

## Vibrio illness in Florida, 1998–2007

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### SUMMARY

This study characterized the current epidemiology of vibrio infections in Florida and examined cases reported from 1998 to 2007. Logistic regression was used to determine risk of death. There were 834 vibrio infections in 825 individuals (average annual incidence rate 4·8/1 000 000). Common *Vibrio* species reported were *Vibrio vulnificus* (33%), *V. parahaemolyticus* (29%), and *V. alginolyticus* (16%). Most exposures were attributed to wounds (42%), and the most common clinical syndromes were wound infections (45%) and gastroenteritis (42%). Almost half of individuals reported an underlying health condition. Risk of death was associated with any underlying condition and increased with the number of conditions ( $P < 0\cdot0001$ ). In Florida, incidence of vibriosis associated with raw oyster consumption has decreased while incidence associated with wound infections has increased. Most prevention efforts to date have focused on oyster consumption. New educational messages focusing on the risk of vibriosis from wound infections should target high-risk populations.

**Key words:** Epidemiology, infectious disease, *Vibrio vulnificus*.

### INTRODUCTION

*Vibrio* are Gram-negative, rod-shaped bacteria commonly found in warm coastal waters worldwide [1, 2]. The Centers for Disease Control and Prevention (CDC) estimates that *Vibrio* spp. cause over 8000 infections annually [3], and the incidence of vibriosis has increased for all species since 1996 [4, 5], due in part to better surveillance and reporting. In the USA, most cases of vibriosis are reported from Gulf Coast states, where vibrios are commonly found in their

natural habitat [6–8]. Infections are acquired by consuming contaminated food or water or exposing wounds and abrasions to marine environments [1, 2]. Cases typically occur in the warm summer months.

The more common species in the USA include *Vibrio vulnificus* and *V. parahaemolyticus*. *V. vulnificus* is often associated with raw oyster consumption, wound infections, and primary septicaemia [2]. *V. parahaemolyticus* is typically associated with gastroenteritis. Other common species include *V. cholerae* non-O1 (gastroenteritis) and *V. alginolyticus* (wound infections) [1].

Vibriosis has the highest case-fatality rate (CFR) of any enteric disease, mainly attributable to *V. vulnificus*, making this a very important public health

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concern despite the low incidence reported annually. Based on FoodNet data from 2007, the incidence of vibriosis was 0.2 cases/100 000 individuals, and the CFR was 3.6% [9]. Incidence rates for other common foodborne bacterial enteric diseases in the USA are higher, although CFRs are much lower. Based on these same data, rates for the most common foodborne diseases are (incidence per 100 000, case fatality): *Salmonella* (14.9, 0.4%), *Campylobacter* (12.8, 0.1%), *Shigella* (6.2, 0.1%), and *Escherichia coli* O157:H7 (1.2, 0.2%) [9]. The highest overall CFR for common foodborne enteric diseases (*Salmonella*, 0.4%) is almost 90% less than the overall CFR for vibriosis (3.6%). Historically, Florida's incidence rate for vibriosis (0.4/100 000) is double and the CFR (10.0%) is almost triple the national rate [10].

Because of the high CFRs associated with *V. vulnificus* from consumption of raw oysters, there has been a focus in the Gulf Coast states to increase awareness in high-risk individuals, i.e. those with underlying health conditions. As required by Florida law since 1993, all food establishments selling raw oysters must have a visible warning posted to make the consumer aware of health risks associated with their consumption. The Florida Department of Health (FDOH) also regularly distributes educational materials and presents data and risk reduction messages at venues statewide to a variety of audiences, from health professionals to consumers. The goal of these efforts is to increase awareness in high-risk population groups and healthcare providers in order to reduce incidence and case fatality. The vast majority of the current messaging is related to the risk of infection with *V. vulnificus* associated with raw oyster consumption.

Vibriosis has been a notifiable disease in Florida since 1981, in the Gulf Coast states since 1988, and nationally since 2007. However, most states have been voluntarily reporting since 1997. The epidemiology of vibrio infections in Florida has been described previously [10, 11]. From 1981 to 1993, the annual incidence of vibriosis was 4.3/1 000 000 individuals. The most common species reported during this period were *V. parahaemolyticus*, *V. vulnificus*, and *V. cholerae* non-O1, respectively, with gastroenteritis being the most commonly reported clinical syndrome, with raw oyster consumption in the week prior to illness reported in 45% of cases [10]. To determine whether trends in vibriosis have changed with time, we sought to describe the current epidemiology of vibrio

infections in Florida using data collected from 1998 to 2007.

