

A Review of Pathogenic *Vibrio* Infections for Clinicians

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Abstract

Vibrio infections are becoming increasingly common in the United States. Pathogenic vibrios cause 3 major syndromes of clinical illness: gastroenteritis, wound infections, and septicemia. Many cases of *Vibrio*-associated gastroenteritis are substantially underrecognized because vibrios are not readily identified in routine stool cultures. Epidemiologic data suggest that the majority of these infections are foodborne and associated with consumption of raw or undercooked shellfish. In persons who develop acute gastroenteritis after eating raw or undercooked shellfish, clinicians should order testing of a stool specimen using a selective medium for vibrios. Clinicians should obtain a travel history when evaluating a patient with acute watery diarrhea, and should consider cholera in the differential diagnosis when a patient has returned from a trip to a country where cholera is known or suspected to be present.

Introduction

Vibrios are gram-negative, curved, rod-shaped bacteria that are natural inhabitants of the marine environment.^[1,2] The CDC estimates that 8028 *Vibrio* infections and 57 deaths occur annually in the United States.^[3] Transmission of *Vibrio* infections is primarily through the consumption of raw or undercooked shellfish or exposure of wounds to warm seawater.^[2,4] The most common clinical presentation of *Vibrio* infection is self-limited gastroenteritis (Table 1), but wound infections and primary septicemia may also occur.^[4] Patients with liver disease are at particularly high risk for significant morbidity and mortality associated with these infections.^[5,6] Many cases of *Vibrio*-associated gastroenteritis are underrecognized because most clinical laboratories do not routinely use the selective medium, thiosulfate-citrate-bile salts- sucrose (TCBS) agar, for processing of stool specimens unless they are specifically requested to do so.^[7] Early detection and initiation of treatment of these infections are very important, particularly for cholera and invasive *Vibrio* infections, because these may rapidly progress to death.^[8,9] Prevention of *Vibrio* infections requires a heightened awareness of these infections by clinicians, laboratory technicians, and epidemiologists. There are at least 12 pathogenic *Vibrio* species recognized to cause human illness.^[10,11] The *Vibrio* species of most medical significance include *Vibrio cholerae* (Figure 1), *Vibrio vulnificus*, and *Vibrio parahaemolyticus*. In this review, we discuss the epidemiology, clinical presentation, diagnosis, and treatment of these medically important vibrios.



Figure 1. *Vibrio cholerae*. (From the Centers for Disease Control and Prevention, Dr William A. Clark.)

Case Report #1

A 21-year-old college student returning from a vacation in Southeast Asia presented to the emergency department complaining of acute watery diarrhea. He states that he ate fried rice and had a beverage containing ice from a street vendor 1 day before boarding his flight back to the United States. During his flight he experienced some nausea and vomiting. He now complains of profuse watery diarrhea (15 bowel movements per day) and severe abdominal cramps. On examination, he is severely dehydrated and has orthostatic blood pressure changes. His potassium level was 2.8 mmol/L and carbon dioxide, 22 mmol/L. A stool specimen was obtained and tested for vibrios using TCBS agar. The patient was initially given intravenous Ringer lactate for replacement therapy until he became hemodynamically stable. His stool culture yielded toxigenic *V cholerae* O1.

Vibrio cholerae

V cholerae O1 is the primary causative agent of cholera.^[2] Infection with this organism can cause profuse watery diarrhea, vomiting, and muscle cramps. Cholera is a dehydrating diarrheal illness that results in substantial loss of fluid and electrolytes. On occasion, stool volumes may approach 1 L/h.^[12,13] The spectrum of illness in cholera includes asymptomatic infection (75%), mild illness (18%), moderate illness (5%), and severe illness (2%). Severe diarrhea may result in hypovolemic shock and possibly death within a few hours without treatment.^[14,15] The incubation period of cholera is usually 2 to 3 days (range, 6 hours to 5 days).

