

Vibriosis:

What You and Your Patients Need To Know

Andrew Bell¹ and Michael Bott²

1. Shellfish Standardization Officer, Shellfish & Recreational Water Program, Delaware Department of Natural Resources and Environmental Control
2. Program Lead, Shellfish & Recreational Water Program, Delaware Department of Natural Resources and Environmental Control

The rapid progression, limited treatment options, and high fatality rate of vibriosis in high-risk individuals, coupled with the apparent increasing incidence of vibriosis, underscore the need for prevention by patients as well as quick diagnosis and treatment by healthcare providers. Yet, vibriosis is an under-recognized and under-reported illness,¹ and awareness of the potential for infection is low among high-risk patients.² Prompt diagnosis and treatment of vibriosis in high-risk patients is necessary to prevent death, and educating high-risk patients on how to avoid infection will save lives.²

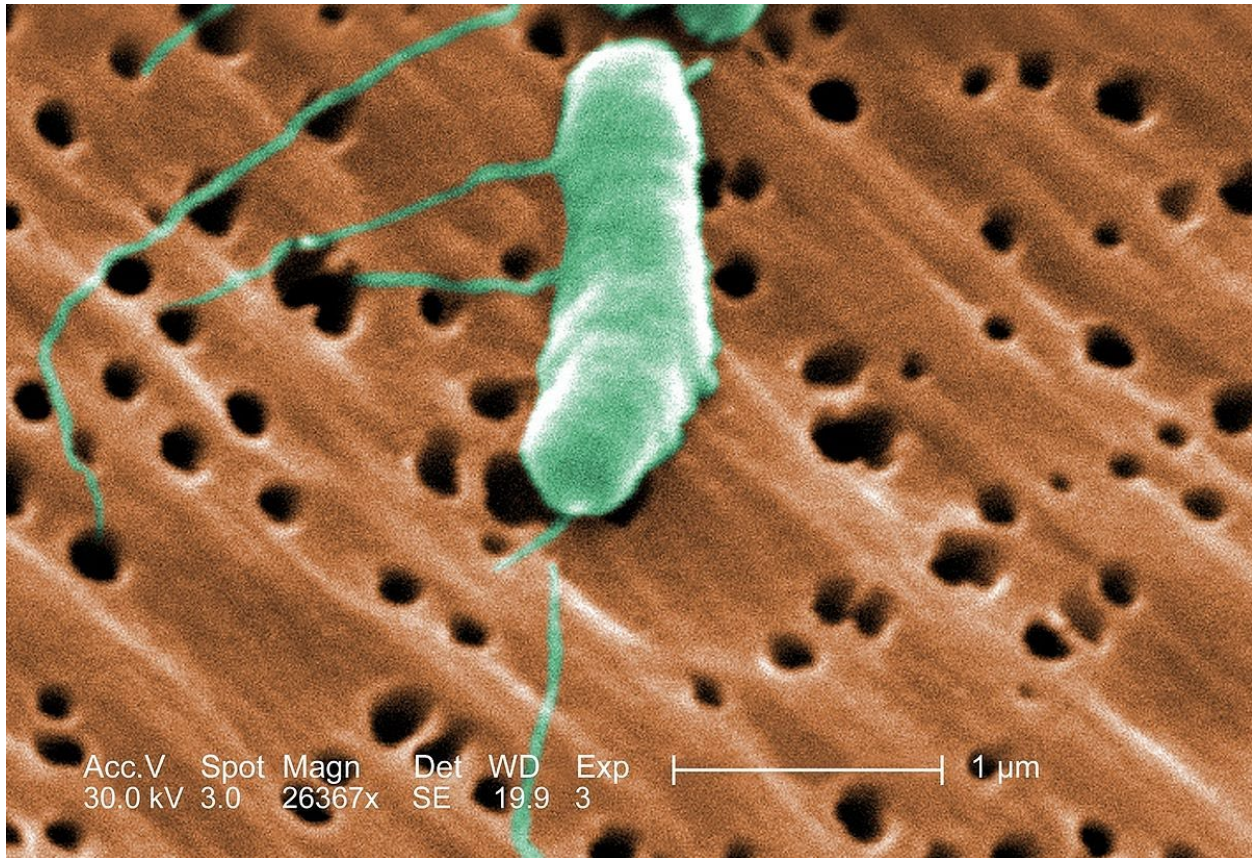
Vibriosis is the human illness caused by pathogenic strains of the *Vibrio* genus of bacteria (excluding *Vibrio cholerae* strains O1 and O139, which cause the separate illness of cholera and which are not the focus of this article). *Vibrio* bacteria are a natural part of the estuarine ecosystem,²⁻⁷ with higher levels present in warm water of moderate salinity.^{2,5-10} There are two common modes of infection: wound contact and seafood consumption, particularly consumption of bivalve shellfish (oysters, clams, mussels, and scallops).^{1-3,6,7}

While healthy individuals are unlikely to develop illness from the opportunistic *Vibrio* pathogen, individuals with certain underlying health conditions or with weakened immune systems may develop life-threatening illness. For this reason, high-risk individuals should never eat raw or partially cooked seafood. Additionally, all individuals should prevent contact between an open wound and salt or brackish water. Healthcare providers are the frontline of educating high-risk individuals on these life-saving prevention measures.

