Thermophilic \textit{Campylobacter} - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam

\textbf{Abstract}

Thermophilic \textit{Campylobacter} are the most common bacterial cause of gastroenteritis in humans worldwide. Poultry and poultry products are the main sources for human infections. Epidemiological data concerning campylobacteriosis in Asia are limited. Overall, it is difficult to accurately assess the burden of \textit{Campylobacter} infections. South-East Asia including Cambodia, Laos and Vietnam is known as a hotspot for emerging diseases. Campylobacteriosis is a problem of public health concern in these countries, hence, epidemiological data are scarce. This is influenced by the limited number of laboratory facilities and lack of equipment and awareness in physicians and veterinarians resulting in the lack of surveys.

This review lists articles and reports on \textit{Campylobacter} and campylobacteriosis in these developing third world countries. Subjects are prevalence of thermophilic \textit{Campylobacter} in humans, animals and food and their resistance to several antibiotics.

\textbf{Keywords:} \textit{Campylobacter}; Cambodia; Laos; Vietnam; Antibiotic resistance

\textbf{Highlights}

This review gives an overview about articles and reports on \textit{Campylobacter} and campylobacteriosis in Cambodia, Laos and Vietnam. The knowledge about these objects is limited for the three countries. One topic in the literature is prevalence of thermophilic \textit{Campylobacter} in humans and their relation to diarrhea. In Vietnam a prevalence rate up to 11% was reported. In Cambodia and Laos it was even higher. Especially, children under five years of age were affected. Animals and food as sources for human infections play an important role. Carriage of \textit{Campylobacter} by different animal species and contamination rate of meat are generally high and can reach more than 70%. Resistance to antibiotics is of public health concern. High rates of resistance to nalidixic acid, erythromycin, tetracycline and ciprofloxacin were detected reaching sometimes 100% of isolates.

\textbf{Introduction}

Zoonoses are diseases and infections which can be transmitted from animals to humans or vice versa. Over 200 pathogens are recognized as zoonotic agents and classified as foodborne and non-foodborne agents. Zoonotic foodborne agents may cause human diseases after uptake of contaminated food or water. Several of these microorganisms can be found in the intestinal tract of healthy food-producing animals. \textit{Campylobacter} species are the most common bacterial cause of gastroenteritis in humans worldwide. Incidence and prevalence of campylobacteriosis have increased in both, developed and developing countries, over the last 10 years [1]. A dramatic increase in the number of reported cases was recognized in Australia, Europe, and North America. In the United States, an incidence of 14.3 campylobacteriosis cases per 100,000 inhabitants was reported for the period between 1996 and 2012 [2]. In Quebec, Canada an annual incidence of 35.2 cases per 100,000 persons was reported [3]. In Europe, \textit{Campylobacter} has become the most frequently reported bacterial pathogen causing gastrointestinal infections in humans since 2005. In 2013, 214,779 confirmed cases were reported by the member states of the European Union (EU) which correlated with a notification rate of 64.8 per 100,000 inhabitants [4]. Hence, the number of fatal cases was very low with 0.05%. Data from African countries are limited and indicate that \textit{Campylobacter} infections are most prevalent in children. In a study in Malawi, 14% of non-diarrhoeic children and 28% children with diarrhea were PCR positive for \textit{C. jejuni} and \textit{C. coli} [5]. \textit{C. jejuni} and \textit{C. coli} were also found to be endemic in children in Madagascar and Kenya [6,7]. Epidemiological data concerning campylobacteriosis in Asia are limited. A study from China reported that 5% of diarrhoeic patients were PCR positive for \textit{C. jejuni}. The highest prevalence was detected in the cohort of children younger than 7 years [8]. Also in Japan and India \textit{Campylobacter} infections occur quite frequently [9,10]. Overall, it is difficult to accurately assess the burden of \textit{Campylobacter} infections in Asia owing to insufficient epidemiological data [1].

International travel, consumption of undercooked chicken and products thereof, environmental exposure, and direct contact with farm animals were recognized as risk factors for human campylobacteriosis [11]. The most important sources of
Thermophilic Campylobacter - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam

Foodborne campylobacteriosis are consumption of contaminated food, especially poultry products, unpasteurized milk and water. Broilers are the main source for thermophilic Campylobacter to humans [12]. Studies in Switzerland estimated that 71% of human cases were caused by uptake of contaminated chicken meat [13,14]. The UK Food Standards Agency found 72.9% of fresh retail chicken Campylobacter positive with nearly 20% being highly contaminated [15]. Besides broilers, turkeys and ducks, and also cattle and pigs serve as reservoirs of thermophilic Campylobacter. Campylobacter contaminated water was responsible for outbreaks of human campylobacteriosis, but also for transmission within animal populations [1].

