Hazards of Healthy Living: Bottled Water and Salad Vegetables as Risk Factors for Campylobacter Infection

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Campylobacter is the most common cause of bacterial gastroenteritis worldwide, yet the etiology of this infection remains only partly explained. In a retrospective cohort study, we compared 213 sporadic campylobacter case-patients with 1,144 patients with negative fecal samples. Information was obtained on food history, animal contact, foreign travel, leisure activities, medical conditions, and medication use. Eating chicken, eating food from a fried chicken outlet, eating salad vegetables, drinking bottled water, and direct contact with cows or calves were all independently associated with infection. The population-attributable fractions for these risk factors explained nearly 70% of sporadic campylobacter infections. Eating chicken is a well-established risk factor, but consuming salad and bottled water are not. The association with salad may be explained by cross-contamination of food within the home, but the possibility that natural mineral water is a risk factor for campylobacter infection could have wide public health implications.

Campylobacter is the most commonly reported bacterial cause of foodborne infection in the Western world and affects more than 2 million people in the United States each year (1). In England and Wales, over 50,000 campylobacter cases are reported each year and no show signs of a decline in incidence (2). For every case reported to laboratory surveillance, another seven cases are estimated to occur in the community, suggesting that from 0.5% to 1.0% of the United Kingdom’s population is infected annually (3). Although the infection usually causes a mild, self-limiting illness, serious sequelae, including Guillain-Barré syndrome and death, occur in approximately 1 in 1,000 and 1 in 20,000 infections, respectively (1). Many national food safety agencies, such as the Food Standards Agency in the United Kingdom, have set goals of reducing food poisoning. To achieve these goals, a much clearer understanding of the etiology of campylobacter infection will be necessary.

In spite of the frequency of campylobacter infections, the cause has proved elusive. Recognized outbreaks are rare and are usually caused by contaminated water, milk, or poultry (4,5). However, these food products explain only a small proportion of sporadic cases, and the source of infection is unaccounted for in >60% of U.K. campylobacter cases (6,7). Several case-control studies of risk factors for sporadic campylobacter infection have been performed in the United Kingdom (6–10), but many unanswered questions remain. We conducted a retrospective cohort study that involved mailing a questionnaire to the patient at the time the fecal specimen was received by the laboratory to investigate the cause of sporadic campylobacter infection in the community.

Methods

The study population included all persons living in the Cardiff area who consulted their general practitioner for gastrointestinal symptoms and subsequently submitted a diagnostic fecal sample for microbiologic testing from January 1 through December 31, 2001. Cardiff Public Health Laboratory is the sole laboratory providing a diagnostic microbiology service for the area. All specimens were cultured for Campylobacter spp., Salmonella spp., Shigella spp., and Escherichia coli O157 and examined for ova and parasites, by standard methods. Follow-up specimens from the same patient (<4 weeks after the previous specimen submission date); specimens received from hospital wards and other sites were excluded from study. The study was approved by the local research ethics committee.

Immediately upon receipt of the specimen at the laboratory (next working day), a questionnaire, together with an explanatory letter and a postage-paid envelope, was mailed to the patient. Patients who had not responded within 1 week were sent a reminder letter and provided with another questionnaire on request. The questionnaire asked about basic personal details, including age, sex,
employment status, occupation, details of illness, and
details of household contacts. It included sections on for-
eign travel, food and drink eaten, animal contact (pets and
farm animals), outdoor leisure activities (gardening, walk-
ing, visits to parks or farms, fishing, swimming, and
sports), and questions on specific medical conditions and
medication (antacids, H2 antagonists, and antibiotics). The
food history covered meat and fish, poultry and eggs, veg-
etables (raw vegetables, leaf vegetables [e.g., lettuce],
salad vegetables [e.g., tomato], and prepared salads [e.g.,
coleslaw]), fruit, milk and dairy products, drinking water
(tap water, bottled water, and other sources), and eating out
(type of restaurant or takeaway). Participants were asked
to respond yes or no, and, to the question of exposure for
tap water, to indicate the number of glasses drunk per day.
All questions related to exposure in the 7 days before the
onset of symptoms, except for those on antibiotics, which
concerned the month before illness onset.

