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ORIGINAL ARTICLE

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Bacterial food-borne illness outbreaks in northern Taiwan, 1995–2001

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Abstract How to reduce the occurrence of food-borne illness has always been one issue of great importance in Taiwan's disease prevention and control efforts, and it is important to determine, from survey results, whether the pathogens in Taiwan are the same or different from those in other countries. Accordingly, data on 1171 food-borne illness outbreaks were collected from the Center for Disease Control (CDC) of the Department of Health in Taiwan. The patients and the cases were numbered according to the guidelines and definition of food poisoning given by the Department of Health in Taiwan. All rectal swabs for culture were collected from the CDC. During 1995 to 2001, 1171 outbreaks of food-borne illness, including 109884 cases, were reported in northern Taiwan, of which 735 (62.8%) were caused by bacterial infection. Bacterial pathogens, particularly *Vibrio parahaemolyticus* (86.0%), *Staphylococcus aureus* (7.6%), and *Salmonella* spp. (4.9%) were the main etiologic agents. The responsible pathogens in Taiwan appeared to be quite different from those in Europe and the United States. It is important to establish a unique surveillance net of our own to prevent and control our situation of food-borne disease outbreaks effectively.

Key words Food-borne illness outbreak · *Vibrio parahaemolyticus* · *Staphylococcus aureus* · *Salmonella*

Introduction

In the United States, food-borne diseases have been estimated to cause 6 million to 81 million illnesses and up to 9000 deaths each year. Food-related illnesses have been a very important health issue in the United States.[1,2] Therefore, the United States FoodNet began to keep laboratory-diagnosed cases under surveillance, including case of infection caused by *Campylobacter*, shiga toxin-producing *Escherichia coli* (STEC) O157, *Listeria monocytogenes*, *Salmonella*, *Shigella*, *Vibrio*, *Yersinia enterocolitica*, *Cryptosporidium parvum*, *Cyclospora cayetanensis*, and non-O157 STEC.[1,3] OzFoodNet, a network in Australia, concluded a national survey of gastroenteritis, showing that, during 2002, there were 23434 notifications of eight bacterial diseases which may have been food-borne; these were campylobacteriosis (62.8%), salmonellosis (33.8%), shigellosis (2.2%), yersiniosis (0.4%), typhoid (0.3%), listeriosis (0.3%), infection with shiga-toxin producing *E. coli* (0.3%), and hemolytic uremic syndrome (0.1%).[4,5] Adak[6] described indigenous food-borne disease (IFD) in England and Wales between 1992 and 2000, showing that, in terms of disease burden, the most important pathogens were *Campylobacter*, *Salmonella*, *Clostridium perfringens*, vero-cytotoxin producing *E. coli* (VTEC) O157, and *L. monocytogenes*.[6] The most important pathogens in Europe and the United States were *Campylobacter*, *Salmonella*, and *E. coli*. Food-borne bacterial infections have a major and perhaps increasing effect on the public health and economy of industrial countries.[7,8] Taiwan, an industrial country in Asia, is located in a subtropical climate area where the temperature is warm enough for fast bacterial growth year-round. Therefore, how to reduce the occurrence of food-borne illness has always been one issue of great importance in Taiwan's disease prevention and control efforts, and it is important to determine, from survey results, whether the pathogens in Taiwan are the same or different from those in other countries. This article is an analysis focusing on the trend of food poisoning cases due to bacterial infections that took place in northern Taiwan in a 7-year period between 1995 and 2001.

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Subjects, materials, and methods

From 1995 through 2001, data on 1171 food-borne illness outbreaks were collected from the Center for Disease Control (CDC) of the Department of Health in Taiwan. The patients and the cases in this study were numbered according to the guidelines and definition of food poisoning given by the Department of Health in Taiwan.[9] A "food poisoning outbreak" was considered to have occurred if two or more people consumed the same food and suffered the same illness, diagnosed by suspicious food remains, stool, vomit, or blood, or by other relevant environmental factors (such as air, water, soil). At the CDC's request, hospitals taking care of food-poisoning patients have to send their patients' rectal swab samples to the CDC. Therefore, in this study, all of the rectal swabs for culture were collected from the CDC.