South-East Asia is known as a hotspot for emerging diseases. Part of the region is former French Indochina including Cambodia (Kingdom of Cambodia), Laos (Lao People’s Democratic Republic) and Vietnam (Socialist Republic of Vietnam) with a shared history since the 19th century. All three countries are developing third world countries suffering the aftermath of the Vietnam War. Campylobacteriosis is a problem of public health concern in these countries, hence. Epidemiological data are scarce. This may be caused by the limited number of laboratory facilities and lack of equipment and awareness in physicians and veterinarians resulting in the lack of surveys. A recent review of foodborne bacterial and parasitic zoonosis in Vietnam summarized a number of studies on thermophilic Campylobacter infections [16] but no data on the prevalence of campylobacteriosis are available for Laos and Cambodia.

Therefore, in this review we summarize literature on Campylobacter affecting human and animal populations, their prevalence as foodborne pathogen and the resistance to antibiotics in these countries from 1971 to 2016. We delineate knowledge and capability gaps, which will foster new research and surveillance programs. This will help to tackle the impact on public health that is caused by Campylobacter infections in the respective countries.

Methods and Research Data
Information presented in this review was collected by searching published studies on database including CABINDIRECT, Science Direct, Pubmed and Google with keywords “Campylobacter and Vietnam”, “Campylobacter and Laos”, “Campylobacter and Cambodia”. The searched publications were reviewed and relevant information was retrieved. All Articles or studies provided information on prevalence of thermophilic Campylobacter in humans, animals or food and/or information on antibiotic resistance in these bacteria. All articles and studies were in relation to South-East Asian countries of Cambodia, Laos and/or Vietnam.

Results and Discussion
Articles on Campylobacter in Cambodia, Laos and Vietnam
Thirty one publications were retrievable in Pubmed and other database concerning Campylobacter in Cambodia, Laos and Vietnam between 1971 and 2016. Nineteen articles were related to Vietnam, 3 articles to Laos and 9 articles to Cambodia. Eleven articles were related to antibiotic resistance but most of the papers dealt with investigations of the prevalence of Campylobacter in humans, animals and food.

Campylobacter in humans
An overview about papers concerning Campylobacter in humans in Vietnam, Laos and Cambodia is given in Table 1. The main source of human campylobacteriosis is the consumption of chicken meat, but meat of other species can also be contaminated with Campylobacter. Identification of thermophilic campylobacters was carried out by cultivation in combination with biochemical methods. Only recently, identification and differentiation by PCR assays was introduced. Detection rates ranged between 0 and 12% depending on country and the method of detection. C. jejuni was detected more often than C. coli. Children under 5 years of age are most frequently affected. The risk of infections seems to be correlated with undernutrition, poor hygiene, keeping of animals in the house, manure and wet litter in house yards and contaminated drinking water [17]. In Cambodia, 12% of 681 human faecal samples were tested positive by PCR assays [18]. Rates for Vietnam and Laos were below 5%. In an investigation in children with and without diarrhoea in Ho Chi Minh City, Vietnam, 2.2% of stool samples were positive, but in the control group without diarrhoea 2.6% samples were also found positive [19]. A similar result was reported from Cambodia. In Phnom Penh 4.7% C. jejuni and 1.5% C. coli were detected in diseased children at an age under 5 years and 6.2% C. jejuni and 2.4% C. coli in the control group [20]. It seems that Campylobacter is widespread in the population, but the mere presence of the bacteria in the gut is not inevitable related to clinical symptoms of campylobacteriosis.

In a detailed study from Cambodia, Osbjer et al. [18] could not detect Campylobacter in 681 stool samples by cultivation of frozen samples [18]. Hence, 66 C. jejuni and 16 C. coli were identified by multiplex PCR. In the group of children up to 15 years, Campylobacter was detected in 18.9% of the samples whereas only 7% to 8% of those of male and female group over 15 years were C. positive. Risk factors for human campylobacteriosis were slaughtering of domestic animals, allowance of animal access to sleeping and food preparation areas and eating of undercooked meat [17].