Case-patients were defined as any patient, not associat-
ed with an outbreak, who submitted a fecal sample that
was positive for Campylobacter spp. on microbiologic cul-
ture. Case-patients were compared with patients whose
samples were negative on culture and microscopic exami-
nation. Patients with an alternative microbiologic diagno-
sis were excluded (unless they had dual infection with
campylobacter).

Initial univariate analysis was performed with Epi Info
software (v. 6.04; Centers for Disease Control and
Prevention) to calculate maximum likelihood estimates for
Mantel-Haenzel odds ratios (OR) with exact 95% mid-p
confidence limits. Continuous variables were analyzed
using the t test or Mann-Whitney U test, as appropriate. All
reported p values are two sided. Multiple logistic regres-
sion models were constructed with Stata software (v. 6,
Stata Corporation, College Station, TX). Risk factors were
selected a priori on biologic grounds and grouped into four
exposure categories: food and drink consumption; animal
contact; leisure activities, including foreign travel; and
medical history. Logistic regression models were first con-
structed for risk factors within each exposure category
(adjustment A). We then fitted a model that combined all
the independent risk factors (for which the Wald test p
value for the adjusted OR was <0.10) from the four expo-
sure categories (adjustment B). Finally, to detect any resid-
ual confounding, we fitted all personal factors with a p
value of <0.10 (age group, presence of a child <5 years of
age in the household, and employment status). Of these,
only age group interacted significantly with the other terms
as tested by goodness of fit and was therefore included in
the final model (adjustment C). The population-attribut-
able fraction for each risk factor associated with campy-
lobacter infection was calculated using methods described by Greenland and Drescher (11).

Results

Questionnaires were sent to 2,694 eligible patients;
fecal samples from 346 (12.8%) were positive for Campylobacter spp. (including 4 dual infections: 3 with salmonella infection, 1 with giardiasis). No campylobacter outbreak occurred during the study period. Ninety-one patients (3.4%) were positive for other organisms (42 Salmonella spp., 20 Giardia lamblia, 12 Cryptosporidium sp., 7 Clostridium difficile, 2 Shigella sp., 2 E. coli O157,
1 amoebic dysentery, and 5 other parasites); these were
excluded from further analysis. Responses were received
from 213 (61.6%) of 346 persons with campylobacter
infection and 1,144 (50.7%) of 2,257 persons with neg-
itive specimen results. Median delay in response (from date
questionnaire sent to date questionnaire returned) was 6
days (range 2–73 days) for case-patients and 7 days (range
1–77 days) for non-case-patients (Kruskal-Wallis H 1.81,
p=0.18).

Personal Factors and Symptoms

Case-patients (median 43 years of age, range 0–80
years of age) were significantly older than non-case-
patients (median 36 years of age, range 0–100 years of
age) (Kruskal-Wallis H 5.31, p=0.02) (Table 1). Non-case-
patients were also more likely to come from a household
that included a child <5 years of age (even after adjusting
for the age of the respondent), although not more likely to
report prior diarrheal illness in a household contact. Case-
patients were more likely to report symptoms than non-
case-patients, particularly fever (OR 3.19; 95% confidence
interval [CI] 2.36 to 4.31), muscle aches (OR 3.13; 95% CI
2.32 to 4.22), and abdominal pain (OR 3.40; 95% CI 2.32
to 5.12. Nearly all case-patients and most non-case-
patients had diarrhea, but case-patients (18.3%) were more
likely than non-case-patients (11.8%) to report blood in the
stool (OR 1.67; 95% CI 1.12 to 2.46).

Food and Drink Consumed

Case-patients were more likely to report eating meat,
including beef, pork, and ham; poultry products, including
chicken and eggs; and a variety of uncooked vegetables
and fruit, including lettuce, other salad vegetables (cucumber,
tomatoes, etc.), prepared salad (coleslaw, etc.), and
fresh or frozen berries. An association existed with drink-
ing bottled water (OR 1.98; 95% CI 1.48 to 2.67) and
between infection and drinking cold tap water (OR 1.51;
95% CI 1.06 to 2.18) but not with drinking cold milk.
Neither tap water nor milk consumption showed a dose
response relationship. Case-patients were more likely to
have eaten out in the 7 days before illness onset, particu-
larly at a fried chicken outlet, sandwich bar, or other
unspecified restaurant.
Table 1. Comparison of personal and household factors in campylobacter case-patients and non-case-patients