All specimens were collected to detect the following six microorganisms and their typing: *Staphylococcus aureus* and typing of its enterotoxin, O-serotype of *Salmonella* spp., K-serotype of *Vibrio parahaemolyticus*, enteropathogenic *E. coli* (EEC), *Shigella* spp., and *Bacillus cereus.* Following the procedures in the *Manual of Clinical Microbiology*,[10] the rectal swabs were cultured in suitable media (Merck, Darmstadt, Germany) at 37°C for 24h; then Gram staining and microscopic inspection were performed. Finally, the cultures were evaluated by using the API (BioMerieux, Marcy l'Etoile, France) system.

S. aureus was grown in a brain heart infusion broth (BHI; Merck) at 37°C for 24h and the supernatant was used for the analysis. After the sample was passed through a 0.2- to 0.4-μm filter, 25μl of sample was used for the detection of enterotoxin, using sensitized latex (anti-A, B, C, and D; MAST, Merseyside, UK).[11]

The detection procedure for O-serotype of *Salmonella* spp. followed the method used by Wang et al.[12]

Serotyping and the KAP-RPLA (Denka Seiken, Tokyo, Japan) tests (MAST) were also done to detect the K antigen of *V. parahaemolyticus*. The first step of detecting serological typing was to test polyantiserum then to test monoantiserum (including Inaba, Ogawa, O139). The detection continued if the result was positive, to detect results on the KAP RPLA test (MAST). Both sera were designed for use in tube procedures, and each antiserum was available in dropper bottles, producing clear, easy-to-read agglutination.

Results

From 1995 to 2001, 109884 people were exposed to poisoned food, but only 10077 of them became ill (the rate of illness occurrence was 9.2%). Table 1 summarizes the statistical data of the 1172 food-borne illness outbreak cases reported by the CDC in Taiwan in the 7-year period of the study. During the 7 years, the average number of ill persons per outbreak case was 8.6 (range, 4.4 to 32.7); 54.2% of the

Table 1. Food-borne illness outbreaks in northern Taiwan, 1995–2001

Year	No. of persons exposed	No. of persons ill (persons ill/ exposed)	No. of illness outbreak cases (persons ill/cases)	No. of bacterial illness outbreak cases (bact. cases/ outbreak cases)	No. of specimens collected (spec. collected/ persons ill)	No. of positive cultures per specimens collected (Pos. culture/ spec. collected)
1995	11463 (10.4%)	2647 (23.1%)	81 (32.7)	33 (40.7%)	752 (28.4%)	341 (45.3%)
1996	10947 (10.0%)	1276 (11.7%)	175 (7.3)	116 (66.3%)	581 (45.5%)	303 (52.2%)
1997	19226 (17.5%)	2036 (10.6%)	178 (11.4)	134 (75.3%)	1060 (52.1%)	619 (58.4%)
1998	13109 (11.9%)	959 (7.3%)	107 (9.0)	77 (72.0%)	577 (60.2%)	354 (61.4%)
1999	10286 (9.4%)	886 (8.6%)	125 (7.1)	88 (70.4%)	459 (51.8%)	270 (58.8%)
2000	33612 (30.6%)	1366 (4.1%)	299 (4.6)	87 (29.1%)	861 (63.0%)	328 (38.1%)
2001	11241 (10.2%)	907 (8.1%)	207 (4.4)	100 (48.3%)	695 (76.6%)	178 (25.6%)
Total	109884 (100%)	10077 (9.2%)	1172 (8.6)	635 (54.2%)	4985 (49.5%)	2393 (48.0%)

Table 2. No. of food-borne pathogen-positive culture specimens

Year	Bacteria				Total
	Vibrio parahaemolyticus	Staphylococcus aureus	Salmonella spp.	Others[a]	
1995	303 (88.9%)	29 (8.5%)	7 (2.1%)	2 (0.6%)	341
1996	257 (84.8%)	4 (1.3%)	28 (9.2%)	14 (4.6%)	303
1997	536 (86.6%)	50 (8.1%)	25 (4.0%)	8 (1.3%)	619
1998	324 (91.5%)	18 (5.1%)	11 (3.1%)	1 (0.3%)	354
1999	234 (86.7%)	24 (8.9%)	10 (3.7%)	2 (0.7%)	270
2000	264 (80.5%)	35 (10.7%)	27 (8.2%)	2 (0.6%)	328
2001	139 (78.1%)	23 (12.9%)	10 (5.6%)	6 (3.4%)	178
Total	2057 (86.0%)	183 (7.6%)	118 (4.9%)	35 (1.5%)	2393

[a] Others were: *Aeromonas* ($n = 13$), *Plesiomonas* ($n = 9$), *Bocillus. cereus* ($n = 6$), *Escherichia coli* ($n = 5$), and *Shigella* ($n = 2$)

cases were due to bacterial infection and the specimen collection rate for bacterial culture was 49.5%. The positive-culture rate was 48.0%.

