Summer 2024

Comes in Waves: Clinical Overview of Vibrio Species

Natalie M. Prosser, MS

Comes in Waves: Clinical Overview of *Vibrio* Species

Natalie M. Prosser, MS

LS 803 Contemporary Topics in Research, Medical Laboratory Sciences Program, Medical Laboratory Sciences and Biotechnology Department, Jefferson College of Health Professions, Thomas Jefferson University, Philadelphia, PA

KEYWORDS

Oceanic Bacteria
Vibrio
Vibriosis
Cholera
Necrotizing fasciitis

ABSTRACT

Earth's oceans, despite their beauty and vast ecosystems, pose numerous threats to marine life and humans living along the coastline. *Vibrio* species (spp.) is a common species of oceanic bacteria native to coastal and brackish waters. This bacterium is capable of causing various degrees of human disease among different populations. Three clinically significant species of *Vibrio* include *Vibrio vulnificus, Vibrio parahaemolyticus,* and *Vibrio cholera*; all three species share virulence factors, but each are capable of causing varying degrees of vibriosis infections. Vibriosis infections include but are not limited to wound infections, necrotizing fasciitis, and gastroenteritis. In particular, *Vibrio cholerae* serotypes O1/O139 are responsible for a unique form of vibriosis, widely known throughout history as Cholera. This review will provide a historical overview of the species itself, and an examination of modern studies to discuss *Vibrio* species, its prevalence, and the spectrum of illness.

Introduction

Earth's oceans, despite their beauty and vast ecosystems, pose numerous threats to marine life and humans living along the coastline. Although some dangers are more well known and visible than others, such as sharks and riptides, there are other threats that are even more dangerous and invisible to the naked eye that must be considered. *Vibrio* species (spp.) is a common genus of oceanic bacteria that is native to coastlines and brackish waters. Although naturally found in these areas, *Vibrio* spp. are pathogenic to humans and exhibit strong virulent traits that have labeled these species a threat to both normal and vulnerable populations.

Vibrio spp. Background Information

Part of the *Vibrionaceae* family, *Vibrio* spp. is a naturally occurring genus of bacterium found along coastal and brackish waters of the United States and other coastlines around the world. *Vibrio* spp. is characterized as facultative anaerobic, halophilic, motile, oxidase positive, and gram-negative rod-shaped bacterium responsible for causing various types of infections, termed vibriosis, in both humans and aquatic life. One unique feature of this species is that it is halophilic, meaning this species tolerates and thrives in high concentrations of salt (ScienceDirect, n.d., Halophile). Although motile on their own, *Vibrio* is more commonly found hitching a ride on various forms of aquatic plankton that are plentiful within our oceans.

This bacterium is vital to the oceanic and aquatic ecosystems, as *Vibrio* spp. is a major factor in the biogeochemical cycle that coastal and brackish water sources depend on (Huang et al., 2021). Recent revelations have unveiled a potential emergence pattern of *Vibrio* as well, as it is more commonly found along coastal waters when sea surface temperatures begin to rise. As the northern hemisphere begins to warm for the spring and summer months, it has been proven that *Vibrio* is more commonly cultured between the months of May and October compared to the rest of the months throughout the year (CDC, 2024). In addition to warmer waters contributing to the prevalence of *Vibrio* species, oysters and shellfish are natural hosts of *Vibrio* spp. As aquatic plankton travel through the ocean, they are filtered and eaten by shellfish and other aquatic life. *Vibrio* bacteria will attach itself to the chitin of plankton, most commonly zooplankton, for nutritional needs and replication, acting as a reservoir for various *Vibrio* species (Vezzulli et al., 2016). Due to the plankton being filtered fed through shellfish, the *Vibrio* spp. catching a ride on the plankton, become lodged in the shellfish, resulting in the proliferation of *Vibrio* in oysters and other shellfish

Vibrio spp. of Clinical Importance

There are over 100 recognized species of *Vibrio* as of the year 2024. According to the CDC, over 20 different species of *Vibrio* can cause human illness, and the three most common species of *Vibrio* isolated from the United States include *Vibrio vulnificus*, *Vibrio parahaemolyticus*, and *Vibrio alginolyticus* species (CDC, 2024). This review paper will discuss three clinically significant isolates of *Vibrio*, including *Vibrio vulnificus*, *Vibrio parahaemolyticus*, and *Vibrio cholerae*, as well as an in-depth discussion regarding *Vibrio cholerae* serotype O1/O139, the strain responsible for Cholera epidemics throughout history.