Severe illness has been associated with high-dose exposure, low gastric acidity, and blood group O.^[16] Severe cholera may be characterized by "rice water" stools, loss of 10% or more of body weight, loss of normal skin turgor, dry

mucous membranes, sunken eyes, lethargy, anuria, weak pulse, altered consciousness, and circulatory collapse. Diarrheal fluid loss may result in profound hypokalemia, metabolic acidosis (from bicarbonate loss), and renal failure. Severe infections may result in death if the dehydration is not treated aggressively with fluid and electrolyte replacement.

In 1992, toxigenic *V cholerae* O139 (the Bengal strain) was recognized as another cause of cholera.^[17] *V cholerae* O139, first discovered on the Indian subcontinent, has been reported in the United States as an imported infection.^[18] Although the primary organism that causes cholera globally is *V cholerae* O1, continued laboratory surveillance of *V cholerae* O139 is recommended because it has similar epidemic potential.^[18] *V cholerae* O1 may be subdivided by biotype: El Tor (the most common biotype) or classic; by serotype: Inaba, Ogawa, or Hikojima; or by toxin production: toxigenic or nontoxigenic.^[19]

Foreign travel and the consumption of contaminated food are the most important risk factors for acquiring cholera. The most common sources of contamination include raw or undercooked shellfish, water, ice, rice, food and beverages from street vendors, and food left out at room temperature for several hours.^[20-23]

Foodborne transmission of cholera may be facilitated through the rapid growth of organisms in moist, alkaline foods held at ambient temperature. Since the infectious dose of *V cholerae* is high (more than $10^{6.0}$ organisms), person-to-person transmission of cholera is not an important mode of transmission.^[24]

Currently, most cases of cholera in the United States are acquired through foreign travel or through eating seafood from the Gulf Coast,^[25] where a particular *V cholerae* O1 strain (biotype El Tor, serotype Inaba) is endemic.^[20] Domestically acquired cholera has been associated with consumption of shellfish.^[23,26-28]

The CDC reports that between January 1995 and July 1999, there were 51 cases of laboratory-confirmed *V cholerae* O1 infections and no cases of *V cholerae* O139 infections.^[25] Fifty-one percent of patients were hospitalized, but no deaths were reported. The antimicrobial resistance of *V cholerae* strains that have been isolated from ill American travelers returning to the United States has increased. Resistance to the commonly used fluoroquinolones (for example, ciprofloxacin) has not been reported.^[25] Because of increasing antimicrobial resistance, antimicrobial susceptibility testing should be performed on all patient isolates to assist in guiding antimicrobial therapy in severe infections.

Though cholera continues to be a devastating disease in many countries, the risk of transmission in the United States remains low because of access to safe drinking water and good sanitation. Because of a high incidence of cholera in developing countries and an increasing number of Americans traveling abroad, clinicians in the United States should be prepared to diagnose and treat imported cases of cholera. When evaluating a patient with acute watery diarrhea, clinicians should always obtain a travel history and consider cholera in the differential diagnosis when a patient has returned from a trip to a country where cholera is known or suspected to be present. After an outbreak of cholera on a commercial flight returning from Latin America, a survey of treatment facilities and pharmacies discovered that US health care facilities were not adequately prepared to diagnose and treat cholera.^[29]

When processing stool specimens, vibrios may grow on blood and MacConkey agars, but isolation is enhanced by using TCBS agar.^[1] After inoculation on TCBS agar, *V cholerae* appears as yellow colonies. A cholera diagnosis may also be made serologically with evidence of serologic conversion (vibriocidal antibody titer of greater than 1:640 suggests recent infection) or a 4-fold rise in vibriocidal antibody titer. Serologic diagnosis may also be made by an increase in titers 2 weeks after exposure and a decrease in titers 2 months after exposure.

Treatment and Prevention

Antimicrobial therapy has been shown to reduce the duration and severity of cholera symptoms, although it is only recommended for cholera patients with severe dehydration. World Health Organization (WHO) guidelines state, "The patients who benefit most from antibiotics are those who are severely dehydrated. Indiscriminate use of antibiotics in mild cases may hasten the development of antibiotic resistance among cholera vibrios."^[30] The widespread use of antibiotics is expensive, may divert from strategies that are well known to be effective for the management of cholera (for example, good case management, sanitation, and hygiene), may rapidly lead to the development of antibiotic resistance, and does not prevent transmission of cholera.