Table 2 lists the causative agents of the food-borne outbreaks in northern Taiwan. Significant organisms isolated from food-borne outbreak specimens included *V. parahaemolyticus* (86.0%), *S. aureus* (7.6%), *Salmonella* spp. (4.9%), and others (1.5%).

Table 3 shows the K serotype of *V. parahaemolyticus* strains isolated from the food-borne illness outbreak specimens in northern Taiwan between 1995 and 2001. About 99.4% of the *V. parahaemolyticus* strains could be identified with K serotyping, while the other 11 strains (0.6%) could not. The most common K serotypes involved were K6 (55.2%), K12 (12.1%), K8 (7.9%), K10 (4.8%), K68 (3.9%), K63 (3.1%) and K15 (2.9%).

Table 3. Serotypes of *Vibrio parahaemolyticus* strains ($n = 2075$) isolated from food-borne illness outbreak specimens in northern Taiwan, 1995–2001

Year	1995	1996	1997	1998	1999	2000	2001	Total
K3			4		1			5
K4		17	6	3	1		1	28
K5	2		1					3
K6		103	451	220	119	178	65	1136 (55.2%)
K7		10		1	1	1		13
K8	42	35	31	4	33	8	10	163 (7.9%)
K9		5		6	4	7	3	25
K10		5	4	36	53			98 (4.8%)
K11	2				1	2		5
K12	233	6	1	5		3		248 (12.1%)
K13	1							1
K14		2						2
K15	7	7	2	29	2	12	1	60 (2.9%)
K19		1						1
K22						2		2
K25					4	14	3	21
K26						1		1
K28					1			1
K29		4				3		7
K32		3						3
K38	2	4	1			2		9
K39						1		1
K41		1	3	9		1	3	17
K45				1				1
K46							12	12
K48				4				4
K51							1	1
K53			1	1	1		1	4
K54		2						2
K55	1	1						2
K56		11				7	4	22
K57			2					2
K60			1					1
K63	13	40	8	1	2			64 (3.1%)
K66			1					1
K68			11	4	8	22	35	80 (3.9%)
Non-typeable			8		3			11 (0.6%)

Table 4. Enterotoxin production by *Staphylococcus aureus* isolated from food-borne illness outbreak specimens in northern Taiwan, 1995–2001

Enterotoxin	Year							Total
	1995	1996	1997	1998	1999	2000	2001	
A	11	4	45	10	8	11	11	100 (54.7%)
B	8	0	3	3	8	15	8	45 (24.6%)
C	5	0	2	5	8	6	3	29 (15.8%)
D	2	0	0	0	0	3	1	6 (3.3%)
Non-typeable	3	0	0	0	0	0	0	3 (1.6%)
Total	29	4	50	18	24	35	23	183 (100%)

Table 5. The O serotypes of *Salmonella* spp. isolated from food-borne illness outbreak specimens in northern Taiwan, 1995–2001

Serotype	Year							Total
	1995	1996	1997	1998	1999	2000	2001	
O3	0	2	0	0	0	0	0	2 (1.7%)
O4	0	4	1	7	4	6	1	23 (19.5%)
O7	0	0	1	4	0	10	1	16 (13.6%)
O8	0	0	0	0	0	0	3	3 (2.5%)
O9	7	20	23	0	6	11	5	72 (61.0%)
O10	0	2	0	0	0	0	0	2 (1.7%)
Total	7	28	25	11	10	27	10	118 (100%)

Table 6. Locations of food mishandling in food-borne illness outbreaks in northern Taiwan, 1995–2001

Year	Location					Total
	Restaurant	Food service	School (lunch box)	Homemade	Others	
1995	15	0	5	5	6	31
1996	32	9	10	10	11	72
1997	48	14	19	5	5	91
1998	24	14	8	4	3	53
1999	8	12	4	9	5	38
2000	44	17	10	14	28	113
2001	38	13	6	11	16	84
Total	209 (43.4%)	79 (16.4%)	62 (12.9%)	58 (12.0%)	74 (15.3%)	482 (100%)

Table 7. Clinical symptoms of infections with three pathogens from the food-borne illness outbreaks in northern Taiwan