| Variable                                      | Case-patients (n=213) | Non-case-patients (n=1,144) | OR (95% CI)      | p value |
|-----------------------------------------------|-----------------------|------------------------------|------------------|---------|
| Female                                        | 99 (46.5)             | 504 (44.1)                   | 1.10 (0.82 to 1.48) | 0.56    |
| Age group                                     |                       |                              |                  |         |
| 0–14 y                                        | 26 (12.2)             | 328 (28.7)                   | Reference        |         |
| 15–44 y                                       | 84 (39.4)             | 323 (28.2)                   | 3.28 (2.06 to 5.23) | <0.001  |
| 45–64 y                                       | 72 (33.8)             | 231 (20.2)                   | 3.93 (2.44 to 6.35) | <0.001  |
| ≥65 y                                         | 30 (14.1)             | 255 (22.3)                   | 1.48 (0.86 to 2.57) | 0.16    |
| Employment status                             |                       |                              |                  |         |
| Employed                                      | 92 (43.2)             | 352 (30.8)                   | Reference        |         |
| Full-time student                             | 27 (12.7)             | 82 (7.2)                     | 1.26 (0.77 to 2.06) | 0.36    |
| Caring for home and family                    | 15 (7.0)              | 84 (7.3)                     | 0.68 (0.38 to 1.23) | 0.21    |
| Other                                         | 45 (21.1)             | 453 (39.6)                   | 0.38 (0.26 to 0.56) | <0.001  |
| Unemployed                                    | 10 (4.7)              | 31 (2.7)                     | 1.23 (0.58 to 2.61) | 0.58    |
| Long-term illness                             | 16 (7.5)              | 84 (7.3)                     | 0.53 (0.24 to 1.14) | 0.29    |
| Mean no. of other people in household (median, range) | 3.0 (3) (1-12)      | 3.2 (3) (1-36)               | 0.98<sup>a</sup> |         |
| Child <5 y of age in the household            | 28 (13.1)             | 326 (28.5)                   | 0.38 (0.25 to 0.57) | <0.0001 |
| Mean no. of children <5 y of age in household (median, range) | 0.21 (0) (0-5)      | 0.41 (0) (0-5)               | <0.0001<sup>b</sup> |         |
| Other ill person in the household            | 15 (7.0)              | 112 (9.8)                    | 0.70 (0.39 to 1.20) | 0.26    |
| Mean no. of other ill people in household (median, range) | 0.09 (0) (0-3)      | 0.15 (0) (0-6)               | 0.20<sup>b</sup> |         |
| Child caregiver                               | 3 (1.4)               | 25 (2.2)                     | 0.64 (0.15 to 1.94) | 0.61<sup>c</sup> |
| Food handler                                  | 8 (3.8)               | 61 (5.3)                     | 0.60 (0.31 to 1.41) | 0.43    |

<sup>a</sup> OR, odds ratio; CI, confidence interval.
<sup>b</sup>Mann-Whitney U test.
<sup>c</sup>Fisher exact test.

Animal Contact, Leisure Activities, and Medical History

Case-patients were no more likely than non-case-patients to report pet ownership or contact with other people’s pets. Non-case-patients were more likely to own a pet rabbit, though this association was weaker after adjusting for age. Case-patients were more likely to have gone walking, to have visited a farm, or to report contact with cows or calves in the 7 days before illness, though the number of persons exposed to cows was very small. No difference existed in history of recent foreign travel. In respect to medical history, case-patients were no more likely than non-case-patients to suffer from diabetes or indigestion, or to be taking antacid or ulcer medicines but were less likely to report preexisting bowel disease or to have taken antibiotics in the month before onset of illness.

Multivariate Analysis

After adjustment for other variables within each of the four exposure groups (adjustment A), several independent risk factors were identified (Table 2). After combining all these variables (adjustment B), eating frozen fish, eggs, or berries; having milk delivered to the home; eating out at a Chinese restaurant or takeaway; and walking were dropped from the model as they made no independent contribution to the outcome. In the final model (adjustment C), five variables were identified as independent risk factors for campylobacter infection: eating chicken, eating salad vegetables other than lettuce (e.g., tomatoes, cucumber), drinking bottled water, eating out at a fried chicken outlet, and contact with cows or calves (Table 3). Eating lamb, owning a pet rabbit, a history of lower bowel problems, and contact with cows or calves (Table 3). Eating lamb, owning a pet rabbit, a history of lower bowel problems, and having had antibiotics in the month before illness all showed a protective effect. The combined population-attributable fraction for the five independent risk variables associated with campylobacter infection was nearly 70%. The highest attributable fractions were for eating chicken (31%), eating salad (21%), or drinking bottled water (12%).