There are over 80 species of *Vibrio* bacteria, over 20 of which can cause vibriosis.³ The species which most frequently cause vibriosis in the US are *Vibrio parahaemolyticus* (Vp) and *Vibrio vulnificus* (Vv, see Figure 1).³ Though Vp is more common, especially in Delaware and the surrounding region, Vv is the most lethal of the *Vibrios*.^{5,9} In fact, Vv has the highest fatality rate of any foodborne pathogen,^{6,7} and causes over 95% of seafood-related deaths in the US.⁷ About 1 in 5 people with serious Vv illnesses die, sometimes within only several days of illness onset, and many others require intensive care or limb amputations.³ Overall, an estimated 80,000 cases of vibriosis, with 500 hospitalizations and 100 deaths, occur each year in the United States.³

These statistics emphasize the critical need for patient education and prompt treatment by healthcare providers.

Figure 1. A micrograph of a *Vibrio vulnificus* cell. Image credit: Janice Haney Carr/CDC via Wikimedia Commons



An Environmental, Seasonal Pathogen

Vibrionaceae is a family of Gram-negative, rod- to curve-shaped, flagellated bacteria found throughout the coastal waters of the United States and other temperate to tropical coastal areas worldwide.⁹ *Vibrio* is not the result of pollution, but is instead a natural part of the microbiota of estuarine waters.²⁻⁷ *Vibrio* is therefore naturally present in many types of raw seafood, including finfish, crustaceans, and seaweed¹⁰; however, the bacteria is present in especially high numbers in bivalve shellfish (oysters, clams, mussels, and scallops). This is because these animals concentrate *Vibrio* from the surrounding water in their tissues as part of their filter-feeding process.^{5,10,11} The target of filter-feeding bivalve shellfish is algae and other food particles, but along with these particles, bivalve shellfish also filter out viruses and bacteria, including *Vibrio*. A single oyster can filter up to 50 gallons of water per day, and as a result, the concentration of *Vibrio* within oysters may be 100 times greater than that of the surrounding water.^{12,13} Adding to the human health risk is that bivalve shellfish, especially oysters, are often consumed raw or partially cooked, so any *Vibrio* present is not destroyed by cooking.^{12,13}

Vibrio reproduces rapidly in waters that are warm⁵⁻⁹ and moderately salty^{2,8-10}; it is therefore most prevalent during warmer months in estuarine waters such as bays, where saltwater from oceans mixes with freshwater from rivers. Thus, infections show a strong seasonal trend, with nationwide cases rising in April before peaking in July and then decreasing in November.² Though infections occur throughout the year, about 80% nationwide occur from May through October.³ This seasonal trend is especially pronounced for foodborne *Vibrio* infections.¹⁴ Likewise, while infections occur throughout coastal areas in the United States, *Vibrio*, and in particular *Vibrio vulnificus*, is most common in the Gulf of Mexico, where levels of the bacteria

can reach 1,000 cells/mL in seawater and 100,000 cells/gram in oyster meat during warm months.⁸

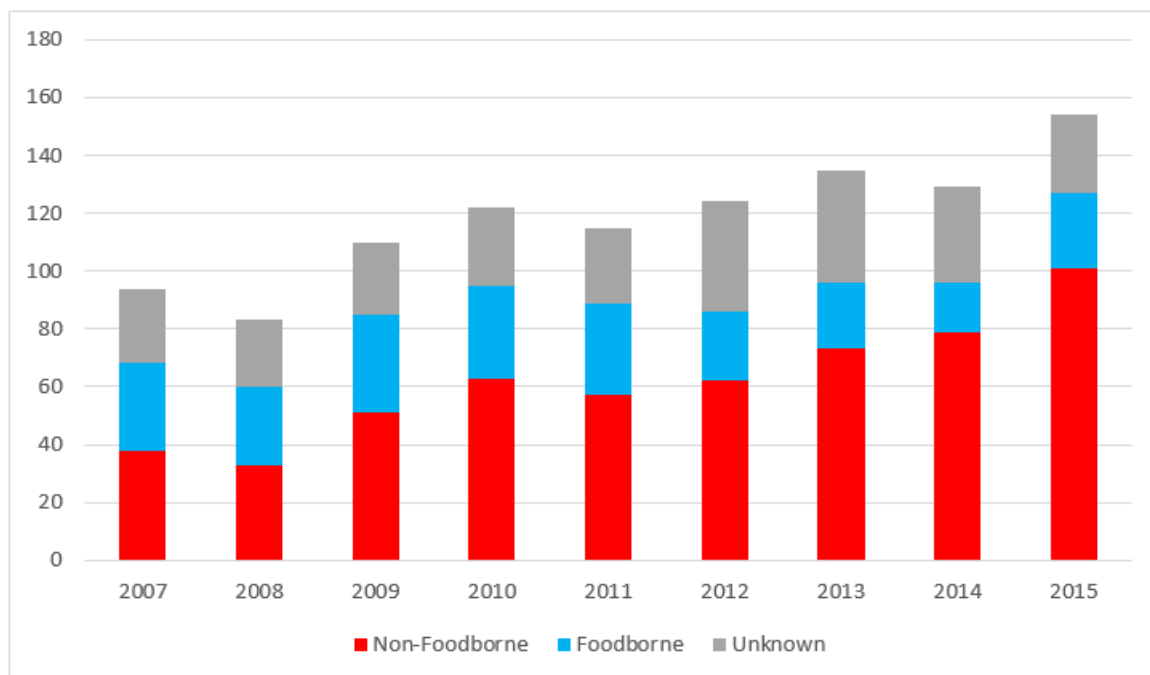
While *V. parahaemolyticus* is the most common and *V. vulnificus* is the most lethal cause of vibriosis, other marine-related species which may cause vibriosis include *V. alginolyticus*, *V. fluvialis*, *V. hollisae*, *V. metschnikovii*, and *V. cholerae*² (*V. cholerae* serogroups O1 and O139 cause the different illness of cholera, generally in developing countries where poor sanitation allows sewage to contaminate drinking water).^{1,3,9} Among pathogenic species of *Vibrio*, not all strains are capable of causing human illness²; conversely, pathogenic strains comprise a small percentage of the total *Vibrio* species present in waters and seafood.^{9,10} *Vibrios* are highly susceptible to cooking, and all strains can be killed by common disinfectants.⁹