Pathogen	Clinical symptom						
	Nausea (%)	Vomiting (%)	Epigastric pain (%)	Stomach ache (%)	Diarrhae (%)	Fever (%)	Incubation period (h)
V. parahaemolyticus	48.5	82.6	25.4	52.2	85.3	36.9	11.5
S. aureus	54.9	82.4	23.5	37.3	82.4	31.3	6.8
Salmonella spp.	38.9	72.2	22.2	61.1	100.0	77.8	12.8

Because *S. aureus* can produce one or more types of enterotoxin, enterotoxins were classified based on the serotype as type A, type B, type C, and type D (Table 4). The results indicated that 100 (54.7%) strains of *S. aureus* were able to produce type A enterotoxin, while only 24.6% of the *S. aureus* strains produced type B enterotoxin, 15.8% of them produced type C enterotoxin, and 3.3% of them produced type D enterotoxin. However, the result also showed that 3 strains were non-typeable. As shown in Table 5, the most common O serotypes of *Salmonella* spp. were O9 (61%), O4 (19.5%), and O7 (13.6%).

To show that the food-borne illness outbreaks were due to food mishandling, we collected 482 cases for analysis, and found that the outbreaks occurred when people ate at restaurants (43.4%), had food service in the office (16.4%), had school lunch boxes (12.9%), and had homemade meals (12.0%) (Table 6). Table 7 lists the clinical symptoms associated with three pathogens causing the food-borne illness outbreaks (*V. parahaemolyticus*, *S. aureus*, and *Salmonella* spp.). The most common clinical symptoms of infection with *V. parahaemolyticus* were diarrhea (85.3%), vomiting (82.6%), and stomach ache (52.2%). As for the major clinical signs of *S. aureus* infection, they were diarrhea (82.4%), vomiting (82.4%), and nausea (54.9%). Moreover, patients with food-borne illness caused by *Salmonella* spp. always had diarrhea (100%). The incubation period of *V. parahaemolyticus* infection was 9.9 to 12.8 h, and the average was 11.5 h. As for *S. aureus* infection, the incubation period was 3.1 to 14 h (6.8 h on average), while that of *Salmonella* spp. was 9.5 to 20 h (12.8 h on average).

Discussion

In Taiwan the average prevalence of reported food-borne illness from 1995 to 2001 was 6.86 per 100 000 population.[9] In Asia, the average prevalence of reported food-borne illness from 1981 to 1995 was 2.44 per 100 000 population in Korea, and 28.01 in Japan.[13] OzFoodNet reported that, in 2002, 5.7% (103/1819) of patients were hospitalized.[14] In the present study, 9.2% of the patients were hospitalized; moreover, the average positive rate of bacterial detection was 54.2%, which was similar to previous findings[15–17]. These above-mentioned data are similar to the results of some studies in other Asian countries. In Korea in 2001, 59.3% of food-borne illness cases were of bacterial origin, and, in Japan, the proportion was 72.8%.[13] From 1973 to 1987, as reported by the Centers for Disease Control and Prevention of the United States, bacterial pathogens accounted for 66% of outbreaks in that country.[13] Between 1992 and 2000 in England and Wales, Adak[6] pointed out that 66.3% of outbreaks were caused by a combination of microorganisms.

From Table 2, it can be seen that the most significant microorganisms isolated from the outbreak specimens in our study were *V. parahaemolyticus*, *S. aureus*, and *Salmonella* spp. However, the results of the present study were different from those of other studies. For example, Chang and Chen[15] reported that, in central Taiwan from 1991 to 2000, the causative agents were *B. cereus* (41.2%), *S. aureus* (17.9%), *V. parahaemolyticus* (15.7%), enteropathogenic *E. coli* (9.1%), *Salmonella* spp. (1.1%), and *S. aureus* enterotoxin (1.5%). But the results of the present study partially matched those of the study of Chiou et al.[16] and that of Pan et al.[17] Chiou et al.[16] reported that, from 1981 to 1989, the main causative agents were *V. parahaemolyticus*, *S. aureus*, and enteropathogenic *E. coli*. In the study by Pan et al.,[17] from 1986 to 1995, *V. parahaemolyticus* played a leading role (35%), followed by *S. aureus* (30%) and *B. cereus* (18%). In Korea, food-borne illness cases of bacterial origin included *Salmonella* spp. (20.7%), *Vibrio* (17.4%), *Staphylococcus* (9.7%), pathogenic *E. coli* (2.4%), and other species (9.1%). In Japan, the majority of the bacterial food-borne illnesses were caused by *Vibrio* (32.3%), *Staphylococcus* (15.9%), *Salmonella* (14.2%), pathogenic *E. coli* (3.0%), and other species (7.2%). Therefore, the trends of indigenous food-borne disease (IFD) in the Asian area are similar, and, in terms of disease burden, the most important pathogens are *Vibrio*, *Staphylococcus*, and *Salmonella*.