High cholera case-fatality rates usually reflect either patients seeking medical care too late or inadequate medical care delivered at treatment centers. During outbreaks of cholera, when appropriate medical care is delivered, case-fatality rates should be less than 1%.^[30] However, many persons may die of cholera (even in the United States) when clinicians are not familiar with cholera's clinical presentation and treatment.

The standard of care for cholera patients is to treat mild to moderate cholera with oral rehydration salts (ORS) solution or an oral electrolyte rehydration solution,^[18,30] and to treat severe cases with intravenous fluids (for example, Ringer lactate) and an antimicrobial agent. Prompt restoration of fluids and electrolytes should be the primary goal of treatment.

Standard rehydration therapy alone can reduce cholera mortality, but it has not been shown to reduce the duration of illness. Patients who have severe dehydration requiring intravenous hydration should be switched to ORS as soon as possible to minimize complications associated with intravenous hydration therapy. Normal saline solution should never be used to treat patients with cholera, since it does not contain the electrolytes needed to replace the profound potassium and bicarbonate loss from cholera.^[31]

Antimicrobial therapy has been shown to reduce the magnitude of fluid loss, duration of illness, and duration of excretion. Ciprofloxacin (1 g orally in 1 dose) and doxycycline (300 mg orally in 1 dose) are the antibiotics of choice for adults (except pregnant women), since only 1 dose is required (Table 2),^[32] while erythromycin for 3 days is recommended for children (10 mg/kg tid) and pregnant women (250 mg qid). Trimethoprim-sulfamethoxazole had been the treatment of choice for children, while furazolidone had been used for treatment of pregnant women with cholera; however, because of increasing global antimicrobial resistance, these antimicrobial agents are no longer recommended as first-line

therapy. Whenever possible, treatment protocols should be based on local antibiogram data.

No cholera vaccine is currently licensed and available in the United States for use by overseas travelers. The previously licensed vaccine in the United States was only about 50% effective and provided only 3 to 6 months of protection.^[33] Newer recombinant DNA vaccines (for example, WC/rBS) have demonstrated protection for more than 1 year. At the moment, neither the CDC nor the WHO recommends routine use of the cholera vaccine for travelers, since it may create a false sense of security and does not affect cholera severity. Travelers to areas affected by epidemic cholera should avoid unboiled or untreated water, food or beverages from street vendors, and raw or undercooked seafood. Furthermore, to reduce likelihood of cholera exposure, travelers should strictly adhere to the mantra of *boil it, cook it, peel it, or forget it*.

Case Report #2

During July, a 45-year-old man presented to the emergency department with fever, chills, nausea, and myalgias. He reported that 2 days before symptom onset, he had eaten raw oysters at a popular seafood restaurant in San Francisco. He was admitted to the hospital with 2 hemorrhagic, fluid-filled bullous lesions on his right leg. The patient had a history of insulin-dependent diabetes mellitus, chronic hepatitis B, and heavy alcohol consumption. The patient, who had a temperature of 39°C (102.2°F), was admitted to the ICU for presumed sepsis and was immediately given ceftazidime and gentamicin. An epinephrine drip was required to maintain blood pressure. On the second day of hospitalization, *V vulnificus* was isolated from blood cultures drawn on admission and fluid from the bullous leg wound. On the third day of the patient's hospitalization, disseminated intravascular coagulation (DIC) developed and he died. Tracing of the oysters eaten by the deceased patient revealed that they were harvested from a site in the Gulf of Mexico.