An Uncommon But Serious & Rising Illness

In 2014 (the most recent year for which the Centers for Disease Control and Prevention (CDC) has published a Cholera and Other Vibrio Illness Surveillance [COVIS] annual summary report), over 1,200 *Vibrio* infections (excluding *V. cholerae* O1 and O139) were reported to COVIS.¹⁴ The species most frequently reported was *V. parahaemolyticus* at 48%, while *V. vulnificus* was reported in 10% of patients.¹⁴ Of patients with Vp, 15% were hospitalized and 1% died, while of patients with the more lethal Vv, 79% were hospitalized and 18% died.¹⁴

Recently, an increase in reported infections has been apparent,⁷ with the CDC estimating that the average annual incidence of *Vibrio* infections increased 54 percent from 2006 to 2017.³ This increased incidence is driven largely by an increase in wound infections⁷ and also likely by the use of new detection methods by healthcare providers, in particular culture-independent diagnostic testing (CIDT). In Delaware, while there has never been a reported *Vibrio* infection related to bivalve shellfish consumption, reports of wound infections have reached a record high in recent years, with 12 infections reported in 2016 and 2017 (see Figure 2).¹⁵

Figure 2. US *Vibrio vulnificus* cases by transmission type



The factors underlying this apparent trend are complex and numerous. First, improvements in the identification and diagnosis of vibriosis have occurred over the past several decades, increasing the national reported incidence.⁷ Specifically, state participation in COVIS gradually increased since its establishment in the 1980s, until all *Vibrio* infections became nationally notifiable in 2007.⁷ More recently, the use of CIDT for *Vibrio* diagnosis has increased case reports significantly. In this way, it is likely that the increase in vibriosis has been partly driven by better surveillance in recent decades. However, other trends suggest that the incidence of *Vibrio* infections may indeed be increasing naturally.

Namely, consumption of oysters is increasing in the United States,¹² with raw bars becoming trendy destinations in recent years. In Delaware, for example, the bivalve shellfish industry has recently expanded, with new legislation establishing an oyster aquaculture industry passed in 2014. Couple the increase in oyster consumption with an increasingly susceptible population, as the numbers of elderly and other individuals with risk factors predisposing them to more progressive cases of vibriosis increase, and these trends may have been partly responsible for the recent increase in vibriosis incidence.⁷

The High-Risk Group

While any exposed person can become infected with *Vibrio* and develop symptoms such as gastroenteritis, in healthy individuals the illness is uncommon and typically mild and temporary.^{2-5,10,11} This is particularly true for cases related to seafood consumption.^{2,10} However, persons with underlying chronic medical conditions or a weakened immune system often develop serious illness that may lead to septicemia and death.^{2,3,9-11} Thus, while all raw shellfish consumers and all persons who work or recreate in saline waterbodies are theoretically at-risk for *Vibrio* infection, a subpopulation of individuals has increased risk of serious illness.^{2,9,10} These individuals must be educated on how to prevent infection, since even with medical treatment, septicemia and death are common outcomes for them.

The percentage of the adult population in the US who are at risk for Vv-related septicemia is estimated at 7% to 20%.^{6,10} Ninety-four percent of molluscan shellfish consumption cases occur in people with pre-existing conditions, especially liver disease: in one case series of Vv infections, 53% of cases had liver disease, 34% had alcohol use disorder, and 16% had diabetes.² Elevated levels of iron in the blood, usually due to liver disease, is a particularly strong risk factor for severe vibriosis,^{2,3,6,9,16} with one study indicating that persons with chronic liver disease are 80 times more likely than healthy individuals to develop Vv septicemia and 200 times more likely to die.^{2,7}

There is both a gender disparity and an age aggregation associated with the incidence of vibriosis, particularly in cases related to seafood consumption and in Vv cases. Of Vv cases reported to COVIS from 1988 to 2010, 86% occurred in males, suggesting that males are approximately six times more likely to be diagnosed with a Vv infection than females.⁷ The reasons for this gender disparity are unknown, but it is likely that greater incidence of underlying risk conditions (particularly liver cirrhosis) is an important factor.⁷ Further, both the incidence and fatality rates for Vv cases are strongly correlated with age: very few cases, with only one fatality, were reported in persons under 25 years old, while persons 40 to 60 years of age comprise 50% of infections and 50% of fatalities.⁷ Thus, while anyone can be diagnosed with vibriosis, it is more common in males of middle age or above.

