an optimal temperature of 42°C.

Transmission of *C. jejuni* from animals to humans usually occurs through ingestion of contaminated food, water, or unpasteurized milk; contact with feces from pets or wild animals; or through direct person-to-person contact with infected patients, particularly infants. Mishandling of raw poultry and consumption of undercooked poultry are the major risk factors for human campylobacteriosis. One of the main risk factors for acquiring *Campylobacter* infection is eating poultry in restaurants.

Poultry represents a large reservoir for the organism. Up to 100% of poultry, including chickens, turkeys, and waterfowl, are infected with the organism in their intestinal tracts, but are asymptomatic. An infected chicken may contain bacterial counts of up to $10^9$ *C. jejuni* per 25 grams, and the bacteria spread rapidly to other chickens.

The gastroenteritis symptoms associated with *Campylobacter jejuni* range from mild to severe diarrheal disease. Most people who become ill with *C. jejuni* have diarrhea (often bloody diarrhea), cramping, abdominal pain, and fever within two to five days after exposure to the organism, with symptoms typically lasting one week. Often the illness is accompanied by nausea and vomiting.

The incidence of sporadic infection follows a bimodal age distribution, with the highest incidence in infants and young children, followed by a second peak in young adults 20 to 40 years old. In the United States, infants and young adults have the highest *Campylobacter* rate of infection. There is a marked seasonality of *C. jejuni* sporadic infection in the U.S.; the rate of infection increases during the spring and peaks in June, July, or August.
Most cases of campylobacteriosis are sporadic or involve small family groups, although some common-source outbreaks involving many people have been traced to unchlorinated water supplies, unpasteurized milk or milk products, or consumption of chicken at large gatherings.

Although *Campylobacter* gastroenteritis is generally self-limiting and lasts about 7-10 days, in some rare instances life-threatening complications have been associated with *C. jejuni* infection, such as reactive arthritis (Reiter’s Syndrome), hemolytic uremic syndrome, and Guillain-Barré Syndrome. Many of these complications are auto-immune diseases and can result in severe, long lasting complications.

*Campylobacter jejuni* first invades the tissue of the jejunum, the ileum, and the colon with as few as 500 organisms. *Campylobacter* penetrates the mucus of the small bowel of humans using flagellar motility, facilitated by its spiral shape. The organism first colonizes and then multiplies in the intestinal mucus layer, destroying epithelial cells and elaborating a variety of virulence factors. The flagellum of *C. jejuni* not only facilitates motility, but also has the ability to secrete discrete invasive antigens.

The diagnosis of *Campylobacter jejuni* is dependent upon either isolating the organism from fresh stool, or performing various serological or molecular tests on a clinical stool specimen to determine either the presence of the organism, antibodies, or molecular portions of the organism.

In most cases, treatment with an antibiotic is not necessary because most *C. jejuni* infections are self-limiting. In severe cases, an antibiotic, usually azithromycin, can reduce symptoms and the carriage of *C. jejuni* in feces if given early in the disease process. Treatment with fluoroquinolones was once effective; however, with the widespread use of fluoroquinolones in animal feed, the emergence of resistance (up to 20%) has been noted. Use of antibiotics in poultry has resulted in the development of fluoroquinolones-resistant populations. Currently, the growing resistance of the *C. jejuni* to fluoroquinolones and macrolides is of major concern.

The consumption of undercooked poultry and cross-contamination of other foods with drippings from raw poultry are leading risk factors for human campylobacteriosis. Reinforcing hygienic practices at each link in the food chain—from producer to consumer—is critical in preventing the disease, and properly preparing poultry and following safe food practices can lower the incidence of disease. The single most important and reliable step for avoiding *C. jejuni* infection is to adequately cook all poultry products to an internal temperature of 165°F.

REFERENCES


Fig. 1. Number of U.S. Cases by Month, 2013*

![Bar chart showing cases by month for different bacteria]

*From: CDC, Reference #2

Figure 2. Electron Micrograph of S-Shaped and Curved Morphology of *Campylobacter*
Table 1. U.S. Incidence (per 100,000 population) of Foodborne Bacterial Infections by Year*