The data in Table 2 indicate that the *V. parahaemolyticus* detection rate is decreasing, but that *S. aureus* is increasing; therefore, it is quite clear which one should be given more concern. Shih et al.[18] stated that Taiwan and Japan are two countries with a high consumption of seafood products, which may explain why *V. parahaemolyticus* has been identified as a leading cause of food-borne illness outbreaks in northern Taiwan. Nicholas et al.[19] reported that *V. parahaemolyticus* infections were associated with the consumption of raw or undercooked shellfish, contaminated food, and exposure to warm seawater. However, the decreasing trend of *V. parahaemolyticus* infections in Taiwan may imply that uncooked seafood is not popular among our younger generation.

Tables 3 and 5 show the serotypes of *V. parahaemolyticus* and *Salmonella* spp., and Table 4 shows enterotoxin details for *S. aureus* isolated in northern Taiwan. For *V. parahaemolyticus*, Chiou et al.[20] and Chang and Chen[15] had similar results. DePaola et al.,[21] too, reported that *V. parahaemolyticus* isolated from outbreaks in Texas, New York, and Asia were predominantly serotype O3:K6. However, according to the study of Wong et al.,[22] the most frequently isolated serovars of *V. parahaemolyticus* from food-borne illness outbreaks during 1992 through 1995 in Taiwan were O5:K15 (18.5%), O4:K8 (16.2%), O3:K29 (12.5%), O1:K56 (8.3%), O2:K3 (6.5%) and O4:K12 (6.0%). Because *V. parahaemolyticus* is an important food-borne pathogen in Taiwan, we need to further explore its serotypes as well as the areas in which each serotype occurs.

In the present study, only four types of *S. aureus* toxins were detected: types A, B, C, and D. This result matched the result of the study of Ko and Chang[23] in 1995; they reported that 78% of *S. aureus* strains were able to produce enterotoxin, and type A was the one most commonly found (81%). Chang and Chen[15] also had similar findings; they classified seven types of enterotoxins: A, B, C, D, A&B, A&D, and A&B&C. However, in the present study, only four types – A, B, C and D – were found, without any mixtures of enterotoxin types. Table 5 shows that the most frequently isolated serotype of *Salmonella* spp. was O9 (61%).

The locations of food mishandling are listed in Table 6. Chang and Chen[1] pointed out that most food-borne illness outbreaks occurred at home (41.2%) and in school (34.3%). In Canada, most occurred when people ate at restaurants (52%), fast-food stands (25%), and private residences (19%).[5] A comparison study of food-borne illness outbreaks in Asia indicated that the outbreaks in Korea were most frequently associated with homemade foods (47%); in Japan, restaurants accounted for 31.3%.[13] Todd[24] reported that, in Canada, most incidents occurred when people ate at homes or restaurants. These results showed that Taiwan, Japan, and Canada shared a similar style of food preparation, because the clinical symptoms of food-borne illness outbreaks were similar, and the main signs were both diarrhea and vomiting. Obana et al.[25] studied infectious enteric diseases in Japan, and discovered that the clinical symptoms of abdominal pain, nausea, and vomiting were frequently observed in the cases caused by *V. parahaemolyticus*, while the highest body temperature and the highest frequency of bowel movements were revealed in the cases caused by *Salmonella* spp. Bloody stool was observed in 55.3% of the cases due to *E. coli*.[25] In the study of Hall et al.,[26] five syndromes were developed from pathogen-specific profiles: a vomiting-toxin syndrome characteristic of *B. cereus* and *S. aureus*, a diarrhea-toxin syndrome characteristic of *Cl. perfringens*, a diarrheaogenic *E. coli* syndrome, a *Norwalk*-like virus syndrome, and a *Salmonella*-like syndrome.

Todd's study[24] recommended how to prevent food-borne events; however, the responsible pathogens in Taiwan appeared to be quite different from those in Japan and the United States, which means the nature of food-poisoning cases is likely locality-dependent. Thus, we should establish a unique surveillance net of our own to prevent and control our situation most effectively.

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