The high-risk group for severe vibriosis include the elderly and persons with the following underlying conditions:

- Liver disease (from hepatitis, cirrhosis, alcoholism, or cancer)^{1-4,6,7,9,10,16}
- Iron overload disease (hemochromatosis) / abnormal iron metabolism (hemosiderosis)^{1,2,4,10}
- Diabetes^{2-6,10,11}
- Renal disease/failure^{2,10,17}
- Cancer or malignancy (including leukemia, lymphoma, Hodgkin's disease)^{1-6,10}
- HIV/AIDS^{2,3,5,10}
- Gastrointestinal disorders (including ulcers)^{2,4,6,10}
- Gastric surgery^{3,5,10}
- Disorders or medicine leading to low gastric acid^{2,5,8,10}
- Heart disease¹⁰
- Hematological conditions^{3,6}
- Hemolytic anemia²
- Thalassemia³
- Transplant recipients¹⁰
- Any other illness or medical treatment that weakens the body's immune system (including chemotherapy and use of steroids or other immunosuppressive medication)^{1,2,4,6,8,10}

Two Modes of Infection

Vibrio can infect persons via seafood consumption or wound exposure to salt/brackish water, raw seafood, or drippings from raw seafood.^{1-3,6,7} The pathogen is opportunistic and the severity of an individual case depends on many factors, including the strain and the dose of bacteria and the patient's underlying health conditions.¹¹ The fatal dose for an at-risk individual is unknown.¹¹ Overall, the most common mode of transmission is consumption of raw or undercooked seafood, particularly oysters¹: in one study of United States vibriosis cases, 56% were classified as foodborne, 35% as wound infections, and 9% as having an unknown transmission route.¹⁴ More specifically, for *Vibrio parahaemolyticus*, about 86% of cases are foodborne,⁹ while for *Vibrio vulnificus*, wound infections comprise 46% of cases, followed closely by foodborne infections at 43%.⁷

In cases related to food consumption, raw or partially cooked oysters are the most commonly associated food,¹⁰ although many other seafood products have been linked to vibriosis, especially to Vp (see Figure 3).⁹ In one case series, among patients with foodborne vibriosis who reported eating a single seafood item, 69% ate oysters, 10% ate finfish, 6% ate crab, and 4% ate clams.¹⁴ More specifically, over 90% of bivalve Vv cases are associated with raw oysters from the Gulf Coast.^{2,7,9,10} Improper refrigeration of seafood products allows the exponential growth of opportunistic *Vibrio* and increases the likelihood of infection, while thorough cooking destroys

the bacteria.⁹ Thus, illnesses typically are caused by consumption of either raw/partially cooked seafood or cooked seafood that has been contaminated with raw seafood.⁹ Because the common pathogenic strains of *Vibrio* are destroyed almost immediately in freshwater, it is not usually transmitted via the fecal-oral route,^{9,10} and thus it typically occurs as sporadic cases and not as outbreaks.^{2,18}

Figure 3. High-risk persons should not eat uncooked seafood, including oysters on the half-shell. Image credit: Jeremy Keith via Flickr



In addition to ingestion, persons (especially those in the high-risk group) can become infected with *Vibrio* when cuts, burns, sores, or other wounds are exposed to seawater, raw seafood, or raw seafood drippings.^{2,5,9,14,17} Pre-existing wounds may contact seawater or seafood, or wounds may be incurred during an activity such as fishing or while preparing food.⁹ Persons with jobs that require marine- or food-related activities may have increased exposure²; for example, shucking oysters or picking crabs can result in a cut to the hand, exposing the body to *Vibrio*. Even a wound as small as an insect bite may allow infection in high-risk persons.¹⁹ Additionally, *Vibrio* wound infections may increase following flooding caused by a hurricane or storm surge: after Hurricane Katrina, 14 wound infections, 3 of which resulted in death, occurred among Louisiana and Mississippi residents exposed to floodwater.² Overall, among patients with non-foodborne transmission, 79% had skin exposure to a waterbody within seven days before symptoms began, 17% had contact with marine wildlife, and 17% handled seafood.¹⁴

Other, unusual modes of *Vibrio* infection have occurred. For example, in one case, corneal ulcers resulting from Vv occurred in an employee at an oyster shucking plant after small oyster shell fragments had contacted his eyes.² Another usual case occurred after a folk healer treated a chronic sore on a patient's leg by spraying it with fresh fish blood.²

The Resulting Illness

While any individual may be infected by *Vibrio*, cases in healthy persons are generally mild, temporary, and self-limiting.^{2,9} In foodborne cases, healthy persons may develop gastroenteritis symptoms but this usually remains localized and rarely requires hospitalization; most people with a mild case of vibriosis recover after about three days with no lasting effects.^{3,9} Symptoms typically occur within 12-72 hours and may include fever/chills, stomach pain/nausea, vomiting, diarrhea, and headache.^{3,4,9,18} In wound infections, healthy persons may develop cellulitis around the wound which requires treatment, but severe symptoms and death remain unlikely.² For all reported vibriosis cases, less than 40% require hospitalization or antibiotic treatment.⁹