Campylobacter in animals and meat
In an investigation from the Mekong delta, Vietnam, the prevalence of Campylobacter in faeces of chickens, ducks and pigs was reported to be 31.9%, 23.9%, and 53.7%, respectively [21]. Similar results were found in Cambodia [18]. In 41.3% of swab and faeces samples of chickens, ducks, pigs and cattle Campylobacter was detected by multiplex PCR. 56.1% of chicken and 23.8% of duck samples were positive. 72.2% of pigs but only 5.3% of cattle samples were tested positive for C. jejuni and C. coli, respectively. C. jejuni was the dominant species in chickens and ducks, C. coli was more prevalent in pigs. The low prevalence rate of Campylobacter in cattle (5.3%) was similar to that in buffaloes in Laos i.e. 2% [22]. A remarkable difference was observed
between cultivation and PCR assays. In contrast to 352 samples that were assessed to be positive by PCR assays (41.3%) only 106 samples were identified as *Campylobacter* positive by cultivation (12.4%). Cultivation of *Campylobacter* is difficult at least under field conditions because of their sensitivity to oxygen and changes in temperature.

Contamination rates of poultry products with thermophilic *Campylobacter* were determined to be between 15% and 35% in Vietnam (Table 2). Schwan, 2010 found 76.0% of swabs of chickens positive for *Campylobacter*, but none of the investigated meat samples was contaminated [23]. In Phnom Penh, Cambodia, was shown that 80.9% of poultry carcasses were contaminated [24]. The result was obtained by cultivation of *Campylobacter*. A lower contamination rate of 35.0% was reported for poultry products from markets in the capital of Cambodia [25]. *C. jejuni* (44.4%), *C. coli* (36.5%), *C. lari* (15.9%) and *C. upsaliensis* (3.2%) were identified among 63 *Campylobacter* isolates.

### Table 1: Studies concerning presence of thermophilic *Campylobacter* in humans

| Country | Region | Group | Method | Result | Reference |
|---------|--------|-------|--------|--------|-----------|
| Vietnam | Red River | 1,655 children under 5 years (one year of investigation) | Cultivation | 150 *C. jejuni* and *C. coli* (43.2%) from 347 cultures isolated from 2,160 cases of diarrhoea | 36 |
| Vietnam | Hanoi | 83 children under 5 years with persistent diarrhoea | | | 37 |
| Vietnam | Hanoi | 291 children under 5 years with acute diarrhoea (one year of investigation) | Cultivation, enzyme immunoassay | 4% *Campylobacter* positive stool samples | 38 |
| Vietnam | Ho Chi Minh City, southern Vietnam | 1,309 stool samples of children up to 12 months with diarrhoea | Real-time PCR | 152 *Campylobacter* positive (11.6%) | 39 |
| Vietnam | Ho Chi Minh City | 1,419 stool samples of children under 5 years with diarrhoea | Cultivation | 6 *Campylobacter* positive in 293 norovirus positive samples | 40 |
| Vietnam | Da Nang | 987 U.S. Marines | | | 41 |
| Vietnam | Ho Chi Minh City | 1,419 children with and 609 without diarrhoea over a one-year period | Cultivation | 31 *Campylobacter* sp. in stools of diarrheal cases (2.2%) and 16 in samples without diarrhea (2.6%) | 19 |
| Vietnam | Hanoi | 636 adults observed for 18 months | Cultivation | 0.6% of stool samples *Campylobacter* positive | 42 |
| Laos | Vientiane | 880 patients with diarrhea in an 11 months period | Cultivation | 2.4% *C. jejuni* and 2.0% *C. coli* | 43 |
| Laos | Vientiane | 70 patients with diarrhoea in a 13 months period (most of them < 5 years) | Cultivation | 2.9% *C. jejuni* | 44 |
| Cambodia | Thai-Cambodian border | 65 stool specimen from children younger 2 years | Cultivation, latex agglutination test | 1.6% *Campylobacter* positive | 45 |
| Cambodia | Thai-Cambodian border | 487 children with diarrhoea under 5 years | Cultivation | 107 out of 487 *Campylobacter* positive (22.0%) | 46 |
| Cambodia | Phnom Penh | 600 children under 5 years with diarrhoea and 578 children without diarrhoea | Cultivation | 4.7% *C. jejuni* and 1.5% *C. coli* in diseased children; 6.2% *C. jejuni* and 2.4% *C. coli* in control group | 20 |
| Cambodia | No information | 25 *C. jejuni* from children under 5 years | Multiplex PCR | Detection of capsule type | 47 |
| Cambodia | Villages in 3 provinces | 681 stool samples | Cultivation, multiplex PCR | No *C. jejuni* detection by cultivation; 12% *Campylobacter* positive in PCR | 17,18 |
Table 2: Studies concerning presence of thermophilic Campylobacter in animals and meat.