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli O157</em></td>
<td>2.03</td>
<td>1.55</td>
<td>1.69</td>
<td>1.06</td>
<td>0.90</td>
<td>1.05</td>
<td>1.30</td>
<td>1.19</td>
<td>1.12</td>
<td>0.99</td>
<td>0.95</td>
<td>0.97</td>
<td>1.11</td>
<td>1.15</td>
</tr>
<tr>
<td>Listeria</td>
<td>0.34</td>
<td>0.27</td>
<td>0.26</td>
<td>0.33</td>
<td>0.27</td>
<td>0.30</td>
<td>0.31</td>
<td>0.27</td>
<td>0.29</td>
<td>0.32</td>
<td>0.27</td>
<td>0.28</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>Shigella</td>
<td>7.67</td>
<td>6.36</td>
<td>10.84</td>
<td>7.26</td>
<td>5.06</td>
<td>4.67</td>
<td>6.09</td>
<td>6.24</td>
<td>6.59</td>
<td>3.96</td>
<td>3.77</td>
<td>3.24</td>
<td>4.47</td>
<td>4.82</td>
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</tbody>
</table>

*From: CDC, MMWR. References #2 and #3.

Table 2. Number of Laboratory-Confirmed Infections by State in 2013*

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>California</th>
<th>Colorado</th>
<th>Connecticut</th>
<th>Georgia</th>
<th>Maryland</th>
<th>Minnesota</th>
<th>New Mexico</th>
<th>New York</th>
<th>Oregon</th>
<th>Tennessee</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campylobacter</td>
<td>1,178</td>
<td>400</td>
<td>599</td>
<td>790</td>
<td>604</td>
<td>950</td>
<td>320</td>
<td>609</td>
<td>885</td>
<td>458</td>
<td>6,793</td>
</tr>
<tr>
<td><em>E. coli O157</em></td>
<td>39</td>
<td>37</td>
<td>19</td>
<td>36</td>
<td>32</td>
<td>114</td>
<td>14</td>
<td>69</td>
<td>95</td>
<td>66</td>
<td>531</td>
</tr>
<tr>
<td>Listeria</td>
<td>18</td>
<td>4</td>
<td>22</td>
<td>15</td>
<td>16</td>
<td>6</td>
<td>5</td>
<td>14</td>
<td>14</td>
<td>7</td>
<td>121</td>
</tr>
<tr>
<td>Salmonella</td>
<td>485</td>
<td>264</td>
<td>454</td>
<td>2,642</td>
<td>907</td>
<td>781</td>
<td>327</td>
<td>502</td>
<td>386</td>
<td>1,052</td>
<td>7,800</td>
</tr>
<tr>
<td>Shigella</td>
<td>216</td>
<td>56</td>
<td>44</td>
<td>662</td>
<td>182</td>
<td>390</td>
<td>96</td>
<td>211</td>
<td>78</td>
<td>203</td>
<td>2,138</td>
</tr>
</tbody>
</table>

Adapted from: Reference #2
Table 3. Selective Media to Isolate *Campylobacter* from Stool Specimens

<table>
<thead>
<tr>
<th>Primary Plating Media</th>
<th>Media Manufacturers*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia base with charcoal, hemin, sodium pyruvate, and antibiotics</td>
<td>BD Diagnostic Systems, <a href="http://www.BD.com">www.BD.com</a></td>
</tr>
<tr>
<td>(vancomycin, cefoperazone, and cyclohexamide)</td>
<td>Hardy Diagnostics, <a href="http://www.hardydiagnostics.com">www.hardydiagnostics.com</a></td>
</tr>
<tr>
<td>Campy-BAP: Brucella agar base with antibiotics</td>
<td>PML, <a href="http://www.pmlmicro.com">www.pmlmicro.com</a></td>
</tr>
<tr>
<td>(trimethoprim, polymyxin B, cephalothin, vancomycin, and amphotericin B)</td>
<td>Oxoid, <a href="http://www.oxoid.com">www.oxoid.com</a></td>
</tr>
<tr>
<td>and 10% sheep blood. More inhibitory to other species of <em>Campylobacter</em></td>
<td>Remel, <a href="http://www.remelinc.com">www.remelinc.com</a></td>
</tr>
<tr>
<td>due to cephalothin.</td>
<td>others</td>
</tr>
<tr>
<td>Campy, Blood-Free, Karmali Agar: Supplements, charcoal, cefoperazone,</td>
<td></td>
</tr>
<tr>
<td>vancomycin, and amphotericin.</td>
<td></td>
</tr>
<tr>
<td>Campy-Blood-Free CAT: Cefoperazone, teicoplanin, and amphotericin.</td>
<td></td>
</tr>
<tr>
<td>Better for <em>Campylobacter upsaliensis</em> recovery.</td>
<td></td>
</tr>
<tr>
<td>Campy Cefex Agar: Brucella agar, horse blood, cefoperazone,</td>
<td></td>
</tr>
<tr>
<td>and cycloheximide.</td>
<td></td>
</tr>
<tr>
<td>Campy-CVA: Brucella agar base with antibiotics</td>
<td></td>
</tr>
<tr>
<td>(cefoxerazone, vancomycin, and amphotericin B), and 5% sheep blood.</td>
<td></td>
</tr>
<tr>
<td>CCDA: Modified charcoal cefoperazone deoxycholate agar. CCDA is a blood</td>
<td></td>
</tr>
<tr>
<td>free selective medium. Less inhibitory than other <em>Campylobacter</em> agar.</td>
<td></td>
</tr>
<tr>
<td>Modified Skirrow’s Media: Columbia blood agar base, 7% lysed-horse blood</td>
<td></td>
</tr>
<tr>
<td>and antibiotics (vancomycin, trimethoprim, and polymyxin B)</td>
<td></td>
</tr>
</tbody>
</table>

