ORIGINAL ARTICLE BACTERIOLOGY

High incidence of *Campylobacter concisus* in gastroenteritis in North Jutland, Denmark: a population-based study

H. L. Nielsen[1], T. Ejlertsen[2], J. Engberg[3] and H. Nielsen[1]

Departments of 1) *Infectious Diseases and* 2) *Clinical Microbiology, Aalborg Hospital, Aarhus University Hospital, Aalborg and* 3) *Department of Clinical Microbiology, Slagelse Hospital, Slagelse, Denmark*

Abstract

The incidence of non-thermophilic *Campylobacter* species was assessed in an unselected population-based study in a mixed urban and rural community in North Jutland, Denmark. In a 2-year study period, 11 314 faecal samples from 8302 patients with gastroenteritis were cultured with supplement of the filter method. We recovered a high incidence of *Campylobacter concisus* (annual incidence 35/100 000 inhabitants), almost as high as the common *Campylobacter jejuni/coli*. In contrast, there was a very low incidence of other non-thermophilic *Campylobacter* species, such as *Campylobacter upsaliensis*. *Campylobacter concisus* was, unlike *C. jejuni/coli*, found more frequently among small children (<1 year) and the elderly (≥65 years). Around 10% of the patients with *C. consisus* had co-infections dominated by *Clostridium difficile* and *Salmonella enterica*, whereas co-infections occurred in about 5% of *C. jejuni/coli* patients. We observed a seasonal variation in *C. jejuni/coli* with a peak incidence in late summer months and autumn, whereas there was an almost constant monthly prevalence of *C. concisus*. Among patients participating in a questionnaire sub-study, there was a higher degree of close contacts with animals, especially dogs, as well as a higher travel exposure among *C. jejuni/coli* patients compared with *C. concisus* patients. We did not culture any *C. concisus* in stool samples from a small cohort of healthy individuals. Future studies have to focus on the clinical follow-up and the long-term risk of inflammatory bowel diseases in *C. concisus*-positive patients. We conclude that there is a high incidence of *C. concisus* in Denmark.

Keywords: Age distribution, *Campylobacter concisus*, *Campylobacter jejuni*, gastroenteritis, incidence, prevalence, seasonal variation
Original Submission: 19 December 2011; **Revised Submission:** 15 March 2012; **Accepted:** 15 March 2012
Editor: S. Cutler
Article published online: 27 March 2012
Clin Microbiol Infect 2013; **19:** 445–450
10.1111/j.1469-0691.2012.03852.x

Corresponding author: H. L. Nielsen, Department of Infectious Diseases, Aalborg Hospital, Aarhus University Hospital, Hobrovej 18–22, DK-9000 Aalborg, Denmark
E-mail: **halin@rn.dk**

Introduction

Campylobacter concisus, first described in 1981 when it was isolated from the human oral cavity, has been proposed as an emerging pathogen of the human intestinal tract [1,2]. It is a fastidious, hydrogen-requiring and slow-growing, gram-negative, s-shaped or curved bacterium with an optimum temperature of about 37°C for growth. As opposed to the thermophilic *Campylobacter jejuni/coli*, no animal reservoirs have been found for *C. concisus*, although it has been detected in diarrhoeic faecal samples from domestic dogs and recently *C. concisus* was cultured from fresh meat and poultry [3,4]. Previously, *C. concisus* was associated with gingivitis and peridontitis, but it has also been found in healthy oral sites [5,6]. The human oral cavity might be a reservoir of *C. concisus*, but data are sparse on how *C. concisus* colonizes the intestinal tract.

In vitro C. concisus has been shown to possess virulence factors that include secreted as well as cell-bound haemolytic activities [7,8]. *Campylobacter concisus* has also shown ability to invade intestinal epithelial cells, and faecal as well as oral isolates of *C. concisus* induce apoptotic leaks together with a reduced expression level of the tight junction protein claudin-5 in HT29/B6 epithelial cells [9,10]. These findings demonstrate a leak-flux mechanism that is similar to the clinical manifestation of diarrhoea.

In recent years a lot of attention has been given to bacterial agents and their potential role for triggering inflammatory bowel diseases [11,12]. High prevalence of *C. concisus*

has been found in faecal samples and colonic biopsies of children with Crohn's disease, as well as in biopsy samples from adults with ulcerative colitis, suggesting that the bacteria may be involved in the intestinal inflammation seen in patients with inflammatory bowel disease [13,14].