In high-risk persons, however, symptoms may rapidly progress and lead to death in as little as 2 days, making prompt treatment of paramount importance.⁴ In foodborne cases, the bacteria may invade the bloodstream via the digestive tract, causing fever/chills that is usually accompanied by nausea, vomiting, diarrhea, and swollen/painful extremities.^{5,9,10,16} Blood pressure commonly drops sharply, potentially leading to shock and death.^{2,5} Also, the majority of high-risk patients develop skin lesions: initially the skin appears red, then painful blisters quickly develop and erode into necrotic ulcers, similar to those found in wound infection cases.^{5,9} In the high-risk subpopulation, septicemia may occur in as little as 24 hours,² and for Vv septicemia there is a 50-60% mortality rate.^{2,6}

For high-risk persons who develop vibriosis after wound exposure, infections usually begin with swelling, redness, and pain surrounding the infected site.⁵ Blisters commonly develop and rapidly progress to tissue necrosis.⁵ Around 50% of patients with Vv-infected wounds require surgical debridement or amputation to prevent the infection from spreading to the bloodstream, in which case death commonly occurs.⁵ Thus, wound infections in high-risk persons can have permanent, life-changing results.⁷

In total for Vv hospitalizations, the outcome is death in 35% of septicemia cases and 20% of wound infection cases.⁹ Strikingly, there is a very short time period – as little as 24 hours – between the onset of symptoms and the final outcome,⁷ making prompt diagnosis critical. Vibriosis is diagnosed by stool, wound, or blood culture, depending on the type of infection at hand.^{3,5,9} Key questions for the screening of patients include:

- Have you recently eaten raw or partially cooked seafood?⁸
- Have you had any recent skin contact with salt/brackish water?⁸
- Have you recently handled raw seafood, seafood drippings, or anything that was used to hold or prepare raw seafood?⁸

Vibriosis Surveillance

Doctors, hospitals, and/or labs are required to report confirmed and probable cases of *Vibrio* infection to state health agencies, who are then required to report cases of this nationally notifiable pathogen to the federal government.² Reporting is critical because it may result in a

state following national protocols to recall shellfish product or temporarily close shellfish waters to harvest, thereby preventing future illnesses. Further, because severe vibriosis has such a high fatality rate, prevention is imperative, and good surveillance allows federal and state government agencies to evaluate prevention strategies for efficacy.² For example, a state with a confirmed Vv illness is required to develop and implement a Vv Control Plan for bivalve shellfish that may include time-to-temperature restrictions to prevent *Vibrio* growth in shellfish after harvest, shading on board harvest vessels, or other important measures.

Health departments report *Vibrio* cases to the Cholera and Other *Vibrio* Illness Surveillance (COVIS) system.³ The COVIS report form includes the following information: a description of the person's illness and underlying health conditions; recent seafood consumption; recent exposure to bodies of water, raw or live seafood or their drippings, or marine life; and the source of any implicated seafood.³ Unfortunately, *Vibrio* infections are under-diagnosed and under-reported²: the CDC estimates that for every 1 foodborne Vv case reported another 1.87 cases occur,² while only 1 in 20 cases of Vp are reported.⁹

An Ounce of Prevention is Worth a Pound of Cure

Treatment for vibriosis in high-risk patients is of limited effectiveness, and thus prevention is critical. There is a 35% mortality rate from Vv septicemia in the high-risk subpopulation,⁹ and a median time period of only 48 hours from hospital admission to death.⁵ Even patients who survive severe infection are frequently left with life-altering consequences such as limb amputations. For these reasons, infection prevention is crucial and will save lives.

Despite the criticality of vibriosis prevention, awareness of the risks of *Vibrio* infection is low among the high-risk subpopulation as well as the population at large (see Table 1). In one survey of oyster consumers, 50% knew that people with liver disease can become extremely ill from eating raw oysters, 34% knew the same for people with weakened immune systems, and only 19% knew that diabetics are at risk of illness from raw oysters.² Compounding the problem of low awareness is that high-risk persons who eat raw oysters do so more frequently (ten times per year) than other consumers (six times per year).²

If awareness of the risks of *Vibrio* infection among high-risk persons is increased, lives will be saved. Health care providers, as trusted sources of important health information, are the frontline of vibriosis education. A survey showed that raw oyster consumers who are informed by health care providers of the risk of *Vibrio* infection are more concerned about raw oyster consumption than those who receive the same information from other sources.²

When a patient with a condition which makes them susceptible to severe vibriosis is diagnosed or seen, inform them to abstain from eating raw or partially cooked seafood, especially filter-feeding oysters and clams.^{5,17} Instead, encourage them to eat fully-cooked shellfish, which have numerous important health benefits. Also inform high-risk patients to avoid contact of wounds with salt/brackish water and seafood, to take care to avoid sustaining a wound when preparing seafood and when participating in marine-related activities such as fishing, and to seek immediate medical treatment if they experience symptoms following any wound contact.^{5,17}