* Check catalogue of manufacturer to determine what media they are currently producing.
<table>
<thead>
<tr>
<th>Test</th>
<th>Principle</th>
<th>Manufacturer or Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campyslide</td>
<td>Latex agglutination, detects all Campylobacter spp.</td>
<td>BD Diagnostics, <a href="http://www.bd.com">www.bd.com</a></td>
</tr>
<tr>
<td></td>
<td>Not specific for C. jejuni only.</td>
<td></td>
</tr>
<tr>
<td>DrySpot Campylobacter</td>
<td>Latex agglutination, detects all Campylobacter spp.</td>
<td>Hardy Diagnostics, <a href="http://www.hardydiagnostics.com">www.hardydiagnostics.com</a></td>
</tr>
<tr>
<td></td>
<td>Not specific for C. jejuni only.</td>
<td>Oxoid, <a href="http://www.oxoid.com">www.oxoid.com</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remel, <a href="http://www.remelinc.com">www.remelinc.com</a></td>
</tr>
<tr>
<td>Microgen Campylobacter Rapid Test</td>
<td>Latex test detects all Campylobacter spp.,</td>
<td>Hardy Diagnostics, <a href="http://www.hardydiagnostics.com">www.hardydiagnostics.com</a></td>
</tr>
<tr>
<td></td>
<td>Not specific for C. jejuni only.</td>
<td>Microgen Bioproducts, <a href="http://www.microgenproducts.com">www.microgenproducts.com</a></td>
</tr>
<tr>
<td>ImmunoCard Stat CAMPY</td>
<td>EIA (immunochromogenic test), bacterial antigen detection</td>
<td>Meridian Bioscience, Inc. <a href="http://www.meridianbioscience.com">www.meridianbioscience.com</a></td>
</tr>
<tr>
<td></td>
<td>in 20 min</td>
<td></td>
</tr>
<tr>
<td>Premier CAMPY</td>
<td>Monoclonal antibody based EIA</td>
<td>Meridian Bioscience, Inc. <a href="http://www.meridianbioscience.com">www.meridianbioscience.com</a></td>
</tr>
<tr>
<td>Microplate Assay</td>
<td></td>
<td>Hardy Diagnostics, <a href="http://www.hardydiagnostics.com">www.hardydiagnostics.com</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remel, <a href="http://www.remelinc.com">www.remelinc.com</a></td>
</tr>
<tr>
<td>Campylobacter jejuni antisera</td>
<td>Antisera for epidemiological typing</td>
<td>Denka Seiken, <a href="http://www.denka-seiken.co.jp">www.denka-seiken.co.jp</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hardy Diagnostics, <a href="http://www.hardydiagnostics.com">www.hardydiagnostics.com</a></td>
</tr>
<tr>
<td>AccuProbe Campylobacter</td>
<td>DNA molecular probe methodology</td>
<td>AccuProbe, Gen-Probe, Inc., <a href="http://www.gen-probe.com">www.gen-probe.com</a></td>
</tr>
</tbody>
</table>
Table 5. Suppliers of Microaerobic Environmental Systems for *Campylobacter*

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerocult C.</td>
<td>VWR, Inc. (<a href="http://www.vwrsp.com">www.vwrsp.com</a>)</td>
</tr>
<tr>
<td>AnaeroPack Campylo System.</td>
<td>Mitsubishi Gas Chemical Co. (<a href="http://www.mgc.co.jp">www.mgc.co.jp</a>)</td>
</tr>
<tr>
<td><em>Campylobacter</em> Gas Generating Kit.</td>
<td>Remel, Inc (<a href="http://www.remelinc.com">www.remelinc.com</a>)</td>
</tr>
<tr>
<td>CampyPak and CampyPouch.</td>
<td>BD Diagnostic Systems, Inc. (<a href="http://www.bd.com">www.bd.com</a>)</td>
</tr>
<tr>
<td>Pouch MicroAero.</td>
<td>Remel, Inc. (<a href="http://www.remelinc.com">www.remelinc.com</a>)</td>
</tr>
</tbody>
</table>