## METHODS

We examined cases of vibriosis reported to FDOH with onset dates from 1998 to 2007. Data were collected using the 'Cholera and Other Vibrio Illness Surveillance Report' (CDC Form 52.79). The average annual incidence rate for cases of vibriosis was calculated using yearly population data from Florida Charts [12] based on data from the Florida Legislature, Office of Economic and Demographic Research.

Descriptive analyses were performed for all reported cases and examined by species. Medians (ranges) were reported for non-normally distributed continuous variables and frequencies (percentages) for categorical variables. Kruskal–Wallis tests were used to compare median values. Crude odds ratios (ORs) and 95% confidence intervals (CIs) were reported for bivariate analyses.

Logistic regression was used to assess the association between various demographic and disease characteristics and death from vibriosis. Predictor variables that were considered in our analyses included age, race/ethnicity, gender, clinical syndrome, exposure, and presence and numbers of underlying health conditions. The clinical syndrome field included the following categories: septicæmia, the presence of bacteria in the blood which can be characterized by fever and chills to hypotension and shock; wound infection, either from injuries sustained in aquatic environments or from pre-existing wounds and characterized by fever, cellulitis, and pain around the site of infection; and gastroenteritis, an inflammation of the stomach and intestines characterized by diarrhoea and vomiting. Adjusted ORs and 95% CIs were reported. Data were analysed using SAS version 9.1 (SAS Institute, USA).

## RESULTS

### All species

There were 834 cases of vibriosis in 825 individuals reported to FDOH from 1998 to 2007 (median 82.5/year). The average annual incidence rate was 4.8 cases/1 000 000 individuals. Infections were most common in males (71.8%), whites (84.5%), and non-Hispanics (84.9%). The median age of reported cases

Table 1. Number of reported cases of vibriosis by species, Florida, 1998–2007

<i>Vibrio</i> species	No.*	%
<i>V. vulnificus</i>	276	33.1
<i>V. parahaemolyticus</i>	245	29.4
<i>V. alginolyticus</i>	131	15.7
<i>V. cholerae</i> non-O1	55	6.6
<i>V. fluvialis</i>	46	5.5
<i>V. hollisae</i>	30	3.6
<i>V. damsela</i>	14	1.7
<i>V. mimicus</i>	13	1.6
Other vibrios	5	0.6
Species not identified	19	2.3
Total	834	100

\* Seven individuals were infected with multiple *Vibrio* species.

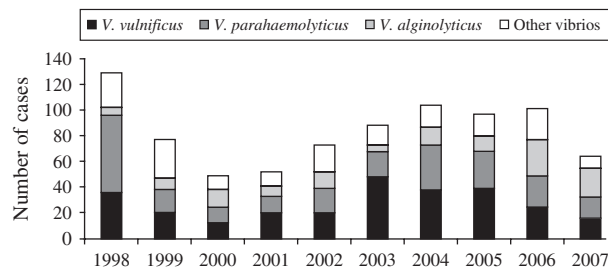


Fig. 1. Cases of vibriosis by species and year of diagnosis, Florida, 1998–2007.

was 50.0 years (range 0–96 years), with the majority (74.9%) between the ages of 30 and 79 years. Seven individuals were simultaneously infected with multiple species.

The most common species were *V. vulnificus*, *V. parahaemolyticus*, and *V. alginolyticus* (Table 1). The frequency of isolated species varied by year of diagnosis (Fig. 1), with most cases occurring during months when the water temperature and weather are warmer (Fig. 2). Seasonality did not vary by species; however, age at diagnosis was different ( $P < 0.0001$ ). The median age at diagnosis for cases of *V. vulnificus* was 58 years, compared to 36 years in cases of *V. alginolyticus* and 42 years for *V. parahaemolyticus*.