| Country | Region | Group | Method         | Result                                                                 | Reference |
|---------|--------|-------|----------------|------------------------------------------------------------------------|-----------|
| Vietnam | Hanoi  | 177 samples of raw food (poultry, pork, beef meat, fish, vegetables) from canteens | Cultivation | 28.3% of poultry samples were contaminated with C. jejuni | 48        |
| Vietnam | Hanoi  | 100 samples from chicken breast | Cultivation | 31.0% were positive for Campylobacter | 49        |
| Vietnam | Ho Chi Minh City | 319 broiler carcasses | Cultivation | 35.1% were positive for Campylobacter | 50        |
| Vietnam | Mekong delta | 96 samples of chicken meat and 96 cloacal swabs from 20 farms | Cultivation, PCR | No Campylobacter from meat; 76.0% of swab samples were Campylobacter positive | 23        |
| Vietnam | Ho Chi Minh City | 150 chicken neck-skins | Cultivation | 15.3% Campylobacter positive | 51        |
| Vietnam | Mekong delta | 634 faecal samples from pigs, chickens, ducks | Cultivation, PCR | Animal level prevalence of Campylobacter was 31.9%, 23.9% and 53.7% for chickens, ducks and pigs | 21        |
| Vietnam | Hanoi  | 9 Campylobacter isolates from chicken and pork meat | Cultivation, PCR | Genotyping by PCR-based methods | 29        |
| Laos    | Vientiane | 82 caecum samples from cattle; 184 caecum samples and 100 bile samples from buffaloes | Cultivation | 4 Campylobacter isolates from buffaloes | 22        |
| Cambodia| Phnom Penh | 152 poultry carcasses | Cultivation | 123 carcasses were positive for Campylobacter | 24        |
| Cambodia| Phnom Penh and peri-urban areas | 180 samples from markets | Cultivation | 63 samples (35.0%) positive for Campylobacter (28 C. jejuni, 23 C. coli, 10 C. lari, 2 C. upsaliensis) | 25        |
| Cambodia| Kampong Thom<sup>a</sup> | 36 monkeys (Macaca fascicularis) | Cultivation, PCR | 36.1% were Campylobacter positive | 26        |
| Cambodia| Villages in 3 provinces | 753 livestock samples | Cultivation, PCR | 342 samples tested positive for Campylobacter (42.5%) | 17        |
| Cambodia| Villages in 3 provinces | 853 livestock samples (cloacal swabs and faeces from chickens, ducks, pigs and cattle) | Cultivation, MALDI-TOF-MS, PCR | Campylobacter detected in 106 samples by cultivation and in 352 samples by PCR (41.3%) | 18        |

<sup>a</sup>kept in Japan

In a study concerning the prevalence of thermophilic Campylobacter in cynomolgus monkeys (Macaca fascicularis) kept in captivity and semi-free-range outdoor areas in Japan, these bacteria were detected in 36% of animals of a group imported from Cambodia, but not in animals from Vietnam [26]. Table 2 gives an overview about reports on Campylobacter in animals and meat in the three Southeast Asian countries.

**Antibiotic resistance of Campylobacter**

Information on antibiotic resistance of thermophilic Campylobacter isolates is very limited in Vietnam and Cambodia, and no was published data about antimicrobial susceptibility of campylobacters in Laos were found. Disc diffusion, agar dilution and broth microdilution test were methods for determination of antibiotic resistance of Campylobacter. Campylobacter isolates were highly resistant to nalidixic acid (58% up to 100%; Table 3) with one exception of 7% [27]. Resistance to ciprofloxacin was in the range from 7% up to 100% (Table 3). Resistance rates to erythromycin were found between 0% and 100% depending on country, source or method of investigation.

In one report, no difference was found in the prevalence of resistance to several antibiotics between different host species [21]. The resistance profiles were identical for C. jejuni and C. coli isolates. Generally, the resistance rate of in C. coli isolates is higher than that of C. jejuni. Remarkable was resistance to chloramphenicol with up to 25% in some reports, because use
of chloramphenicol is banned in animal breeding in Europe for more than 20 years, but it is still often used in many third world countries [28]. C. coli isolates were resistant to ciprofloxacin, nalidixic acid, streptomycin and tetracycline [29].

Resistance rates of Cambodian campylobacters from chicken to ciprofloxacin reached 90.0% for C. lari isolates and was lower for C. jejuni and C. coli with 60.7% and 52.2%, respectively [25]. C. coli (30.4%) showed a higher resistance rate to erythromycin in comparison to C. jejuni (17.9%). Resistance to tetracycline varied around 50% whereupon C. coli showed the highest value (56.5%). Campylobacter isolated from faeces of monkeys were 100% sensitive to erythromycin and chloramphenicol [26]. Archawakulathep et al. [30] 2014 gave a good overview of perspectives on antimicrobial resistance in livestock and livestock products in ASEAN countries [30].