Table 6. Food Handling Practices to Prevent *Campylobacter* Infection

- Cook all poultry products thoroughly. Be sure the meat is cooked throughout; i.e., no longer pink and any juices run clear. All poultry should be cooked to reach a minimum internal temperature of 165 °F.
- If you are served undercooked poultry in a restaurant, send it back for further cooking.
- Wash hands with soap before preparing food.
- Wash hands with soap after handling raw foods of animal origin and before touching anything else.
- Prevent cross-contamination in the kitchen by using separate cutting boards for foods of animal origin and other foods and by carefully cleaning all cutting boards, countertops, and utensils with soap and hot water after preparing raw food of animal origin.
- Avoid consuming unpasteurized milk, unpasteurized milk products, and unchlorinated surface water.
• Be sure that persons with diarrhea, especially children, wash their hands carefully and frequently with soap to reduce the risk of spreading the infection.

• Wash hands with soap after contact with pet feces.
REVIEW QUESTIONS
Course #DL-994
Choose the one best answer:

1. Prior to the 1970s, *C. jejuni* was not isolated because:
   a. the disease did not exist prior to 1970s
   b. the classification of *Campylobacter* was not understood
   c. the required media and environmental techniques were not understood
   d. poultry producers were not yet required to report diseased flocks

2. What atmospheric condition does *Campylobacter jejuni* require for growth?
   a. a reduced oxygen concentration
   b. a reduced nitrogen concentration
   c. a reduced carbon dioxide concentration
   d. a reduction of all gases depending upon temperature

3. One reason for the increased resistance of *C. jejuni* to fluoroquinolones is:
   a. the addition of fluoroquinolones to meat products
   b. the addition of fluoroquinolones to animal feed
   c. the increased usage of fluoroquinolones in humans
   d. feedlot animals who have developed a resistance to erythromycin

4. Which of the following complications has not been associated with previous *C. jejuni* infection?
   a. Guillain-Barré syndrome
   b. toxic shock syndrome
   c. hemolytic uremic syndrome
   d. Reiter’s syndrome

5. Which set of symptoms is most typical of *C. jejuni* infection?
   a. diarrhea, fever, shock, chills
   b. diarrhea, toxic shock, fever, headache
   c. diarrhea, pneumonia, productive cough
   d. diarrhea, cramps, abdominal pain, nausea and vomiting

6. The average incubation period of *C. jejuni* infection after ingestion of contaminated food is:
   a. three days
   b. 12 hours
   c. one week
   d. five days

7. Which of the following Gram stain morphological characteristics is typical of *C. jejuni*?
   a. curved, S-shaped or gull-winged, Gram negative rods with spores
   b. thin, curved Gram positive rods, with spores
   c. slender, curved, S-shaped or gull-winged, Gram negative rods
   d. slender, curved, S-shaped or gull-winged Gram positive rods

8. In the U.S., which age group of patients typically has the highest rate of *C. jejuni* infection?
   a. middle-aged women
   b. teenagers with poor hygiene
   c. adults
   d. infants and young children
9. Which of the following profiles best fits the growth requirements of *C. jejuni*?
   a. 42°C, candle-jar, Campy media
   b. 35-37°C, anaerobic, sheep-blood agar
   c. 42°C, microaerobic, Campy media
   d. 35-37°C, CO₂ incubator, Campy media

10. Some patients with *C. jejuni* infection may have no diarrhea initially, but instead may have symptoms of:
   a. chills, high fever, cough
   b. headache, myalgias, malaise
   c. chest pain, cough, chills
   d. arthritis, high fever, cough

11. Which pathogenic factor is associated with *C. jejuni* infection?
    a. exotoxins that act as invasive antigens
    b. N-linked glycosylation that induces toxic shock
    c. LPS that induces the cork-screw motility of *C. jejuni*
    d. CDT that hijacks the control of eukaryotic cells and causes cell death

12. What do Guillain-Barré and Reiter’s syndrome have in common?
    a. autoimmune disorders
    b. induced by exotoxins
    c. both occur in elderly patients
    d. induced by identical toxins of *E. coli* O157:H7

13. The estimated percentage of worldwide foodborne disease due to *C. jejuni* is:
    a. 6%
    b. 36%
    c. 12%
    d. 22%