Vibrio vulnificus

V vulnificus is the most important pathogenic vibrio in the United States because of its invasiveness and the high fatality rates associated with infection. It was first identified and described by the CDC in 1976^[34] and has become the leading cause of seafood-associated deaths in the United States. *V vulnificus* is a halophilic (salt-loving) organism whose infectious dose is unknown. The severity of *V vulnificus* infections (and probably the infectious dose required for infection) depends on both bacterial and host factors. *V vulnificus* produces a number of enzymes (hyaluronidase, mucinase, DNAase, lipase, and protease) that may facilitate pathogenesis.^[10,19] In addition, the presence of a capsule appears to be associated with invasive forms of *V vulnificus*, since encapsulated forms are more commonly found among clinical isolates than among environmental isolates.^[35] *V vulnificus* is sensitive to the degree of iron bound by transferrin in a given host, because it uses transferrin-bound iron for growth.^[36-38] Therefore, persons with elevated transferrin-bound iron saturation (greater than 70%) or elevated ferritin levels, which includes persons with hemochromatosis, thalassemia, or liver

disease, are at increased risk for invasive infections. A Florida study showed that persons with liver disease were 80 times more likely to develop *V vulnificus* infections than were persons without liver disease.^[39]

Among the 422 culture-confirmed *V vulnificus* infections reported to the CDC through the *Vibrio* Surveillance System on the Gulf Coast between 1988 and 1996, 45% were classified as wound infections, 43% as primary septicemia, and 5% as gastroenteritis; 7% were from other or unknown sites of infection. Of the patients with information on clinical outcome, 39% died of their infection.^[40]

Primary septicemia refers to bloodstream infections that are acquired through ingestion of the organism through the GI tract. *V vulnificus* primary septicemia infections are fatal about 50% of the time.^[41,42] Persons with known liver disease, particularly those patients with cirrhosis, are at high risk for *V vulnificus* primary septicemia.^[43] The clinical course of *V vulnificus* bloodstream infections may be fulminant and result in death within hours. Distinctive bullous skin lesions filled with hemorrhagic fluid (typically present on the extremities or the trunk), thrombocytopenia, leukopenia, and DIC are often seen in patients with fulminant primary septicemia.

V vulnificus can also cause an infection of the skin when open wounds are exposed to warm seawater. These skin infections may lead to cellulitis, ulceration, necrotizing fasciitis, and sepsis. Because of the invasiveness of these wound infections, debridement of infected wounds is generally recommended to avoid limb amputation. Thirty-five percent of patients with wounds may become bacteremic, and 25% of those with bacteremia secondary to wound infections may die as a result of their infection.^[42,44] In addition to wound infections, septicemia, and gastroenteritis, *V vulnificus* has been associated with other clinical syndromes, including pneumonia,^[45] osteomyelitis,^[46] spontaneous bacterial peritonitis,^[47] eye infections,^[48] and meningitis.^[49]

The number of *V vulnificus* organisms found in the environment has been shown to increase as a function of ambient seawater temperatures. In a review of *V vulnificus* infections in the United States, 96% of patients with primary septicemia consumed raw oysters within 7 days before symptom onset.^[40] All tracebacks with complete information implicated oysters harvested in the Gulf of Mexico; 89% were harvested in seawater warmer than 22°C (71.6°F). All clinical syndromes of *V vulnificus* are more common during the warmer months.

Treatment

V vulnificus wound infections and primary septicemia require antimicrobial treatment to improve the course of illness and to prevent complications. Antimicrobial agents most effective against *V vulnificus* infections include tetracycline,^[50,51] fluoroquinolones (for example, ciprofloxacin), third-generation cephalosporins (for example, ceftazidime), and aminoglycosides (for example, gentamicin). The most current antimicrobial recommendation includes treatment with ceftazidime (2 g IV tid) and doxycycline (100 mg PO or IV bid)^[32] or doxycycline in combination with ciprofloxacin or an aminoglycoside. Early administration of antimicrobial therapy may reduce the morbidity and mortality associated with *V vulnificus* infections.

Because of the high case-fatality rates associated with these infections, it is particularly important for clinicians to suspect *V vulnificus* wound or bloodstream infections in persons with shellfish or warm seawater exposure and a history of chronic liver disease.