Wound-related symptoms were reported for 373 (44.7%) cases, followed by 350 (42.0%) with gastroenteritis, 45 (5.4%) with septicaemia, and 66 (7.9%) with other reported symptoms (Fig. 3). There were 220 (26.4%) cases attributed to raw oyster consumption, 313 (37.5%) to wound infections, 96 (11.5%) to other seafood exposures, and 205 (24.6%) had no reported exposure (Fig. 4).

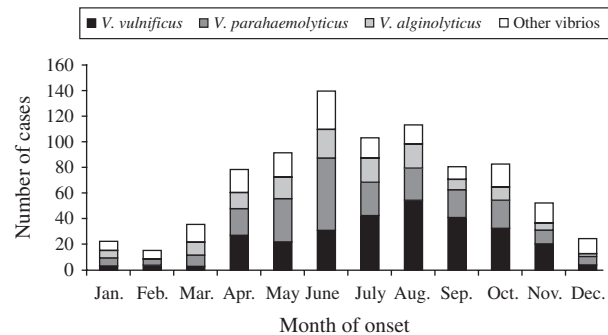


Fig. 2. Seasonality of vibriosis by species, Florida, 1998–2007.

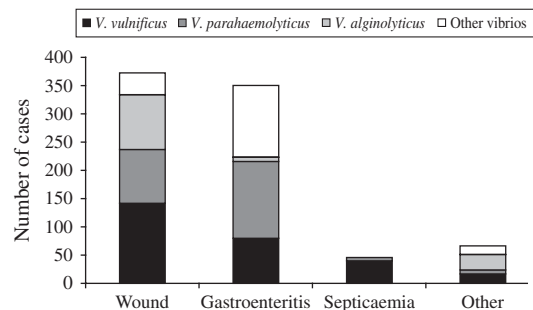


Fig. 3. Clinical syndromes of vibriosis by species, Florida, 1998–2007.

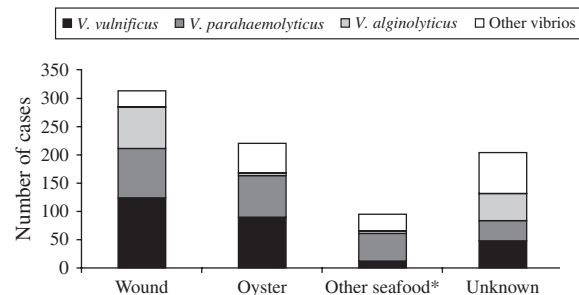


Fig. 4. Exposures associated with cases of vibriosis by species, Florida, 1998–2007. \* Other seafood includes clams, mussels, shrimp, crab, fish, etc.

Presence of any underlying health condition was reported for 400 (48.5%) cases. Of these, 228 (57.0%) had multiple conditions reported. Heart disease, alcoholism, and liver disease were the most common (Table 2).

There were 82 deaths reported, yielding a CFR of 9.9%. Age at onset, gender, presence of any underlying health condition and total number of conditions, mode of exposure, and clinical syndrome were significantly associated with death. The odds of death from vibriosis increased by 2.3% for every 1 year increase in age ( $P = 0.0001$ ). Median age at diagnosis was higher ( $P = 0.0001$ ) for cases resulting in death

Table 2. Underlying conditions in cases of vibriosis, Florida, 1998–2007

Characteristics of underlying conditions	No.	%
Total cases	825	100.0
Number of underlying conditions per case		
0	425	51.5
1	172	20.9
2	122	14.8
3	75	9.1
≥4	31	3.8
Type of underlying condition		
Heart disease	141	17.1
Alcoholism	132	16.0
Liver disease	131	15.9
Diabetes	105	12.7
Malignancy	62	7.5
Renal disease	49	5.9
Immunodeficiency	45	5.5
Haematological disease	42	5.1
Gastric surgery	35	4.2
Peptic ulcer	34	4.1

than those that did not. Being male was associated with death (crude OR 2.92, 95% CI 1.48–5.78). Most deaths (95.1%) had one or more underlying health conditions reported. The odds of death in cases with one or more underlying health conditions were 25.5 (95% CI 9.2–70.4) times that of cases with no underlying condition. The odds increased with the total number of underlying health conditions ( $P < 0.0001$ ). Odds of death also differed by exposure and clinical symptoms, with oyster consumption, gastroenteritis, and septicaemia being significantly associated with death (Table 3).