Table 1. Common Shellfish Consumer Myths

MYTH	REALITY
------	---------

Though I am in the high-risk group, eating only a few raw shellfish can't hurt me.	A fatality has been documented where the patient consumed only three raw oysters. ¹¹
I'll be fine if I avoid raw shellfish from polluted waters.	<i>Vibrio</i> is a naturally-occurring part of the environment and has no connection to pollution. ¹¹
If I avoid oysters in months without the letter "R", I'll be fine.	Though <i>Vibrio</i> is more abundant during warmer months, many cases occur during the cooler months from September through April. ¹¹
Experienced oyster connoisseurs can tell a good oyster from a bad one.	<i>Vibrio</i> does not change the appearance, taste, or odor of shellfish. ^{11,17}
I'll be fine if I drink alcohol along with the raw shellfish.	Alcohol has little effect on harmful bacteria. ¹¹
I'll be fine if I smother raw shellfish in hot sauce or lemon juice.	This works no better than using plain water. ¹¹

Seafood Health Benefits

Oysters, clams, and other seafood are an important part of a balanced diet and convey numerous important health benefits. For healthy persons, eating raw or partially cooked seafood is a decision that should be made with a knowledge of associated risks and in consultation with their doctor. Persons whose age or underlying medical conditions put them in the high-risk group should abstain from consuming raw or partially cooked seafood, but they may still enjoy it thoroughly cooked for its delicious taste and many health benefits.

- Seafood is a source of high-quality protein that is rich in vitamins, minerals, and beneficial omega-3 fatty acids.⁸ Compared to other protein-rich animal foods, most seafood is lower in calories, total fat, and saturated fat.⁸
- Seafood consumption is linked to improved coronary health in adults and to improved cognitive and visual development in infants and children.⁸ Eating seafood regularly can decrease risk of heart attack, stroke, and high blood pressure.⁸
- For good health, consumers should eat 8 or more ounces per week of a variety of seafood types. A daily EPA+DHA intake of at least 250mg is recommended for most people, increased to 1000mg for people with cardiovascular disease.⁸

Tips for High-Risk Persons

WHEN PREPARING AND EATING SEAFOOD:

Abstain from eating raw or partially-cooked seafood, especially oysters and clams.^{5,17} Instead, enjoy thoroughly cooked seafood for its delicious taste and important health benefits.

Purchase seafood only from reputable sources.⁸ Purchase only shellfish whose shells are closed. Before cooking, discard any shellfish with shells already open.^{3,4}

Refrigerate seafood below 40⁰F until use to prevent the exponential growth of *Vibrio* and any other pathogens present into an infectious dose.^{8,9}

Wash hands before and after handling raw or cooked seafood.^{3,8} Avoid contact between a wound and seafood or its drippings.³ Take care to prevent sustaining a wound when handling raw seafood and when shucking shellfish, and immediately wash any wounds sustained then cover them with an impermeable bandage.³

Prevent contact between cooked seafood and raw seafood or its drippings.^{3,8,11} Wash utensils and surfaces before reusing to prevent cross-contamination.^{8,9} After kitchen surfaces are washed, sanitize them with a product sold as a kitchen sanitizer.⁹

Cook seafood until it reaches an internal temperature of 145⁰F for at least 15 seconds.^{8,9} Increase temperature to 155⁰F for dishes like fishcakes and to 165⁰F for dishes like stuffed fish.⁹

For shellfish in the shell, either boil until shells open then continue boiling for another 3-5 minutes, or add to a steamer when water is already steaming then cook for another 4-9 minutes.^{3,4} Use small pots so that shellfish in the middle are cooked fully. Only eat shellfish that open during cooking, discarding any shellfish that do not open fully after cooking.^{3,4}

For shucked shellfish, either boil for at least 3 minutes, fry in oil for at least 3 minutes at 375⁰F, broil 3 inches from heat for 3 minutes, or bake at 450⁰F for at least 10 minutes.^{3,4}

Seek immediate medical attention if you experience symptoms of illness following seafood consumption.³

WHEN WORKING OR RECREATING IN NATURAL WATERS:

Avoid contact between the water and cuts, burns, sores, or any other skin wounds.^{3,4,13} If water contact cannot be avoided, cover wounds with impermeable bandages.^{3,13}

Take precautions to prevent sustaining a wound while swimming, fishing, or participating in related activities. Carry potable water and soap or hand sanitizer to immediately clean any minor injuries that occur.^{3,13}

Wear gloves when handling raw seafood, crab pots, or other equipment.^{3,13} Wear water shoes to avoid cuts and scrapes.^{3,13}

Always shower after contacting natural waters, and wash hands before eating or handling food.¹³

Seek immediate medical attention if you experience symptoms of illness following contact between a wound and natural water.³

Other Pathogens Relevant to Shellfish & Recreational Water

In addition to *Vibrio*, there are many other pathogens that occur in marine waters and pose a potential threat to public health. Many of the pathogens of potential public health concern for

raw bivalve shellfish do not proliferate during post-harvest handling and storage, unlike *Vibrio* which can quickly increase in harvested product if strict temperature controls are not followed.²⁰ These pathogens and toxin-producing organisms, which originate and bio-accumulate to dangerous levels in shellfish waters, can be divided into two major categories: biotoxins produced by phytoplankton, and viral and bacterial pathogens from fecal contamination.