### Table 3: Studies concerning antibiotic resistance of thermophilic Campylobacter of different origin.

| Country   | Region       | Source                        | Number of Isolates | Method of Investigation                      | Resistance Rate to Antibiotics | Reference |
|-----------|--------------|-------------------------------|--------------------|----------------------------------------------|--------------------------------|-----------|
| Vietnam   | -            | Human                         | 88 isolates        | MIC agar-plate dilution test                  | NA: 7%                         | 27        |
| Vietnam   | Hanoi        | Human                         |                    | CIP: 7%                                       |                                | 38        |
| Vietnam   | Mekong delta | Chicken                       | 22 C. jejuni and 6 C. coli | Broth microdilution test                   | NA: 6% 1), 100% 2) CIP: 6% 1), 100% 2) | 23        |
| Vietnam   | Ho Chi Minh City | Chicken                        | 20 chicken neck-skin samples | Disc diffusion test                     | AMP: 40% | 51        |
| Vietnam   | Mekong delta | Chicken, ducks, pigs          | 202 Campylobacter isolates | (C. jejuni and C. coli); Disc diffusion method | ERY: 100% | 21        |
| Vietnam   | Ho Chi Minh City | Human                        | 66 Campylobacter isolates from children with diarrhea; 16 isolates from non-diarrheal control; E-test using disc diffusion | AMP: 26.3%                 | 19        |
| Vietnam   | Hanoi        | Chicken and pig meat          | 9 Campylobacter isolates (8 C. jejuni and 1 C. coli); Broth microdilution test | CIP: 62.5% 1) | 29        |
| Cambodia  | Phnom Penh   | Poultry carcasses             | 139 Campylobacter isolates | (C. jejuni, C. coli, C. lari); Disc diffusion method | CIP: 25.9% | 24        |
| Cambodia  | Phnom Penh   | Human                         | 23 C. coli and 64 C. jejuni isolates; Disc diffusion method | NA: 34% 1), 57% 1) | 20        |

Citation: Nguyen TNM, Hotzel H, El-Adawy H, Tran HT, Hong Le MT, et al. (2017) Thermophilic Campylobacter - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam. Gastroenterol Hepatol Open Access 8(3): 00279. DOI: 10.15406/ghoa.2017.08.00279
Thermophilic Campylobacter - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam

| Country   | Region                        | Animal          | Campylobacter isolates (C. jejuni; C. coli; C. lari; C. upsaliensis) | REsistances | Notes |
|-----------|-------------------------------|-----------------|-------------------------------------------------------------|-------------|-------|
| Cambodia  | Phnom Penh and peri-urban areas | Poultry, carcasses, environment | 63 Campylobacter isolates | CIP: 61.9%; ERY: 22.2%; TET: 50.8% | 25    |
| Cambodia  | Kampong Thom                 | Cynomolgus monkeys | 15 Campylobacter isolates | CIP: 100%; STR: 100%; TET: 100% | 26    |

NA: Nalidixic Acid; CIP: Ciprofloxacin; AZM: Azithromycin; AMP: Ampicillin; ERY: Erythromycin; SXT: Sulfamethoxazole-Trimethoprim; CHL: Chloramphenicol; STR: Streptomycin; TET: Tetracycline; GEN: Gentamicin

Consequence of finding of fluoroquinolone in imported basa catfish from Vietnam was the stop of sale of 350 tons of seafood in the US by the U.S. Food and Drug Administration (FDA) in 2005 [31]. Motivation was the emerging of resistance to enrofloxacin in Campylobacter caused by treatment of chickens and turkeys with this antimicrobial agent in poultry production and the risk for human health.

Other Topics

Recently, five genomes of Campylobacter jejuni isolates from Vietnam were sequenced. Some of these isolates had a cluster of genes of the type-6 secretion system (T6SS) which play roles in pathogen-pathogen and host-pathogen interactions. T6SS is associated with virulence, cell adhesion and cytotoxicity toward erythrocytes. Using the marker gene hcp (haemolysin co-regulated protein) the T6SS was detected in more than 70% of Vietnamese human and chicken isolates [32].

Another study gave a detailed characterization of Vietnamese Campylobacter isolates [29]. Investigations concerning genotyping and antimicrobial resistance of Campylobacter isolates were carried out using flaA typing, MLST and DNA microarray assays. Resistance of Campylobacter to several antibiotics was determined phenotypically and by molecular biological methods. A limitation was the low number of isolates. In a study concerning the regional risks and seasonality in travel-associated campylobacteriosis in East Asia including Cambodia, Laos and Vietnam the risk was estimated to be 386 infections per 100,000 Swedish travelers per year. This is the highest value in the world apart from the Indian subcontinent with 1,253 cases per 100,000 travelers per year [33].