Case Report #3

A 50-year-old man presented with fever (temperature, 38.5°C [101.3°F]) and a necrotic skin lesion on his left arm. He reported that he sustained a small cut on his hand while fishing. One day later, he went swimming along the South Atlantic coast of Florida. The next day, redness, pain, and swelling developed in the area of the wound. The patient was admitted to the hospital for cellulitis and treated with cefazolin and gentamicin. The cellulitis quickly spread from his hand to his entire arm, resulting in ulceration and necrotizing fasciitis requiring aggressive debridement. The patient was successfully treated, but barely avoided arm amputation. *V parahaemolyticus* was isolated from his wound culture.

Vibrio parahaemolyticus

V parahaemolyticus was first identified as a cause of foodborne illness in 1950.^[52] The first confirmed US outbreak occurred in 1971 and was associated with consumption of crabs.^[53] During the past 3 decades, *V parahaemolyticus* has been implicated as a common cause of seafood-associated gastroenteritis during outbreaks in the United States.^[54-57]

The most common clinical manifestation of *V parahaemolyticus* infection is gastroenteritis.^[4] Acute watery diarrhea, abdominal cramps, and nausea usually characterize the illness. The mean incubation period is typically 24 to 48 hours, with a mean duration of illness of 3 days. The illness is usually mild to moderate and self-limited, although some cases may be severe and require hospitalization. Infection may cause severe illness in persons with chronic medical disease (for example, persons with liver disease, diabetes, iron overload states, compromised immune systems, or GI problems). Between 1988 and 1997, a review of *V parahaemolyticus* infections in the United States found that 59% of persons had gastroenteritis, 34% had wound infections, 5% had primary septicemia, and 2% had other sites of infections.^[58] Fulminating septicemia from *V parahaemolyticus* infection has been reported and characterized as a syndrome of erythema multiforme, hemolytic anemia, and hypotension.^[59] Similar to other enteric bacteria, such as *Salmonella*, *Shigella*, *Campylobacter*, and *Yersinia*, *V parahaemolyticus* may also induce a reactive arthritis or Reiter syndrome.^[60] Raw oysters are the primary source of ingestion-associated *V parahaemolyticus* infection. Between 1988 and 1997, a review of infections found that 88% of patients with *V parahaemolyticus* gastroenteritis and 91% of patients with *V parahaemolyticus* primary septicemia and known food history reported eating raw oysters.^[58] Consumption of crustacean and molluscan shellfish has commonly been implicated in the transmission of *V parahaemolyticus*. Studies indicate that

the infectious dose of *V parahaemolyticus* is between $10^{[5]}$ and $10^{[7]}$ viable cells ingested.^[61]

Similar to other vibrios, *V parahaemolyticus* may be overlooked if plated on nonselective medium; therefore, it should be plated on TCBS. On TCBS, *V parahaemolyticus* isolates appear as distinct green colonies. Virulence can be determined by b-hemolysis of red blood cells using Wagatsuma blood agar, although newer methods use DNA gene probes.^[62]

Between 1973 and 1998, 40 outbreaks of *V parahaemolyticus* infection were reported to the CDC.^[58] Most of the outbreaks occurred during the warmer months. Recent *V parahaemolyticus* outbreaks during 1997 and 1998 (both El Niño years) were linked to consumption of raw or undercooked shellfish (oysters and clams) harvested from all the coastal waters of United States.^[54,55,57,58] It has been suggested that these recent outbreaks may have been associated with warmer water temperatures, which increased *V parahaemolyticus* levels and therefore increased the probability of infection.

Treatment

V parahaemolyticus strains that cause gastroenteritis are usually susceptible to antimicrobial agents routinely used to treat enteric infections, although most patients with gastroenteritis can effectively be treated with oral rehydration alone.^[57] However, for patients with *V parahaemolyticus* wound infections and septicemia, the treatment is similar to that for patients with *V vulnificus* infection: intravenous antimicrobial agents.

Other Pathogenic Vibrios

Non-O1 *Vibrio cholerae*

Some strains of *V cholerae* do not agglutinate in O1 antiserum but can still cause diarrheal illness. In most situations, there is not much additional benefit in subtyping *V cholerae* that is not O1. Non-O1 *V cholerae* has been associated with gastroenteritis, septicemia, and wound infections, usually following consumption of contaminated shellfish or exposure of broken skin to contaminated water. The most common presentation is self-limited gastroenteritis associated with watery diarrhea and abdominal cramps; occasionally, the patient has fever. Approximately a quarter of infected patients have bloody stools.