The clinical epidemiology of *C. concisus* is unclear, and no study has reported its incidence in the general population. There are studies describing a high incidence of *C. concisus* in paediatric diarrhoeic stool samples and in immunocompromised patients with diarrhoea in a tertiary hospital setting; however, it has also occasionally been found in healthy controls, especially children [15,16]. Nevertheless, the overall prevalence of *C. concisus* in faecal samples seems to be underreported because the time-consuming filter method is not used in routine diagnostics in favour of a selective media for cultivation of *Campylobacter* species. In this paper we describe the incidence of *C. concisus* in unselected clinical diarrhoeic faecal samples from the population in North Jutland, Denmark.

Materials and Methods

Study population

In the study period from January 2009 to December 2010 the Department of Clinical Microbiology, Aalborg Hospital, Aarhus University Hospital, Denmark, provided microbiological services for seven hospitals and 355 general practitioners in the North Denmark region with a background population of 580 515 inhabitants in a mixed urban and rural community. A total of 29 242 human diarrhoeic stool samples were cultured for pathogenic enteric bacteria by routine methods as described previously [17].

Isolation of *Campylobacter* species

In Denmark, *Campylobacter* species have been isolated using the selective media, the modified charcoal cefoperazone deoxycholate agar (mCCDA; SSI Diagnostica, Hillerød, Denmark) whereas the time-consuming filter method has not been used routinely. To assess the incidence of non-thermophilic *Campylobacter* species we randomly selected on a daily basis 11 314 (39%) human diarrhoeic stool samples which were cultured with the addition of the filter method as described elsewhere [15]. Stool samples from 108 healthy volunteers, mainly staff members and children with no history of gastrointestinal illnesses or antibiotic treatment, were also cultivated using the filter method.

Identification of *Campylobacter* species

Campylobacter jejuni/coli were routinely identified by their macroscopic morphology on the mCCDA plates, by their swarming growth on the 5% horse blood agar plate with extra yeast extract and by a positive wet smear of highly motile spiral bacteria. Differentiation between *C. jejuni* and *C. coli* was not performed. Antimicrobial susceptibility testing was performed using Neo-Sensitabs™ (Rosco Diagnostica A/S, Taastrup, Denmark) with CLSI potencies according to the manufacturer's instructions. *Campylobacter jejuni/coli* were tested for resistance against erythromycin (15 μg) and ciprofloxacin (5 μg) on 5% horse blood agar plate (SSI Diagnostica). Non-thermophilic *Campylobacter* species were identified as highly motile, gram-negative spiral, s-shaped or curved rods with a negative L-alanyl aminopeptidase (L-ALA test; O.B.I.S Campy, Oxoid, Cambridge, UK). Non-thermophilic *Campylobacter* species were tested for hydrogen sulphide production in triple sugar iron medium (SSI Diagnostica), hydrolysis of indoxyl acetate (Diatabs™; Rosco Diagnostica A/S), resistance to nalidixic acid (30 μg) and sensitivity to cephalothin (30 μg) for a presumptive diagnosis. Sensitivity for azithromycin (15 μg), ciprofloxacin (5 μg), tetracycline (30 μg) and amoxicillin (30 μg) was tested on a 5% horse blood agar plate containing 1% yeast extract. Final identification of all non-thermophilic *Campylobacter* species was carried out using a species-specific real-time PCR based on the *cpn60* gene, as described by Chaban *et al.* [18]. Reference strains were used as positive controls (*C. concisus* ATCC 33237, *Campylobacter upsaliensis* ATCC 43954 and *Campylobacter curvus* ATCC 35224).

Travel exposure and contact with animals

Data regarding recent travel exposure and contact with animals were reviewed by using a questionnaire survey. Travel exposure was simply defined as travel outside Denmark, regardless of the purpose, within 2 weeks before the onset of diarrhoea. Patients were requested by telephone to participate in the survey by the clinical investigator. All patients who participated in the investigation signed a written informed consent form. For children the informed consent was obtained from their parents. Scientific and ethics approval for the study was obtained from The Ethics Committee for North Denmark Region, Denmark (N-20080056).