In an evaluation study of gastrointestinal pathogens in stool samples from diarrheic patients the usefulness of a multipanel pathogen identification system was shown. It represented a sensitive, specific and easy approach as an alternative to classical detection methods [34].

Conclusion

Little information about Campylobacter was reported in the past in the three South East Asian countries of Cambodia, Laos and Vietnam. Often, investigations were related to human infections especially in children of young age in big cities like Hanoi, Vientiane, Phnom Penh or Ho Chi Minh City. Knowledge about the prevalence of Campylobacter in humans and poultry and the antibiotic resistance is much better in Vietnam than in Laos or Cambodia. However, there exist no data about the prevalence of Campylobacter in milk or water sources, although Campylobacter contamination in both could be a risk for humans. Moreover, the common habit of consumption of unpasteurized milk in children under 5 year of age underlines the relevance of this potential route of transmission in these countries. However, food safety awareness and concepts are existing [35]. Surveillance and collaborative research within the South East Asian countries can clarify the epidemiology of foodborne infections like campylobacteriosis in humans. It can be also important for control of bacterial contamination in livestock and food of animal origin.

Prerequisite of improvement of food safety and as a consequence of human health is the introduction of modern diagnostics. PCR assays are rapid, reliable and comparably cheap, but especially in Laos molecular techniques are practically not in use yet and there is a substantial lack of laboratory infrastructure and equipment in all three countries. An increasing problem is antibiotic resistance in bacteria like Campylobacter. In the EU, antibiotic use of antibiotics as growth promoters in food animals was completely banned several years ago. National monitoring and control programmes for antimicrobial resistance in foodborne pathogens have not been established in ASEAN countries yet [30,36-51]. Limited data on the amount of antibiotics used in the farming industry exist, because there is no effective control, policy or regulation. In summary, national surveillance programs and international collaborations are needed to address the substantial gaps in knowledge about the epidemiology of campylobacteriosis in developing countries such as Cambodia, Laos and Vietnam.

Establishment of at least one National Reference Laboratory with modern equipment and well trained personnel in each country is recommended.

Acknowledgement

This work was supported by Friedrich-Loeffler-Institut, Institute of Bacterial Infections and Zoonoses, Germany and Vietnam Ministry of Agriculture and Rural Development.

Conflict of Interest

No competing financial interests exist.

References

1. Kaakoush NO, Castano-Rodríguez N, Mitchell HM, Man SM (2015) Global epidemiology of Campylobacter infection. Clin Microbiol Rev 28(3): 687-719.
2. Gillies D, Cronquist AB, Cartter M, Tobin-D’Angelo M, Blythe D, et al. (2013) Incidence and trends of infection with pathogens

Citation: Nguyen TNM, Hotzel H, El-Adawy H, Tnn HT, Hong Le MT, et al. (2017) Thermophilic Campylobacter - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam. Gastroenterol Hepatol Open Access 8(3): 00279. DOI: 10.15406/ghoa.2017.08.00279
Thermophilic Campylobacter - Neglected Foodborne Pathogens in Cambodia, Laos and Vietnam

transmitted commonly through food-foodborne diseases active surveillance network, 10. U. S. sites, 1996-2012. MMWR Rep 62: 283-287.

3. Arsenault J, Berke O, Michel P, Ravel A, Gosselin P (2012) Environmental and demographic risk factors for campylobacteriosis: do various geographical scales tell the same story? BMC Infect Dis 12: 318.

4. EFSAC/ECDC (2015) The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. EFSJ 13: 3991.

5. Mason J, Iturriza-Gomara M, O’Bright SJ, Ngwira BM, Dove W, et al. (2013) Campylobacter infection in children in Malawi is common and is frequently associated with enteric virus co-infections. PLoS One 8(3): e59663.

6. Randremanana RV, Randrianirina F, Sabatier P, Rakotonirina HC, Randriamanantena A, et al. (2014) Campylobacter infection in a cohort of rural children in Moramanga, Madagascar. BMC Infect Dis 14: 372.

7. Swierczewski BE, Oudono EA, Koech MC, Ndongye JN, Kiriéra RK, et al. (2013) Enteric pathogen surveillance in a case-control study of acute diarrhoea in Kisi Town, Kenya. J Microbiol Med 62(pt 11): 1774-1776.

8. Huang JL, Xu HY, Bao GY, Zhou XH, Ji D, et al. (2009) Epidemiological surveillance of Campylobacter jejuni in chicken, dairy cattle and diarrhoea patients. Epidemiol Infect 137(8): 1111-1120.