In multivariable analyses, the best predictive model for death from vibriosis included total number of underlying health conditions and exposure, based on model fit statistics. The odds of death increased with increasing number of underlying conditions: one (OR 9.8, 95% CI 2.7–35.6), two (OR 18.7, 95% CI 5.3–66.3), and three or more conditions (OR 50.7, 95% CI 14.5–177.1). The odds of death were greater for exposure through oyster consumption (OR 6.7, 95% CI 3.2–14.0) compared to wound infection.

### *V. vulnificus*

From 1998 to 2007, there were 276 cases of *V. vulnificus* reported (average annual incidence 1.6/1 000 000). There were 141 (50.7%) cases presenting

with wound-related symptoms, 79 (28.6%) cases presenting with gastroenteritis, 40 (14.5%) with septicaemia, and 16 (5.8%) with unknown syndrome reported (Fig. 3). The most common cause was wound infection (125 cases, 45.3%). Ninety-one (33.0%) cases were associated with oyster consumption, 12 (4.3%) with other seafood consumption, and 48 (17.4%) had unknown cause (Fig. 4). At least one underlying health condition was reported for 75.0% of cases, with most (70.0%) reporting multiple conditions.

There were 76 deaths among *V. vulnificus* infections (CFR 27.5%), with 33 deaths in those presenting with septicaemia (CFR 82.5%), and 73 in those with underlying health conditions (CFR 96.1%). Most (56%) deaths were associated with raw oyster consumption, and 14% were associated with wound infections. The odds of death in cases of *V. vulnificus* with one or more underlying conditions were 11.8 (95% CI 3.6–38.8) times the odds of death in those with none.

### *V. parahaemolyticus*

There were 245 cases of *V. parahaemolyticus* reported (average annual incidence 1.4/1 000 000). The most common presenting clinical syndromes were gastroenteritis (137 cases, 55.9%) and wound infection (96 cases, 39.2%) (Fig. 3). Most (50.2%) cases were associated with consumption of seafood: 73 (29.8%) with oysters and 50 (20.4%) with other seafood (e.g. crabs, shrimp). There were 86 (35.1%) cases associated with wound infections (Fig. 4). Eighty-four (32.6%) cases had an underlying health condition reported. There was one death in cases of *V. parahaemolyticus* infection.

From 1998 to 2007, there were 28 documented outbreaks of *V. parahaemolyticus* that included 301 individuals [average 11 cases (range 2–115)]. Of the outbreaks, 35.7% were laboratory confirmed. Most (82.1%) were associated with seafood consumption at a restaurant. Crustacean shellfish were the most commonly implicated source (50.0%), followed by molluscan shellfish (28.6%), with specific vehicles including shrimp (28.6%), crabs (25.0%), and oysters (21.4%). The most frequent contamination factors were cross-contamination from raw ingredients of animal origin, bare-handed contact, and inadequate cleaning. Almost all of the reported proliferation factors were related to time-temperature abuse, including inadequate cold-holding and slow cooling.

Table 3. Predictors of death in cases of vibriosis, Florida, 1998–2007

	Non-fatal		Fatal		Crude associations	
	No.	%	No.	%	OR	95% CI
Presence of any underlying condition*	322	43.3	78	95.1	25.5	(9.2–70.4)
Number of underlying conditions						
0	421	56.7	4	4.9	1.0	(reference)
1	155	20.9	17	20.7	11.5	(3.8–34.8)
2	101	13.6	21	25.6	21.9	(7.3–65.2)
≥3	66	8.9	40	48.8	63.8	(22.1–184.1)
Exposure†						
Wound infection	300	53.4	11	14.1	1.0	(reference)
Oyster consumption	174	31.0	44	56.4	6.9	(3.5–13.7)
Other seafood consumption	88	15.7	5	6.1	1.6	(0.5–4.6)
Clinical syndromes						
Wound infection	355	47.8	14	17.1	1.0	(reference)
Gastroenteritis	316	42.5	30	36.6	2.4	(1.3–4.6)
Septicaemia	11	1.5	34	41.5	78.4	(33.0–186.1)
Other	61	8.2	4	4.9	1.7	(0.5–5.2)
Gender						
Female	218	29.3	10	12.2	1.0	(reference)
Male	522	70.3	70	85.4	2.9	(1.5–5.8)

OR, Odds ratio; CI, confidence interval.