Results

Study population and overall prevalence of pathogenic enteric bacteria

The 8302 patients had a median age of 45 years (interquartile range (IQR), 20–67 years) and compised 4535 (55%) women and 3767 (45%) men. In the 2-year study period 1532 patients (median 46 years; IQR 22–67 years) were

identified with a pathogenic enteric bacterium in their diarrhoeic stool sample (Table 1). Two-hundred and fifty-five patients had more than one positive faecal sample giving a total of 1872 isolates. Sixty-seven per cent of the patients (5565 patients) were seen in general practice and the remaining 33% (2737 patients) were hospitalized.

Prevalence of *Campylobacter* species

All strains of non-thermophilic *Campylobacter* species were isolated using the filter method only, whereas the *C. jejuni/coli* were isolated using the mCCDA-medium as well as the filter method. There was no significant difference in the recovery rate between the two isolation procedures. The most prevalent Campylobacteraceae were *C. jejuni/coli* with 489 patients (median 33 years; IQR 19–50 years). Nearly as frequent was *C. concisus* with 400 patients (median 52 years; IQR 21–68 years) corresponding to an average annual incidence of 35/100 000 inhabitants. There was a very low prevalence of other non-thermophilic *Campylobacter* species and *C. curvus* (n = 5) and *C. upsaliensis* (n = 2) were the only ones cultivated in this study. We also cultivated one isolate of the close-related *Arcobacter cryaerophilus* (using the MALDI-TOF (matrix-assisted laser desorption/ionization-time of flight) Biotyper for identification, data not shown). One hundred and forty (35%) patients infected with *C. concisus* were hospitalized and 260 patients were seen in general practice. Only 102 (21%) patients infected with *C. jejuni/coli* were hospitalized. For both *Campylobacter* groups there was a similar hospitalization rate (data not shown) in all age groups, and half of all elderly patients were hospitalized.

TABLE 1. Number of patients and isolates with pathogenic enteric bacteria in 11 314 diarrhoeic stool samples from 8302 patients, North Jutland, Denmark

Microorganism	Patients	Isolates
Campylobacteraceae		
Campylobacter jejuni/coli	489	541
Campylobacter concisus	400	441
Campylobacter curvus	5	5
Campylobacter upsaliensis	2	2
Arcobacter cryaerophilus[a]	1	1
Other bacteria		
Clostridium difficile[b]	379	546
Salmonella enterica serovar Typhimurium	75	93
Salmonella enterica	72	81
Salmonella enterica serovar Enteritidis	64	76
Shigella species	20	29
Yersinia enterocolitica	15	21
Escherichia coli, (EHEC)	6	6
Other[c]	4	5
Total	1532	1847

[a]Identified with use of the MALDI-TOF (matrix-assisted laser desorption/ionization-time of flight) biotyper.
[b]Samples were not cultured for *Clostridium difficile* if they were from children <2 years of age or patients with a travel exposure.
[c]*Plesiomonas shigelloides, Yersinia enterocolitica* and *Aeromonas sobria.*

No Campylobacteraceae was cultured in stool samples from healthy volunteers (median 14 years; range 0–69 years, with equal sex ratio). Co-infections with *Clostridium difficile* were twice as frequent in *C. concisus*-infected patients (n = 22) compared with patients with *C. jejuni/coli* (n = 11) and concurrent detection of *Salmonella enterica* was even higher with more than triple frequency in *C. concisus* patients (n = 18) compared with patients with *C. jejuni/coli* (n = 5). Two patients had *C. concisus* as well as *C. jejuni/coli* in their faecal sample, and three *C. concisus* patients had co-infections with *Plesiomonas shigelloides*, *Yersinia enterocolitica*, or *Shigella sonnei*, respectively.

Incidence of *Campylobacter concisus* and *Campylobacter jejuni/coli*

Both *C. concisus* and *C. jejuni/coli* were isolated from patients of all ages; however, the age-specific incidences showed that *C. concisus* as well as *C. jejuni/coli* were frequent among toddlers. *Campylobacter concisus* was also frequent among very small children (<1 year) and older patients whereas *C. jejuni/coli* were frequent in young adults (Fig. 1).