Discussion

Our study identified five risk factors for campylobacter infection that, if taken together, could account for most sporadic cases. Most important was eating chicken in the 7 days before onset of illness. Two other risk factors, not previously described, could also potentially account for a sizeable proportion of case-patients: eating salad vegetables such as tomatoes or cucumber and drinking bottled water. The study used a retrospective cohort design that included all patients submitting fecal specimens through their general practitioner to a single laboratory. This design controls for patient characteristics associated with physician-consulting behavior and may also minimize recall bias associated with using healthy controls. Use of a laboratory study population does, however, have several disad-
vantages. Non-case-patients probably represent a group whose illnesses have disparate cause. Many may have had viral gastroenteritis since this is known to be common in the community and is not detectable by routine laboratory testing. This fact would explain why symptoms reported by non-case-patients were milder. Non-case-patients were also significantly more likely than case-patients to report a history of lower bowel problems, suggesting that some had pre-existing disease that might predispose to non-infectious diarrhea. Antibiotic use in the month before onset of illness was also more common in non-case-patients, and symptoms in these persons may therefore be a side effect of antibiotic treatment. Persons with pre-existing bowel problems may have atypical dietary habits, but neither a history of bowel problems nor of antibiotic use should affect the accuracy of food histories. The multivariate analysis controlled for both these variables.

The most consistent finding in studies of campylobacter infection etiology has been an association with eating chicken. This finding has been described in three previous U.K. studies (6,7,9), and in studies from the United States (12–16), Scandinavia (17–19), the Netherlands (20), Switzerland (21), and New Zealand (22,23). However, the relationship with chicken is sometimes only seen for eating undercooked chicken (12,22,23) or eating chicken away from home (8,15,22,23). Recent microbiologic studies of raw poultry in the United Kingdom indicate continuing high levels of campylobacter contamination in chicken and the occurrence of identical subtypes in both chicken and human isolates (24). Our finding of an association between illness and eating chicken or eating from a fried chicken outlet highlights the fact that chicken remains a major risk factor for campylobacter in the United Kingdom and that measures are needed both in the food industry and at home to promote thorough cooking of chicken and to reduce the risk for cross-contamination.

Neither eating salad vegetables nor drinking bottled water has previously been recognized as a risk factor. In our study, both these associations made a significant contribution to the final logistic regression model and could explain a substantial number of campylobacter infections. Both are also biologically plausible. Salad vegetables could be contaminated with campylobacter either before or after the point of sale. Contamination at the source could occur through contaminated soil or contaminated water during harvesting. Salad vegetables are often imported from abroad, and changes in the sourcing of such items could introduce new vehicles of campylobacter infection into the U.K. food chain. For example, contaminated imported lettuce has been identified as a vehicle of infection in recent salmonella and shigella outbreaks in the United Kingdom (25). However, recent extensive sampling of organic fruit and vegetables and ready-to-eat prepackaged salads in the United Kingdom found no pathogens such as Campylobacter, Salmonella, or E. coli O157, suggesting that contamination of such items is either rare or intermittent (26). Two reports on campylobacter outbreaks associated with salad have been published. Both of these involved contamination in the kitchen. The first was a 3-month long outbreak from