Vibrio vulnificus

Since its discovery in 1964 by the CDC, *Vibrio vulnificus* is not only one of the most commonly isolated species, but it is the most pathogenic and virulent species of *Vibrio*. *V. vulnificus* is the deadliest species of *Vibrio*, according to the CDC, as one in five vibriosis cases caused by *V. vulnificus* is fatal, with some patients perishing within 48 hours of symptom onset (CDC, 2024). *V. vulnificus* is responsible for causing wound infections that can lead

Corresponding Author: natalie.prosser@students.jefferson.edu

to necrotizing fasciitis, gastroenteritis infections, and has the potential to cause sepsis (Janda et al., 2015). This species is most commonly transmitted via exposing wounds to oceanic or brackish waters, and via the consumption of raw oysters, leading to gastroenteritis and other GI related symptoms (Choi & Choi, 2022).

V. vulnificus is one of the most common and most fatal culprits regarding foodborne illness. According to Baker-Austin & Oliver the fatality and virulence of this pathogen is so severe, that *V. vulnificus* infections can be related to biological warfare organisms; "This striking case fatality rate (CFR) is similar to a range of category Biosafety Level (BSL) 3 and 4 pathogens, such as anthrax, bubonic plague, Ebola and Marburg fever" (2017). However, it has been confirmed that *V. vulnificus* related deaths are most prevalent among patients who had previous health conditions prior to contracting vibriosis. Some recognized health conditions related to the more severe and fatal cases include a history of liver disease, cirrhosis, or hepatitis, hemochromatosis, diabetes, and various diseases resulting in the patient becoming immunocompromised (Choi & Choi, 2022).

Vibrio parahaemolyticus

Vibrio parahaemolyticus since its discovery off the coasts of Japan in the 1950s, is the most contracted species of *Vibrio* and is the leading cause of GI related vibriosis (Bonnin-Jusserand et al., 2017). *V. parahaemolyticus* is responsible for causing a wide spectrum of disease, from gastroenteritis, wound infections, and even sepsis. According to Janda et al., *V. parahaemolyticus* is the most common cause of foodborne related vibriosis in the United State and on a global scale; "*V parahaemolyticus* is the most common cause of foodborne vibriosis in the United States and is a leading cause of food-associated gastroenteritis in many countries, including Japan and Taiwan, where culinary habits often involve the consumption of raw seafood or fish as part of the daily diet" (Janda et al., 2015).

The most common method of transmission of *V. parahaemolyticus* is via consumption of raw or undercooked seafoods, including but not limited to clams, mussels, and most commonly oysters. Transmission of this species of *Vibrio* is commonly seen during the warmer months between May and October, due to this species thriving in warmer water temperatures (CDC, 2024). The primary virulence factor of this species is the cytotoxin thermostable direct hemolysin (TDH), the toxin thought to be directly related to gastroenteritis symptoms. TDH is seen in 88% to 96% of clinically recovered specimens but is only naturally found in 1% of *V. parahaemolyticus* species (Rezny & Evans, 2023). There is no universal treatment for vibriosis infections associated with *V. parahaemolyticus;* treatments include supportive care, drinking fluids, and rest without the need of additional treatment.

Vibrio cholerae

Vibrio cholerae is the species of *Vibrio* responsible for the easily transmitted deadly disease, Cholera. Cholera is a highly contagious, gastrointestinal disease responsible for pandemics and death within communities over the last few hundred years. Cholera epidemics have been seen throughout the world, with the outbreaks being unpredictable and with high morbidity and mortality rates. Prior to medical interventions, the mortality rate for severe Cholera was greater than 50%, with this rate being higher in women and children (Rodriguez et al., 2024). Not all serotypes of *V. cholerae* cause Cholera pandemics; however, only serotypes O1 and O139 cause severe Cholera outbreaks in regions (Rodriguez et al., 2024).

V. cholerae is transmitted via the fecal oral route due to ingestion of contaminated food or water, direct contact with sick individuals, and fomites. Although all individuals have an equal chance of contracting Cholera, those with type O blood are more likely to develop severe Cholera compared to those with other blood groups (Conner et al., 2016). Despite *V. cholerae* infections being severe, the species itself has a weak spot with low acid tolerance. According to Rodriguez et al., in order for *V. cholerae* to cause infection, a large inoculum is required for some bacteria to pass through the stomach and reach the large intestine (2024).