14. The number of *C. jejuni* organisms required to cause disease (infectious dose) is believed to be:
    a. 5,000 organisms
    b. 500
    c. 10⁶ organisms
    d. 35 organisms

15. Most sporadic cases of *C. jejuni* increase during:
    a. the summer
    b. the winter
    c. the fall
    d. the holidays

16. Which description best characterizes the normal habitat of *C. jejuni*?
    a. normal respiratory flora of cattle
    b. normal fecal flora of man
    c. found only in sick cattle
    d. part of the normal fecal flora of birds

17. The term zoonotic infection means:
a. an organism that occurs normally in animals that can cause disease in man  
 b. an organism that occurs in animals from a zoo  
 c. an organism that is transmitted to animals from man  
 d. an infection caused by organisms that are commensal in animals but can cause disease in other animals

18. One complication that is not associated with prior Campylobacter jejuni infection is:  
 a. reactive arthritis  
 b. thrombocytopenic purpura  
 c. Guillain-Barré syndrome  
 d. hemolytic uremic syndrome

19. One advantage of using a rapid immunoassay test for C. jejuni would be:  
 a. to allow triage of patients for earlier therapy  
 b. to allow patients a faster discharge  
 c. to allow placing patients in intensive care unit faster  
 d. to allow for cost savings for the clinical laboratory

20. Antibiotic therapy may be important to give to some C. jejuni patients because the antibiotic:  
 a. eliminates the need for further laboratory testing  
 b. prevents secondary toxic shock symptoms  
 c. prevents secondary lipopolysaccharide production  
 d. shortens the duration of symptoms and eliminates the organism in stool

21. If an antibiotic is given to treat a C. jejuni infection, the drug of choice would be:  
 a. clindamycin  
 b. ciprofloxacin  
 c. azithromycin  
 d. a 3rd generation cephalosporin

22. One reason the incidence of C. jejuni infection in the U.S. may have recently decreased is due to:  
 a. improvements in the food processing industry  
 b. the majority of the population is no longer in direct contact with animals  
 c. better antibiotic usage in poultry  
 d. the organism has become less virulent

23. Which is not a cause of sporadic C. jejuni infection?  
 a. traveling to developing countries  
 b. handling domestic animals  
 c. drinking unpasteurized milk  
 d. consuming lettuce

24. Reiter’s syndrome is not associated with:  
 a. an HLA-B27 lymphocyte antigen  
 b. the previous production of exotoxin  
 c. an arthritis in large joints of the body  
 d. an autoimmune condition

25. The correct physical and biochemical traits for C. jejuni are:  
 a. oxidase positive, hippurate negative, slow growing, saccharolytic  
 b. oxidase negative, hippurate positive, slow growing, saccharolytic
c. oxidase positive, hippurate positive, slow growing, asaccharolytic
d. oxidase negative, hippurate negative, slow growing, asaccharolytic

26. The flagellum of *C. jejuni* is important as a pathogenic mechanism because:
   a. it allows rapid motility through the stomach, and penetration through mucus
   b. it facilitates motility through the stomach, and secretes invasive antibodies
   c. it facilitates motility through mucus, and secretes invasive antigens
   d. it secretes invasive antibodies and promotes rapid motility through stomach

27. Three central features for preventing *C. jejuni* infection are:
   a. wash hands after handling pets, use separate cutting board for raw meats, avoid buying off-brand raw meat products
   b. use only one cutting board for raw chicken, wash chicken thoroughly, wash hands before contact with pets
   c. cook poultry until juices are pink, use only one cutting board, wash hands after contact with food
   d. cook poultry thoroughly, avoid cross-contamination in the kitchen, wash hands before preparing food

28. When an oxidase test is performed on *C. jejuni* grown on media containing glucose, a weak or negative oxidase test may be due to the fact that:
   a. the organism is asaccharolytic to glucose
   b. the organism is protein sparing
   c. the organism is biochemically inert
   d. the organism has a microaerobic requirement

29. When performing a Gram stain for *C. jejuni*, it is best to use:
   a. 0.1% aqueous safranin as a counterstain
   b. 0.1% aqueous methyl red as a counterstain
   c. 0.1% aqueous basic fuchsin as a counterstain
   d. 0.1% aqueous phenol red as a counterstain

30. Media that contain cephalothin, colistin, and polymyxin B may:
   a. enhance the recovery of *C. jejuni*
   b. be more selective for *C. jejuni*
   c. select for thermophilic strains of *Campylobacter* spp.
   d. inhibit some strains of *C. jejuni*