\* Compared to no underlying condition.

† Excludes cases with unknown exposure ( $n = 203$ ).

### *V. alginolyticus*

There were 131 cases of *V. alginolyticus* reported (average annual incidence 0.7/1 000 000). Most cases presented with wound infections (97 cases, 74.1%) or other symptoms (27 cases, 20.6%) (Fig. 3), and most were associated with exposure from wounds (74 cases, 56.5%) (Fig. 4). All cases in individuals aged 0–19 years presented with wound or other symptoms. Forty-one (31.3%) cases had at least one underlying health condition. There were no outbreaks and no deaths associated with *V. alginolyticus* during this 10-year period.

## DISCUSSION

This analysis updates a previous summary of reported vibrio infections in Florida [10]. The clinical and epidemiological features of vibriosis have changed since the 1996 report. Most notably, we have seen a change in common species and risk factors and an increase in incidence and CFRs. The most commonly reported species changed from *V. parahaemolyticus* (1981–1993) to *V. vulnificus* (1998–2007). Cases of vibriosis attributed to raw oyster consumption have decreased from 45% to 26% over the same time-frame. Wound

infections were the most common clinical syndrome in the current analysis compared to gastroenteritis as reported by Hlady *et al.* [10]. Incidence of vibriosis has increased in Florida from 4.3/1 000 000 individuals (1981–1993) to 4.8/1 000 000 (1998–2007). CFRs also increased for vibriosis presenting with gastroenteritis (2–9%) and septicaemia (47–76%). Due to changes in the way risk factor and background population data were recorded over the years, we were unable to assess the relative risks in certain high-risk groups, such as people with AIDS and raw oyster-consuming adults, as done previously [10].

*V. vulnificus* was the most common species in Florida, unlike other areas of the country where *V. parahaemolyticus* was the most common [13]. *V. vulnificus* is associated with more serious illness [1, 4, 7], and is the leading cause of death related to seafood consumption [6, 7]. *V. parahaemolyticus* is recognized as the leading cause of gastroenteritis associated with seafood consumption in the USA [14–16], and is often associated with foodborne outbreaks [1, 14, 17]. The median number of cases reported annually in Florida has increased from 16 (1981–1993) [10] to 20 cases (1998–2007). An increase in incidence of *V. parahaemolyticus* has also been noted throughout the USA and in other countries [1, 14]. Rising



water temperatures [1, 17] and the emergence of new strains of *V. parahaemolyticus* throughout the world, specifically the O3:K6 strain and its serovariants [18] have been suggested as possible causes. Finally, *V. alginolyticus* is commonly associated with ear infections and illness in younger individuals [8], with similar associations found in Florida.

Wound infections and seafood consumption were an equal source of exposure to *Vibrio* spp. in Florida, whereas seafood consumption is most often associated with vibriosis throughout the USA [13]. A possible cause for increased wound-related exposures is that Florida has over 2000 miles of shoreline [19]. This access may lead to increased participation in water activities, possibly yielding a higher number of wound exposures. Further, Florida has higher average ambient air and water temperatures year-round than many parts of the country, which may increase the likelihood of such exposures because of the longer season for water activities and higher vibrio bacterial counts.

In accord with other studies, incidence and mortality rates associated with vibriosis in Florida were higher in summer months [4, 17] and in males [1, 8], consistent with historical Florida trends [10]. Male gender was significantly associated with death in crude analysis; however, gender was not a significant predictor or confounder in adjusted analyses. Another important feature of vibriosis is that the greatest risk of illness and death is in those with underlying health conditions. We also found a strong association between underlying health conditions and death from *V. vulnificus*. Individuals with alcoholism and liver or heart disease have increased risk of infection, as well as increased risk of death.

Increases in incidence and CFRs seen in Florida may be partially attributable to increased awareness of vibriosis in healthcare providers and increased surveillance. In addition, we have experienced several large outbreaks of *V. parahaemolyticus* in Florida during this period. However, increases in incidence have also been found in FoodNet states [4]. Even after excluding cases of *V. parahaemolyticus* that occurred during known outbreaks, incidence in this species in the FoodNet states has also increased [4].