Other than *V cholerae* O139, non-O1 *V cholerae* usually causes a less severe diarrhea than *V cholerae* O1, although certain strains, especially those that produce cholera toxin, can cause severe cholera-like disease.^[63] Septicemia with non-O1 *V cholerae* is seen in immunocompromised hosts, particularly patients with cirrhosis. In one series, all 15 patients with non-O1 *V cholerae* bacteremia had hepatic cirrhosis and 7 (47%) died.^[64] Soft tissue infections, including cellulitis and necrotizing fasciitis, are a less common presentation of non-O1 *V cholerae* infection. There were 130 cases of non-O1 *V cholerae* infection (third most common *Vibrio* infection after *V parahaemolyticus* and *V vulnificus* infections) reported in Florida from 1981 to 1993. Of these cases, 67% were classified as

gastroenteritis, 15% as primary septicemia, 9% as wound infection, 3% as other infection (pulmonary infection in drowning victim, ear infection, or urinary tract infection), and 6% as unknown.^[5]

Vibrio alginolyticus

V alginolyticus is a halophilic *Vibrio* first recognized as being pathogenic in humans in 1973.^[65] Wound infections account for 71% of *V alginolyticus* infections.^[5] Ear infections are also seen with this organism. Gastroenteritis was thought to be a rare presentation of *V alginolyticus* infection, but it accounted for 12% of infections in one series.^[5] Other clinical syndromes reported in association with *V alginolyticus* infection include chronic diarrhea in a patient with AIDS,^[66] conjunctivitis,^[67] and post-traumatic intracranial infection.^[68] Resistance to tetracycline and chloramphenicol has been reported in a few isolates of *V alginolyticus*, but all strains appear to be sensitive to ciprofloxacin.^[69]

Vibrio mimicus

V mimicus is a non-halophilic *Vibrio* named according to its similarity to *V cholerae*. *V mimicus* can cause sporadic episodes of acute gastroenteritis and ear infections. Of the 21 strains of *V mimicus* studied at the CDC in 1981, 19 were from patients with diarrhea and 2 were from patients with otitis media.^[70] Among 40 reported cases of *V mimicus* infection in Florida between 1981 and 1993, gastroenteritis accounted for 34 (85%).^[5]

Vibrio fluvialis

V fluvialis is a halophilic *Vibrio* first identified in 1975 in a patient with diarrhea in Bahrain.^[71] It is biochemically similar to *Aeromonas hydrophila* but can be differentiated from this organism by its ability to grow well on media containing 6% to 7% sodium chloride. The largest series of *V fluvialis* infections involved 500 patients in Bangladesh, half of whom were young children.^[72] In that series, patients presented with diarrhea (100%, 75% bloody), vomiting (97%), abdominal pain (75%), dehydration (67%), and fever (35%). *V fluvialis* rarely causes wound infections or primary septicemia.^[5,73]

Photobacterium damsela

P damsela (formerly *Vibrio damsela*) is a halophilic gram-negative bacillus similar to *V vulnificus* that strictly causes soft tissue infections following exposure of wounds to brackish water or injury by saltwater animals.^[74] *P damsela* infections can be fulminant and are frequently fatal even in immunocompetent hosts. Of the 16 cases of *P damsela* infection reported between 1982 and 1996, 4 were fatal.^[75]

Vibrio hollisae

V hollisae, a halophilic *Vibrio* first described in 1982, most commonly causes gastroenteritis. *V hollisae* is difficult to isolate, since it grows poorly on selective TCBS

media and it needs to be isolated from colonies on a blood agar plate. *V hollisae* septicemia and wound infections have been reported but are rare.^[5,76]

Vibrio furnissii

V furnissii was originally thought to be an aerogenic (able to produce gas from glucose) strain of *V fluvialis*. In 1983, however, *V furnissii* was shown to be a distinct species by genetic analysis.^[77] This organism has most commonly been isolated from stool samples. *V furnissii* was retrospectively implicated in an outbreak of gastroenteritis occurring on an aircraft in 1969.^[78] In 1994, during a cholera surveillance program in Peru, *V furnissii* was isolated from 14 patients, 6 with diarrhea and 8 without symptoms.^[79] The importance of *V furnissii* as an enteric pathogen remains unclear.