9. Kubota K, Kasuga F, Iwasaki E, Inagaki S, Sakurai Y, et al. (2011) Estimating the burden of acute gastroenteritis and foodborne illness caused by Campylobacter, Salmonella, and Vibrio parahaemolyticus by using population-based telephone survey data, Miyagi Prefecture, Japan, 2005 to 2006. J Food Prot 74(10): 1592-1598.

10. Mukherjee P, Ramamurthy T, Bhattacharya MK, Rajendran K, Mukhopadhyay AK (2013) Campylobacter jejuni in hospitalized patients with diarrhoea, Kolkata, India. Emerg Infect Dis 19(7): 1155-1156.

11. Domingues AR, Pires SM, Halaza T, Hald T (2012) Source attribution of human campylobacteriosis using a meta-analysis of case-control studies of sporadic infections. Epidemiol Infect 140(6): 970-981.

12. Skirrow MB (1977) Campylobacter enteritis: a "new" disease. Br Med J 2(6078): 9-11.

13. Kitti S, Heckel G, Korczak BM, Kuhnert P (2013) Source attribution of human Campylobacter isolates by MLST and fla-typing and association of genotypes with quinolone resistance. PLoS One 8(11): e81796.

14. Wei W, Schüpbach G, Held L (2015) Time-series analysis of Campylobacter incidence in Switzerland. Epidemiol Infect 143(9): 1982-1989.

15. Food Standards Agency (FSA) (2014) A microbiological survey of Campylobacter contamination in fresh whole UK produced chilled chickens at retail sale – an interim report to cover Quarters 1&2. Food Standards Agency, London, UK.

16. Carrique-Mas JJ, Bryant JE (2013) A review of foodborne bacterial and parasitic zoonoses in Vietnam. EcoHealth 10(4): 465-489.

17. Osbjer K, Boyvjest S, Solerya S, Chheng K, San S, et al. (2016) Risk factors associated with Campylobacter detected by PCR in humans and animals in rural Cambodia. Epidemiol Infect 144(14): 1-10.

18. Osbjer K, Tan O, Chhuyheang L, Mak-Kwasiak AO, Fernström LL, et al. (2016) Detection of Campylobacter in human and animal field samples in Cambodia. APMIS 124(6): 508-515.

19. Thompson CN, Phan MVT, Hoang NVM, Minh PV, Vinh NT, et al. (2015) A prospective multi-center observational study of children hospitalized with diarrhoea in Ho Chi Minh City, Vietnam. Am J Trop Med Hyg 92(5): 1045-1052.

20. Meng CY, Smith BL, Bodhidatta L, Richard SA, Vansith K, et al. (2011) Etiology of diarrhoea in young children and patterns of antibiotic resistance in Cambodia. Pediatr Infect Dis J 30: 331-335.

21. Carrique-Mas JJ, Bryant JE, Cuong NV, Hoang NVM, Campbell J, et al. (2014) An epidemiological investigation of Campylobacter in pig and poultry farms in the Mekong delta of Vietnam. Epidemiol Infect 142(7): 1425-1436.

22. Boonmar S, Chanda C, Markivitchit K, Chaunchom S, Yingnakmonkon S, et al. (2007) Prevalence of Campylobacter spp. in slaughtered cattle and buffaloes in Vientiane, Lao People’s Democratic Republic. J Vet Med Sci 69(8): 853-855.

23. Schwan P (2010) Prevalence and antibiotic resistance of Campylobacter spp. in poultry and raw meat in the Can Tho Province, Vietnam. SLU Examensarbete.

24. Lay KS, Vuthy Y, Song P, Phol K, Sathou JL (2011) Prevalence, numbers and antimicrobial susceptibilities of Salmonella serovars and Campylobacter spp. in retail poultry in Phnom Penh, Cambodia. J Vet Med Sci 73(3): 325-329.

25. Otto P (2012) CambodiaCase Study: An integrated surveillance study of AMR in Salmonella subsp. Campylobacter spp, Escherichia coli and Enterococcus spp in poultry. Regional Workshop on the Use of Antimicrobials in Animal Production and AMR in the Asia-Pacific Region. Negombo, Sri Lanka, pp. 22-23.

26. Koga T, Aoki W, Mizuno T, Wakazono K, Ohno J, Nakai T, et al. (2015) Antimicrobial resistance in Campylobacter coli and Campylobacter jejuni in cynomolgus monkeys (Macaca fascicularis) and eradication regimen. J Microbiol Immunol Infect 50(1): 75-82.