Seasonal influence

We found a high prevalence of *C. jejuni/coli* from June to October (Fig. 2). There was a more constant prevalence of *C. concisus* during the study period. Furthermore, *C. concisus* was isolated in a rather high number during the winter months, especially in March, where *C. jejuni/coli* were isolated in a low number.

Phenotype characteristics and antimicrobial resistance

Phenotype characteristics and antimicrobial resistance are presented in Table 2. We observed a very low number of *C. concisus* isolates resistant to macrolide, tetracycline and amoxicillin. The isolates of *C. jejuni/coli* also showed very low macrolide resistance. In contrast, there was a high resistance toward ciprofloxacin in both *C. jejuni/coli* isolates (34%) and *C. concisus* isolates (16%). Isolates of *C. concisus* were not

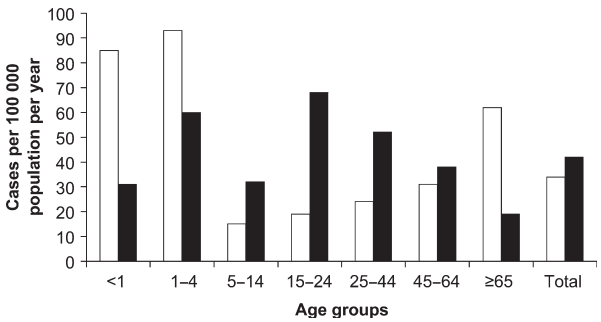

FIG. 1. Age-related annual incidence of *Campylobacter concisus* (white) and *Campylobacter jejuni/coli* (black) gastroenteritis in North Jutland, Denmark.

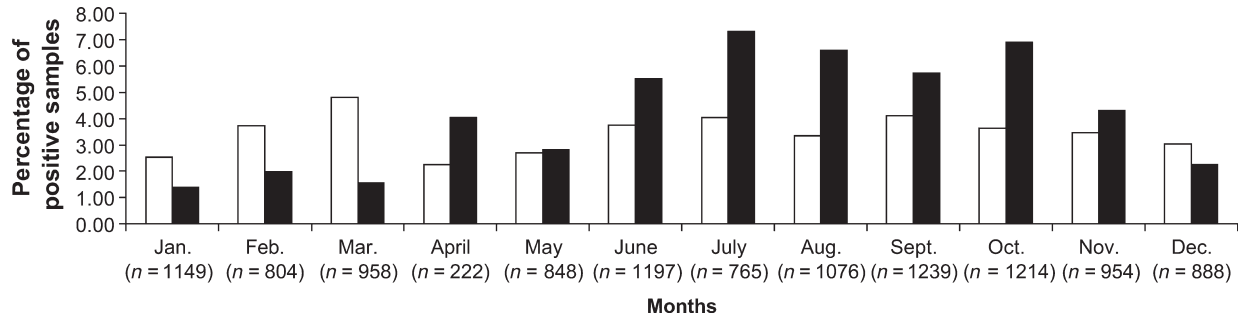

FIG. 2. Monthly percentages of positive samples with either *Campylobacter concisus* (white, *n* = 400) or *Campylobacter jejuni/coli* (black, *n* = 489) in North Jutland, Denmark. The corresponding sample size is given in brackets.

TABLE 2. Phenotypic characteristics and antimicrobial resistance of *C. concisus* and *C. jejuni/coli*

	C. concisus (*N* = 441)	*C. curvus* (*N* = 5)	*C. upsaliensis* (*N* = 2)	*C. jejuni/coli* (*N* = 541)
Phenotypic characteristics				
Negative L-ALA test[a]	441	5	2	–
TSI[b]	335	4	0	–
Indoxyl acetate hydrolysis	15	1	0	–
Antimicrobial resistance[c]				–
Nalidixic acid (ID[d])	364	5	1	–
Cephalothin (ID)	0	0	0	–
Tetracyclin	2	0	0	–
Ampicillin	1	0	1	–
Macrolide[e]	4	0	0	5
Ciprofloxacin	69	0	0	184

[a]Enzyme L-alanyl aminopeptidase (L-ALA).
[b]Hydrogen sulfide production in triple sugar iron medium.
[c]Using Neo-Sensitabs™ (Rosco Diagostica A/S).
[d]Only for presumptive diagnostics.
[e]*Campylobacter jejuni/coli* were tested with erythromycin and *C. concisus* with azithromycin.