Vibrio metschnikovii

V metschnikovii was first described in 1888. It is often isolated from the environment but is rarely isolated from human specimens. In the first report of human infection, the organism was isolated from the blood of a diabetic woman with acute cholecystitis.^[80] Most recently, *V metschnikovii* was isolated from 5 infants with diarrhea during a cholera surveillance program in Peru.^[81] All isolates were identified within a 10-day period. No common source of infection was found and no additional isolates of the organism were identified in the following year.

Vibrio cincinnatiensis

V cincinnatiensis is the most recently described pathogenic *Vibrio*. In the only report to date, this organism was isolated from the cerebrospinal fluid and blood of a patient presenting with confusion to the University of Cincinnati in 1986.^[82] The patient drank alcohol heavily but had no evidence of liver disease. He had no known exposure to seawater or seafood. He recovered uneventfully after treatment with moxalactam.

Summary

In patients in whom acute gastroenteritis develops after they have eaten raw or undercooked shellfish, clinicians should order that a stool specimen be tested for vibrios using TCBS agar. To reduce the risk of *Vibrio* infection, consumers should avoid eating raw or undercooked shellfish during the warmer months (months without "R"). Patients with liver disease or weakened immune systems, in particular, should be counseled by clinicians to avoid consumption of raw or undercooked shellfish because of the high risk of invasive disease and death. Clinicians should be aware that pathogenic vibrios can cause severe wound infections in both immunocompromised and healthy individuals whose wounds are exposed to warm seawater.

Table 1. Association of *Vibrio* species with different clinical syndromes

Organism	Gastroenteritis	Wound infection	Primary septicemia
<i>Vibrio alginolyticus</i>	+	++	
<i>Vibrio cholerae</i> non-O1	++	+	+
<i>Vibrio cholerae</i> O1	++		
<i>Vibrio cincinnatiensis</i>			
<i>Vibrio damsela</i>		++	
<i>Vibrio fluvialis</i>	++	(+)	(+)
<i>Vibrio furnissii</i>	++		
<i>Vibrio hollisae</i>	++	(+)	(+)
<i>Vibrio metschnikovii</i>	(+)		
<i>Vibrio mimicus</i>	++	(+)	(+)
<i>Vibrio parahaemolyticus</i>	++	+	(+)
<i>Vibrio vulnificus</i>	+	++	++

+, less common presentation; ++, common presentation; (+), rare presentation.

Table 2. Recommended antimicrobial therapy for *Vibrio* infections

<i>Vibrio</i> species	Recommended antimicrobial agent
<i>Vibrio cholerae</i> O1 or O139	
Mild	No antimicrobial therapy, oral rehydration only
Moderate to severe	Doxycycline, 300 mg (single dose), or ciprofloxacin, 1 g (single dose), or norfloxacin, 400 mg bid for 3 days
Non-cholerae <i>Vibrio</i>	
Gastroenteritis	
Mild	No antimicrobial therapy, oral rehydration only
Moderate to severe	Ciprofloxacin, 500 mg PO bid for 3 days, or doxycycline, 100 mg PO bid for 3 days, or norfloxacin, 400 mg bid for 3 days
Wound infection/cellulitis	Ceftazidime, 2 g IV tid, or cefotaxime, 2 g IV tid, and/or doxycycline, 100 mg IV bid, or ciprofloxacin, 400 mg IV

	bid
Septicemia	Ceftazidime, 2 g IV tid, or cefotaxime, 2 g IV tid, and/or doxycycline, 100 mg IV bid, or ciprofloxacin, 400 mg IV bid

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