First, biotoxins produced by some marine algae species can cause serious illness if individuals consume bivalve shellfish which have concentrated these toxins or when individuals have contact with waterbodies experiencing harmful algal blooms. Nationally, five specific toxins of concern are associated with bivalve shellfish, and thresholds have been established to protect consumers. To mitigate the public health threat from biotoxins, states monitor waterbodies for these five specific toxins, as well as for other toxins whose thresholds have not been established but may cause shellfish-borne illness.²¹ Unlike bacterial and viral pathogens, biotoxins are not destroyed by cooking and can still pose a risk of gastrointestinal and neurological illness if present in cooked products.⁸

Second, contamination of waters with bacterial and viral pathogens from fecal sources can pose a significant public health threat, especially for pathogens originating from humans. Some of these pathogens can also cause infection through food contamination by infected workers; these pathogens include Norovirus, Hepatitis A virus, *Shigella spp.*, Enterohemorrhagic or Shiga Toxin-producing *Escherichia coli*, and *Salmonella typhi*.²² In particular, Norovirus is one of the most common pathogens found in water or shellfish impacted by human fecal contamination and has been implicated in illness outbreaks associated with bi-valve shellfish.²³ Norovirus infections are most frequently observed from November through April, with symptoms including diarrhea, vomiting, nausea and stomach pain.²³ Unlike biotoxins, viral and bacterial pathogens like Norovirus within shellfish can be killed by thorough cooking,^{12,13} although post-cooking cross contamination remains possible.

DNREC's Shellfish & Recreational Water Program

The mission of the Shellfish & Recreational Water Program of the Delaware Department of Natural Resources & Environmental Control (DNREC) is to prevent human illness from consumption of bivalve shellfish and from recreational contact with natural waterbodies. To mitigate the risk of pathogens which are associated with fecal contamination, fecal indicator bacteria (FIB) are monitored in recreational waters and shellfish growing waters to identify times when there may be an elevated risk to public health. For recreational waters, DNREC monitors waters for elevated levels of *Enterococcus* FIB and issues swimming advisories when high levels are found. The U.S. Environmental Protection Agency established that *Enterococcus* was one of two FIB for marine and freshwater recreational waters “that have consistently performed well as indicators of illness in sewage-contaminated waters during epidemiological studies.”²¹ Similar to recreational waters, states are also required to conduct FIB monitoring of shellfish growing areas using either Fecal or Total Coliform bacteria.²⁴ The sampling results are used to classify waters as approved or prohibited for shellfish harvest, and these harvest classifications are assessed annually to identify changes in water quality trends. These monitoring strategies are effective in identifying long term trends in water quality, but other monitoring for fecal contamination originating from isolated events such as waste water treatment plant failures and bypasses, illegal discharges from vessels, and other potential anthropogenic sources is conducted by state resource managers to evaluate public health risk.

Vibrio bacteria are not sampled as part of this process, because they are a natural part of the estuarine ecosystem and so cannot be mitigated through shellfish harvest classifications and swimming advisories. In Delaware, *Vibrio vulnificus* poses the greatest risk to individuals who contract wound infections through injury or wound exposure to natural marine waters. Currently there is no established recreational water quality criteria for *Vibrio* infections, which underscores the importance of education to reduce the risk of illness.

In bivalve shellfish, *Vibrio* can quickly increase to dangerous levels following harvest if proper precautions are not followed. To mitigate the risk of shellfish-borne *Vibrio* infections, DNREC establishes time-to-temperature requirements for bivalve shellfish through the State's annual *Vibrio parahaemolyticus* (Vp) management plan. This plan establishes the timeframes and restrictions that shellfish harvesters and dealers must follow during months with increased risks of elevated *Vibrio* levels, currently June through September depending on the body of water from which the shellfish were harvested. Though there has never been a confirmed *Vibrio* illness linked to shellfish harvested from Delaware waters, risk assessments identify Vp as the primary *Vibrio* pathogen of concern, which is why the state implements a Vp management plan during warmer months. The bivalve shellfish industry works diligently to follow these requirements and to keep their products safe for raw consumption by healthy persons, if consumers are equipped with the education to keep shellfish products safe after purchase.

Conclusion

Vibrio is an opportunistic pathogen that is naturally occurring in salt/brackish water and in uncooked seafood, especially oysters. Human infection can occur after an open wound is exposed to water or seafood containing *Vibrio*, or after uncooked seafood is consumed that contains *Vibrio*. While vibriosis is uncommon overall and is typically not serious in healthy people, in high-risk persons, especially those with liver problems, infection can be life-altering, if not lethal. Because of the rapid progression, limited effective treatment, and high mortality rate for vibriosis in high-risk individuals, infection prevention is of paramount importance. Yet, patient knowledge of how to avoid infection remains low.

Healthcare providers are the front lines of patient education on vibriosis, and we urge you to inform high-risk patients to not eat raw seafood and to prevent contact between a wound and seawater. Through this education, you can save lives.

Disclaimer: The information contained in this article is provided for information only. This information does not constitute medical advice, and it should not be relied upon as such. The Delaware Department of Natural Resources and Environmental Control (DNREC) does not engage in the practice of medicine. DNREC, under no circumstances, recommends particular treatments for specific individuals, and in all cases recommends that you consult your physician before pursuing any course of treatment.