TABLE 3. Travel exposure and animal contact among 216 patients with *C. concisus* and 260 patients with *C. jejuni/coli* gastroenteritis, North Jutland, Denmark

	C. concisus (*n* = 216)	*C. jejuni/coli* (*n* = 260)	p-value[a]
Travel exposure[b]	24 (11%)	73 (28%)	<0.001
Contact with animals[c]	80 (37%)	134 (52%)	<0.01
Dogs	44 (20%)	89 (34%)	<0.01
Cats	35 (16%)	57 (22%)	0.18
Other[d]	21 (10%)	31 (12%)	0.65

[a]Fisher's exact test was used for dichotomous variables.
[b]Travel destinations (UN geographical sub regions) among *C. concisus* patients: Northern Europe = 2, Western Europe = 2, Eastern Europe = 2, Southern Europe = 5, Northern Africa = 5, Western Asia = 5, Eastern Asia = 1, Central America = 1, and South America = 1; and among *C. jejuni/coli* patients: Northern Europe = 2, Western Europe = 10, Eastern Europe = 4, Southern Europe = 15, Northern Africa = 9, Eastern Africa = 2, Western Asia = 10, Southern Asia = 7, Eastern Asia = 2, South-eastern Asia = 8, Western Africa = 1, Southern Africa = 2, Unknown destination = 1.
[c]Seventeen *C. concisus* and 36 *C. jejuni/coli* patients had contact with two animals or more.
[d]Includes: hamsters, pigs, sheep's, chickens, birds, pigeons, goats, horses and rabbits.

solely positive or negative in triple sugar iron medium or indoxyl acetate hydrolysis. This makes it difficult to obtain a phenotypic distinction for this species.

Travel exposure and animal contact

Two hundred and seventy-one patients (68%) with *C. concisus* and 335 patients (69%) with *C. jejuni/coli* gave consent to participate in the questionnaire survey. The questionnaire was returned by 216 *C. concisus* patients (80%) and 260 *C. jejuni/coli* patients (78%). Travel exposure was significantly higher among patients with *C. jejuni/coli*, and they also had more frequent contact with animals, especially dogs (Table 3).

Discussion

The present report is the first to describe the clinical epidemiology of *C. concisus* in diarrhoeic stool samples in an unselected population-based community. We found a high incidence of *C. concisus*, almost as high as the common *C. jejuni/coli*, in samples from patients with gastroenteritis from a mixed urban and rural community. This demonstration of high incidence of *C. concisus* is based on a large sample size. Nevertheless, the overall incidence in North Jutland might be twice as high if we had examined all samples, because only 39% of all faecal specimens were included in the study.

Earlier reports have cultured *C. concisus* in paediatric diarrhoeic stool samples as well as in immunocompromised patients [15,16]. In contrast to The Red Cross Children's Hospital in Cape Town, South Africa, which has isolated *Campylobacter* species since 1977, we had a very low yield of other non-thermophilic *Campylobacter* species, such as *C. upsaliensis* [2]. This may be explained by the significant tertiary service they provide, whereas our results are from an unselected population-based community. *Campylobacter concisus* was frequent among infants (<1 year) and toddlers but was also frequent among older patients whereas *C. jejuni/coli* were most frequent in young adults. The difference in age distribution may explain the differences in hospitalization between

C. concisus and *C. jejuni/coli* patients but there is an urgent need of clinical data.

Around 10% of the patients with *C. consisus* had another pathogenic enteric bacterium in their stool sample, whereas this was <5% for *C. jejuni/coli* patients. Co-infections were predominant in elderly patients and dominated by *Clostridium difficile* and *S. enterica*. The *C. jejuni/coli* patients were mainly small children and young adults, which might explain the lower number of co-infections with *Clostridium difficile*. However, the large difference in age distribution between *C. concisus* and *C. jejuni/coli* cannot explain the more than threefold difference in co-infection with *S. enterica*.

We did not culture any *C. concisus* in stool samples in the small cohort of healthy individuals. This conflicts with earlier reports in which *C. concisus* occasionally could be cultured in healthy controls, especially children, challenging the role of *C. concisus* in gastrointestinal disease [15,16]. The small sample size gives our study limited power to rule out a presence of *C. concisus* in healthy individuals. However, a large healthy cohort of different age groups, with both oral and faecal samples, is required for a definitive description of the true prevalence of *C. concisus* in asymptomatic individuals.