It is alarming that there are higher incidence and fatality rates in Florida despite increased educational campaigns aimed at high-risk groups. Other Gulf Coast states have seen similar increases in incidence over time, as well. Louisiana had an average annual incidence rate in 2000–2001 of 5.9 cases/1 000 000 compared to 6.7 in 2006–2007, while Mississippi

increased from 2.3 to 2.9/1 000 000 and Texas increased from 1.4 to 2.3/1 000 000 during those same years [20].

Florida law requires a warning notice in all food service establishments and retail markets serving or selling raw oysters. The FDOH interacts with state-wide medical organizations and health support groups to present prevention messages to the health-care community, and distributes educational pamphlets and materials at health fairs. Further, there are several ongoing national educational campaigns sponsored by the Interstate Shellfish Sanitation Conference (ISSC) [21] and the Gulf & South Atlantic Fisheries Foundation [22] that aim to raise awareness in people with underlying health conditions regarding their risk of *V. vulnificus* infection associated with raw oyster consumption [23]. Given the increasing incidence seen nationwide, the ISSC is currently also working on regulatory policies related to molluscan shellfish in order to prevent vibriosis.

Florida education efforts seem to have been successful, with an almost 50% reduction in total number of cases associated with raw oyster consumption compared to that reported previously [10]. Despite this success, these campaigns are mainly funded to focus on one high-risk group, raw oyster consumers, and exclude those with wound infections. Florida has seen an increase in the number of cases associated with wound infections. While there is a continued need to warn consumers about the risk from consuming raw oysters, future prevention efforts should focus on those at highest risk for wound infections such as those with diabetes. Outreach efforts should target specialist groups for wounds such as wound care treatment centres, endocrinologists, and other providers that treat diabetic patients, as well as local diabetes support groups. These new educational campaigns should include risk messaging related to wounds sustained during water-related recreational activities or exposure to aquatic environments. Outreach programmes should focus on *V. vulnificus*-related wound infections. Although it is possible to get wound infections from other vibrios, *V. vulnificus* is particularly virulent, and messaging should focus on the recognition, treatment, and prevention of these infections.

Little research has focused specifically on wound-related cases of vibriosis which are more numerous than oyster-related *V. vulnificus* infections; therefore, another direction would be to examine the extent of wound infections and treatment of these cases, including wound debridement and amputation.

Research is also needed to address the potential impact that the environment has on increasing incidence of vibriosis, particularly the role that environmental conditions in oyster harvesting areas have on the bacterial count of harvested oysters.

There are a few limitations that should be noted. We chose to examine the 10 most recent years with complete vibrio data available. The previous study included data up to 1993 [10]. However, we did not include the years 1994–1997 in our analysis due to concerns regarding data quality for those years. As with all foodborne illnesses, cases of vibriosis are underreported, and reporting is probably biased towards more severe cases. Cases of non-cholera vibriosis were not nationally notifiable until 2007 but have been reported in Florida since 1981. This may account for some of the differences between the epidemiology of vibriosis in Florida and elsewhere in the USA. Data were also not always complete on each individual. In Florida, case investigation and reporting is typically performed at the county-level, and there may be inconsistencies in the way data were collected. Moreover, patients or their families were not always able to recall details of food histories or other exposures. Almost 25% of reported cases had no known exposure, a huge gap in epidemiological data. Finally, we were unable to assess some factors related to vibriosis (e.g. hospitalization, treatment) since these variables were not included in our database.

The changing patterns of vibriosis noted in this and other studies may be related to increased awareness and surveillance, as well as higher water temperatures and other environmental factors. However, the increased incidence in vibrio infections highlights the need for continued and improved education and risk reduction for at-risk populations, with a new focus on wound-related infections. Because certain *Vibrio* spp. are associated with significant morbidity and mortality, especially in those with underlying health conditions, a continuing focus on increasing awareness and understanding of vibriosis in healthcare providers, high-risk populations with specific underlying health conditions, seafood consumers, and those with occupational or recreational exposures to seawater is needed.

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#### DECLARATION OF INTEREST

None.

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