Table 2. Frequency of food exposure, animal contact, leisure activities and medical history in campylobacter infected case-patients and non-case-patients

| Exposure                          | Case-patients (%) | Non-case-patients (%) | Crude OR* (95% CI) | Adjusted OR (95% CI) | p value |
|-----------------------------------|-------------------|-----------------------|--------------------|----------------------|---------|
| Food and drink                    |                   |                       |                    |                      |         |
| Lamb                              | 47 (22.1)         | 282 (24.7)            | 0.87 (0.61 to 1.22) | 0.67 (0.45 to 0.99)  | 0.046   |
| Frozen fish                       | 53 (24.9)         | 341 (29.8)            | 0.78 (0.55 to 1.09) | 0.64 (0.45 to 0.93)  | 0.020   |
| Chicken                           | 177 (83.1)        | 777 (67.9)            | 2.32 (1.60 to 3.43) | 1.61 (1.03 to 2.50)  | 0.036   |
| Eggs                              | 141 (66.2)        | 606 (53.0)            | 1.74 (1.28 to 2.37) | 1.35 (0.95 to 1.92)  | 0.096   |
| Salad vegetables                  | 159 (74.6)        | 635 (55.5)            | 2.36 (1.70 to 3.30) | 1.73 (1.09 to 2.74)  | 0.019   |
| Fresh or frozen berries           | 51 (23.9)         | 173 (15.1)            | 1.77 (1.23 to 2.51) | 1.43 (0.95 to 2.13)  | 0.086   |
| Milk delivered to the doorstep    | 29 (13.6)         | 215 (18.8)            | 0.68 (0.44 to 1.03) | 0.60 (0.38 to 0.94)  | 0.026   |
| Bottled water                     | 114 (53.5)        | 420 (36.7)            | 1.98 (1.48 to 2.67) | 1.39 (0.98 to 1.96)  | 0.062   |
| Ate at a fried chicken outlet     | 22 (10.3)         | 51 (4.5)              | 2.47 (1.44 to 4.13) | 1.82 (1.00 to 3.30)  | 0.050   |
| Ate at a Chinese restaurant       | 23 (10.8)         | 114 (10.0)            | 1.09 (0.67 to 1.74) | 0.58 (0.33 to 0.99)  | 0.048   |
| Animal contact                    |                   |                       |                    |                      |         |
| Own a pet rabbit                  | 7 (3.3)           | 89 (7.8)              | 0.40 (0.17 to 0.84) | 0.46 (0.20 to 1.05)  | 0.066   |
| Had contact with cows or calves   | 5 (2.3)           | 6 (0.5)               | 4.55 (1.27 to 15.74)| 5.44 (1.05 to 28.1)  | 0.043   |
| Leisure activities                |                   |                       |                    |                      |         |
| Walking (>15 min)                 | 162 (76.0)        | 712 (62.2)            | 1.93 (1.38 to 2.72) | 1.92 (1.34 to 2.73)  | <0.001  |
| Medical history                   |                   |                       |                    |                      |         |
| History of lower bowel problems   | 21 (9.9)          | 197 (17.2)            | 0.53 (0.32 to 0.83) | 0.55 (0.34 to 0.90)  | 0.018   |
| Antibiotic in month before illness| 11 (5.2)          | 160 (14.0)            | 0.34 (0.17 to 0.61) | 0.34 (0.18 to 0.65)  | 0.001   |

*Adjusted for potential confounders within each exposure group; OR, odds ratio; CI, confidence interval.
cucumber served at a salad bar; the outbreak resolved after changes were made in food preparation and storage procedures (27). The second involved salad prepared by a foodhandler who exhibited symptoms of campylobacter infection (28). In a recent review of outbreaks in England and Wales (including five from campylobacter) linked with salad vegetables and fruit, cross-contamination was also the most frequently identified contributory factor (25). The association we observed was specific to items such as salad vegetables and fruit, cross-contamination was also identified two potentially important new risk factors (36,37), and molecular evidence suggests a link between campylobacter in the farm environment with those causing disease in the community (38).

Our study confirms that eating chicken still plays an important role in the cause of campylobacter infection. It also identifies two potentially important new risk factors that merit further investigation: salad vegetables (and the associated risks of cross-contamination in the home) and bottled natural mineral water. Cross-contamination in the domestic kitchen is potentially preventable, but we need to know how it happens and what interventions are most effective at reducing the risk. Bottled water is a $35 billion worldwide industry (39). In the United States, 1.7 billion gallons of natural mineral water were consumed in 2000 (39). Consumption is also increasing dramatically in the United Kingdom (by approximately 10% each year), and approximately 300 million gallons of bottled water are now consumed annually (40). Consequently, increased illness from contamination of bottled water could be considerable. More studies of the microbiologic quality of natural mineral waters are required, and these should include testing for *Campylobacter* spp.
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