We observed a seasonal variation in *C. jejuni/coli* with a peak incidence in late summer months and autumn as described earlier [19,20]. In contrast there was an almost constant prevalence of *C. concisus*. The reason for this is unclear but it may be explained by differences in reservoir. If the primary reservoir for *C. concisus* is the human oral cavity it would be interesting to know if the diarrhoeal disease is caused by the patients' oral commensal strains of *C. concisus* or by an exposure for a person-to-person transmission of a virulent strain of *C. concisus*.

Recently, *C. concisus* was reported in fresh chicken meat and minced beef [3]. To determine *C. concisus* as a zoonotic infection, stool samples from poultry, pigs and cattle have to be investigated for *C. concisus*. *Campylobacter concisus* has also been reported in faecal samples from domestic dogs, so pets and close contact with animals might be a source of infection, as occasionally reported for *C. jejuni/coli* and *C. upsaliensis* [21]. However, our *C. concisus* patients had a lower degree of close contacts with animals, especially contacts with dogs, compared with *C. jejuni/coli* patients. Moreover, we would expect more isolates of *C. upsaliensis* in the present study if dogs were the patients' true source of infection, so the main conclusion is that transmission from pets is of minor importance.

In our study, a significantly higher proportion of patients with *C. jejuni/coli* had travel exposure and a high level of ciprofloxacin resistance was found. Since 1998, the Red Cross Children's Hospital (Cape Town, South Africa) reported increasing ciprofloxacin resistance levels from 6.9% to 18% in *C. concisus* isolates [22]. We detected a very similar ciprofloxacin resistance level of 16% for our *C. concisus* isolates. In contrast to the rising resistance level toward macrolide of 21.7% by the Red Cross Children's Hospital we found a very low resistance level in *C. jejuni/coli* and *C. concisus*. So far, there are no data on whether patients with *C. concisus* may benefit from antimicrobial treatment. Clinical trials are needed to investigate a potential beneficial effect of antibiotics. However, before these studies are performed, investigations strengthening the evidence of the pathogenicity of *C. concisus* are necessary.

In conclusion, we found a high incidence of *C. concisus*, almost equal to *C. jejuni/coli*, in patients with gastroenteritis in an unselected population-based community. Our study was based on a large sample size, and although the distribution of the different *Campylobacter* species will be the same, the overall incidence might be twice as high. In contrast to earlier studies, we had a very low prevalence of other non-thermophilic *Campylobacter* species, such as *C. upsaliensis*. Additional laboratory and clinical studies are required to elucidate the pathogenic role of *C. concisus*. There is an urgent need of clinical follow-up of *C. concisus* patients and knowledge about the clinical outcome in different age groups, for example, the long-term risk of inflammatory bowel diseases in the years after *C. concisus* has to be investigated.

Acknowledgements

We gratefully acknowledge the assistance of the microbiology staff in the faeces laboratory at Department of Clinical Microbiology, Aalborg Hospital; and all patients who took part in the study. Part of this study was presented at ECCMID 2011, Milan, Italy.

Transparency Declaration

This work was supported by grants from the Hertha Christensen foundation, Heinrich Kopp's legate, and the A. P. Møller Foundation for the Advancement of Medical Science. The authors declare that they have no conflicting interests in relation to this work.

References

1. Tanner AC, Dzink JL, Ebersole JL, Socransky SS. *Wolinella recta*, *Campylobacter concisus*, *Bacteroides gracilis*, and *Eikenella corrodens* from periodontal lesions. *J Periodontal Res* 1987; 22: 327–330.