27. Isenbarger DW, Hoge CW, Srijan A, Pitarangsi C, Vithayasai N, et al. (2002) Comparative antibiotic resistance of diarrheal pathogens from Vietnam and Thailand, 1996-1999. Emerg Infect Dis 8(2): 175-180.

28. European Food Safety Authority (EFSA) (2014) Scientific opinion on chloramphenicol in food and feed. EFSA J 12:3907.

29. Nguyen TNM, Hotzel H, El-Adawy H, Tran HT, Le MTH, et al. (2016) Genotyping and antibiotic resistance of thermophilic Campylobacter isolated from chicken and pig meat in Vietnam. Gut Pathog 8: 19.

30. Archawakulathep A, Kim CT, Meunsene D, Habdijatno D, Hassim HA, et al. (2014) Perspectives on antimicrobial resistance in livestock and livestock products in ASEAN countries. Thai J Vet Med 44: 5-13.

31. (2005) Louisiana recalls and stops sale of some 700.000 pounds of fish from Vietnam pending investigation into use of antibiotic banned by the FDA in July. Campylobacter Blog – Surveillance & Analysis on Campylobacter News & Outbreaks.

32. Harrison JW, Dung TTN, Siddiqui F, Korbrisate S, Bukhari H, et al. (2014) Identification of possible virulence marker from Campylobacter jejuni isolates. Emerg Infect Dis 20(6): 1026-1029.
33. Ekdahl K, Andersson Y (2004) Regional risks and seasonality in travel-associated campylobacteriosis. BMC Infect Dis 4(1): 54.
34. Duong VT, Phat VV, Tuyen HT, Dung TTN, Trung PD, et al. (2016) Evaluation of Luminex xTAG Gastrointestinal Pathogen Panel Assay for detection of multiple diarrheal pathogens in fecal samples in Vietnam. J Clin Microbiol 54(4): 1094-1100.
35. Padungtod P, Kadokawa M, Hill G (2007) Food safety concepts and foodborne bacteria in food animals in Thailand, Lao PDR and Vietnam. Chiang Mai Vet J 5: 113-122.
36. Isenbarger DW, Hien BT, Ha HT, Ha TT, Bodhidatta L, et al. (2001) Prospective study of the incidence of diarrhoea and prevalence of bacterial pathogens in a cohort of Vietnamese children along the Red River. Epidemiol Infect 127(2): 229-236.
37. Ngan PK, Khanh NG, Tuong CV, Quy PP, Anh DN, et al. (1992) Persistent diarrhea in Vietnamese children: a preliminary report. Acta Paediatr 81 Suppl 381: 124-126.
38. Bodhidatta L, Lan NT, Hien BT, Lai NV, Srijan A, et al. (2007) Rotavirus disease in young children from Hanoi, Vietnam. Pediatr Infect Dis J 26(4): 325-328.
39. Anders KL, Thompson CN, Thuy NTV, Nguyet NM, Tu LTP, et al. (2015) The epidemiology and aetiology of diarrhoeal disease in infancy in southern Vietnam: a birth cohort study. Int J Infect Dis 35: 3-10.
40. My PVT, Thompson C, Phuc HL, Tuyet PTN, Vinh H, et al. (2013) Endemic norovirus infections in children, Ho Chi Minh City, Vietnam, 2009-2010. Emerg Infect Dis 19(6): 977-978.
41. Forman DW, Tong MJ, Murrell KD, Cross JH (1991) Etiologic study of diarrheal disease in Vietnam. Am J Trop Med Hyg 8: 273-276.
42. Poly F, Serichantalergs O, Kuroiwa J, Pootong P, Mason C, et al. (2015) Updated Campylobacter jejuni capsule PCR multiplex typing system and its application to clinical isolates from South and Southeast Asia. PLoS One 10: e0144349.
43. Huong LQ, Hanh TT, Cam PD, Be NT (2006) Study of Salmonella, Campylobacter, and Escherichia coli contamination in raw food available in factories, schools, and hospital canteens in Hanoi, Vietnam. Ann NY Acad Sci 1081: 262-265.
44. Bao VN, Fries R, Zeesin KH, Kyule MN, Pinthong R, et al. (2006) Salmonella and Campylobacter in broiler carcasses in Vietnam. Proc 11th Int Symp Vet Epidemiol Econom.
45. Garin B, Gouali M, Worafa M, Perchech AM, Thu PM, et al. (2012) Prevalence, quantification and antimicrobial resistance of Campylobacter spp. on chicken neck-skins at points of slaughter in 5 major cities located on 4 continents. Int J Food Microbiol 157(1): 102-107.