Correspondence: Andrew Bell, Andrew.bell@delaware.gov

References

1. Centers for Disease Control and Prevention. (2017). Vibriosis (any species of the family *Vibrionaceae*, other than toxigenic *Vibrio cholerae* O1 or O139): 2017 case definition. <https://wwwn.cdc.gov/nndss/conditions/vibriosis/case-definition/2017/>

2. University of Georgia Marine Extension and Georgia Sea Grant. (2017). Your gateway to information on *Vibrio vulnificus* infection from consumption of raw shellfish or marine-related wounds. Safeoysters.org. <http://www.safeoysters.org/>
3. Centers for Disease Control and Prevention. (2019). *Vibrio* species causing vibriosis. <https://www.cdc.gov/vibrio/index.html>
4. Interstate Shellfish Sanitation Conference. (n.d.). The risk of eating raw molluscan shellfish containing *Vibrio vulnificus*: Advice for persons with liver disease, diabetes, or weakened immune systems. Issc.org. <http://www.issc.org/Data/Sites/1/media/Education/VvFactSheet.pdf>
5. Interstate Shellfish Sanitation Conference. (n.d.). *Vibrio vulnificus* fact sheet for health care providers. Issc.org. <http://www.issc.org/Data/Sites/1/media/Education/VvFactSheet.pdf>
6. Food and Agriculture Organization of the United Nations. (2005). Microbiological risk assessment series no.8: Risk assessment of *Vibrio vulnificus* in raw oysters: Interpretive summary and technical report. Fao.org. <http://www.fao.org/3/a0252e/a0252e00.pdf>
7. Baker-Austin, C., & Oliver, J. D. (2018, February). *Vibrio vulnificus*: New insights into a deadly opportunistic pathogen. *Environmental Microbiology*, 20(2), 423–430. Retrieved from <https://sfamjournals.onlinelibrary.wiley.com/doi/full/10.1111/1462-2920.13955>
[PubMed https://doi.org/10.1111/1462-2920.13955](https://doi.org/10.1111/1462-2920.13955)
8. Seafood Health Facts. (n.d.). Seafood for health: Information for healthcare providers. <https://dev-seafoodhealthfacts.pantheon.io/sites/default/files/final-seafood-health-reference-guide-for-professionals.pdf>
9. US Food and Drug Administration. (2012). Bad bug book: Handbook of foodborne pathogenic microorganisms and natural toxins. <https://www.fda.gov/media/83271/download>
10. Center for Food Safety and Applied Nutrition, US Food and Drug Administration. (2005, July). Quantitative risk assessment on the public health impact of pathogenic *Vibrio parahaemolyticus* in raw oysters. <https://www.fda.gov/media/77879/download>
11. Interstate Shellfish Sanitation Conference. (n.d.). *Vibrio vulnificus* and diabetes. <http://www.issc.org/Data/Sites/1/media/education/vibrio%20vulnificus%20and%20diabetes.pdf>
12. Food and Agriculture Organization of the United States. (2019, May). GLOBEFISH – information and analysis on world fish trade: Bivalves market very positive. <http://www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1136590/>
13. Brohawn, K. (2019). Marylander’s guide to skin wounds and water contact. <https://mde.maryland.gov/PublicHealth/Documents/Vibrio-Citizens-Fact-Sheetrev2019.pdf>
14. Centers for Disease Control and Prevention. (2016, May). National enteric disease surveillance: COVIS annual summary, 2014. <https://www.cdc.gov/nationalsurveillance/pdfs/covis-annual-summary-2014-508c.pdf>
15. Lauria, M. (2018, Aug 2). Warnings lag in mid-Atlantic as deadly marine bacteria increases threat in summer. <https://www.delawareonline.com/story/news/local/2018/08/29/vibrio-vulnificus-everlasting-threat-summertime-water-enthusiasts/923886002/>

16. Interstate Shellfish Sanitation Conference. (n.d.). *Vibrio vulnificus* and liver disease. <http://www.issc.org/Data/Sites/1/media/education/vibrio%20vulnificus%20and%20liver%20disease.pdf>
17. Brohawn, K. (2019). *Vibrio* infections: Information for health care providers. https://mde.maryland.gov/PublicHealth/Documents/Vibrio_Providers_Final4,rev2019.pdf
18. Delaware Dept of Health and Social Services, Division of Public Health. (2011, June). *Vibriosis (non-cholera Vibrio species infection)*. <https://dhss.delaware.gov/dhss/dph/files/vibriofaq.pdf>
19. Texas, A., & University, M. (2016, Jun 30). Texas A&M Corpus Christi *Vibrio* expert discusses flesh-eating bacteria found in Gulf of Mexico. https://tamucc.edu/news/2016/06/060316%20Vibrio_Buck%20WEB.html#.X4iNPnUpDb2
20. Interstate Shellfish Sanitation Conference. (2018). *National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish 2017 Revision*, 375.
21. US Environmental Protection Agency. (2012). *Recreational Water Quality Criteria*, 9.
22. Interstate Shellfish Sanitation Conference. (2018). *National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish 2017 Revision*, 104.
23. Centers for Disease Control and Prevention. (2019). *Norovirus*. <https://www.cdc.gov/norovirus/index.html>
24. Interstate Shellfish Sanitation Conference. (2018). *National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish 2017 Revision*, 53.

Copyright (c) 2021 Delaware Academy of Medicine / Delaware Public Health Association.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.