2. Lastovica AJ. Emerging *Campylobacter* spp.: the tip of the iceberg. *Clin Microbiol Newsl* 2006; 28: 49–56.
3. Lynch OA, Cagney C, McDowell DA, Duffy G. Occurrence of fastidious *Campylobacter* spp. in fresh meat and poultry using an adapted cultural protocol. *Int J Food Microbiol* 2011; 150: 171–177.
4. Chaban B, Ngeleka M, Hill JE. Detection and quantification of 14 *Campylobacter* species in pet dogs reveals an increase in species richness in feces of diarrheic animals. *BMC Microbiol* 2010; 10: 73.
5. Zhang L, Budiman V, Day AS *et al.* Isolation and detection of *Campylobacter concisus* from saliva of healthy individuals and patients with inflammatory bowel disease. *J Clin Microbiol* 2010; 48: 2965–2967.
6. Macuch PJ, Tanner AC. *Campylobacter* species in health, gingivitis, and periodontitis. *J Dent Res* 2000; 79: 785–792.
7. Istivan TS, Smith SC, Fry BN, Coloe PJ. Characterization of *Campylobacter concisus* hemolysins. *FEMS Immunol Med Microbiol* 2008; 54: 224–235.
8. Kaakoush NO, Man SM, Lamb S *et al.* The secretome of *Campylobacter concisus*. *FEBS J* 2010; 277: 1606–1617.
9. Nielsen HL, Nielsen H, Ejlertsen T *et al.* Oral and fecal *Campylobacter concisus* strains perturb barrier function by apoptosis induction in HT-29/B6 intestinal epithelial cells. *PLoS One* 2011; 6: e23858.
10. Man SM, Kaakoush NO, Leach ST *et al.* Host attachment, invasion, and stimulation of proinflammatory cytokines by *Campylobacter concisus* and other non-*Campylobacter jejuni Campylobacter* species. *J Infect Dis*.2010; 202: 1855–1865.
11. Gradel KO, Nielsen HL, Schonheyder HC, Ejlertsen T, Kristensen B, Nielsen H. Increased short- and long-term risk of inflammatory bowel disease after salmonella or campylobacter gastroenteritis. *Gastroenterology* 2009; 137: 495–501.
12. Man SM. The clinical importance of emerging *Campylobacter* species. *Nat Rev Gastroenterol Hepatol* 2011; 8: 669–685.
13. Man SM, Zhang L, Day AS, Leach ST, Lemberg DA, Mitchell H. *Campylobacter concisus* and other *Campylobacter* species in children with newly diagnosed Crohn's disease. *Inflamm Bowel Dis* 2010; 16: 1008–1016.
14. Mukhopadhya I, Thomson JM, Hansen R, Berry SH, El-Omar EM, Hold GL. Detection of *Campylobacter concisus* and other *Campylobacter* species in colonic biopsies from adults with ulcerative colitis. *PLoS One* 2011; 6: e21490.
15. Engberg J, On SL, Harrington CS, Gerner-Smidt P. Prevalence of *Campylobacter*, *Arcobacter*, *Helicobacter*, and *Sutterella* spp. in human fecal samples as estimated by a reevaluation of isolation methods for *Campylobacters*. *J Clin Microbiol* 2000; 38: 286–291.
16. Van ER, Breynaert J, Revets H *et al.* Isolation of *Campylobacter concisus* from feces of children with and without diarrhea. *J Clin Microbiol* 1996; 34: 2304–2306.
17. Olesen B, Neimann J, Bottiger B *et al.* Etiology of diarrhea in young children in Denmark: a case–control study. *J Clin Microbiol* 2005; 43: 3636–3641.
18. Chaban B, Musil KM, Himsworth CG, Hill JE. Development of cpn60-based real-time quantitative PCR assays for the detection of 14 *Campylobacter* species and application to screening of canine fecal samples. *Appl Environ Microbiol* 2009; 75: 3055–3061.
19. Boysen L, Vigre H, Rosenquist H. Seasonal influence on the prevalence of thermotolerant *Campylobacter* in retail broiler meat in Denmark. *Food Microbiol* 2011; 28: 1028–1032.
20. Olson CK, Ethelberg S, Pelt WV, Tauxe RV. Epidemiology of *Campylobacter jejuni* infections in industrialized nations. In: Nachamkin I, Szymanski CM, Blaser MJ, eds, *Campylobacter*, 3rd edn. Washington, DC: ASM press, 2008; 163–189.
21. Blaser MJ, Engberg J. Clinical aspects of *Campylobacter jejuni* and *Campylobacter coli* infections. In: Nachamkin I, Szymanski CM, Blaser MJ, eds, *Campylobacter*, 3rd edn. Washington, DC: ASM press, 2008; 99–121.
22. Moore JE, Barton MD, Blair IS *et al.* The epidemiology of antibiotic resistance in *Campylobacter*. *Microbes Infect* 2006; 8: 1955–1966.