Diagnosis of *V. cholerae* is primarily achieved in the clinical setting, with confirmatory testing taking place in the laboratory. Confirmatory testing for *V. cholerae* includes isolating the bacteria from the stool, polymerase chain reaction (PCR) testing, and rapid tests (Rodriguez et al., 2024). Acute infections are treated with supportive care of pushing fluids and plenty of rest, with antibiotic care following behind. According to Rodriguez et al., it is suggested to begin antibiotic therapy after the patient is rehydrated properly and vomiting has ceased. Most patients with *V. cholerae* infections that are commonly treated with antibiotics are treated with tetracycline and doxycycline (2024).

Transmission

Vibrio spp. can be transmitted in two primary ways, including transmission via ingestion of raw seafood, or direct contact with contaminated water or seafood drippings with an open wound. The method of transmission directly correlates to the type of vibriosis infection that will develop, as well as providing potential hints as to what species of *Vibrio* is causing the infection. Individuals who ingest raw or undercooked shellfish, especially oysters, are at a higher risk of contracting GI related vibriosis infections (CDC, 2024). According to the Centers of Disease Control and Prevention (CDC), GI related vibriosis symptoms include stomach cramps, watery diarrhea, nausea, vomiting, fever, and chills (2024). The most common *Vibrio* species responsible for causing GI related vibriosis is *V. parahaemolyticus*. Vibriosis wound infections have similar symptoms, but also include symptoms specific to a wound or body site, including redness, pain, swelling, warmth, discoloration of skin, and discharge of fluids (CDC, 2024). The *Vibrio* species that will most likely lead to wound infections is *V. vulnificus*. There has been no evidence to indicate that *Vibrio* species is transmitted in any other methods, and person to person transmission has yet to be documented.

Pathogenicity & Virulence

Vibrio spp. is not only considered a health concern to vulnerable or immunocompromised populations, but *Vibrio* infections can also affect healthy, uncomplicated populations as well. *Vibrio* spp. is a pathogenic bacterium that has the capability to cause infections in humans via the use of their virulence factors. The presence of specific virulent factors in certain species of *Vibrio* will determine the severity of illness that specific species will cause. There are three

Corresponding Author: natalie.prosser@students.jefferson.edu

primary virulence methods *Vibrio* spp. use to invade human hosts and cause disease; these methods include adhesion factor, presence of a capsule and exterior polysaccharides, and cytotoxins (Huang et al., 2021).

Adhesion Factor

The ability to adhere to the surfaces of cells is one of the most important virulence factor a bacterium can possess, as it allows a surface for the bacterium to replicate and further invade other areas. “Adhesion is the prerequisite for pathogenic bacteria to cause disease to the body infection, and it is of great significance in invading the host and effectively exerting the virulence” (Huang et al., 2021). Adhesion factors of *Vibrio* spp. include the presence of fimbriae and cilia on the exterior, outer membrane proteins, lipopolysaccharides, and extracellular polysaccharides (Huang et al., 2021). Without the presence of adhesion factors, *Vibrio* would not be able to attach itself to the host, would not be able to proliferate, and would not be able to spread to different areas of the body.

Capsule & Polysaccharides

The presence of a capsule and polysaccharides are essential for the bacterium to survive and thrive in a host. The capsule is a crucial component in resisting host defenses and contributing to the life cycle of the bacterium. "The capsules, polymers that bacteria secrete near their cell wall, participate in numerous bacterial life processes and play a crucial role in resisting host immune attacks and adapting to their niche" (Gao et al., 1970). According to Huang et al., the high molecular weight of the capsule in *Vibrio* spp. allows the bacteria to evade host defenses and opsonization via complement proteins, resulting in increased survival rates of *Vibrio* in human serum compared to other species of bacteria (2021). Without a capsule, bacteria are more likely to be taken over by host defenses, resulting in lack of survival and proliferation of infection. In addition to the capsule, capsular or extracellular lipopolysaccharides are essential in bacterial survival and virulence. Lipopolysaccharides make up part of the extracellular matrix seen in gram-negative bacteria and are vital in the production of toxins. Huang et al. explain that lipopolysaccharides present in the extracellular matrix of gram-negative bacteria are one of the first factors in creating endotoxins (2021). With the use of both extracellular lipopolysaccharides and capsule, *Vibrio* spp. are able to effectively cause disease within the host while simultaneously evading the immune system.

Cytotoxins

The production of cytotoxins by bacteria is used exclusively to cause damage within the host and to ease proliferation of the bacteria. The production of cytotoxins can be correlated with increased virulence of a bacterium, relating to more severe infections. There are 5 unique toxins related to the virulence of *Vibrio* spp. These toxins include thermostable direct hemolysin (TDH), TDH-related hemolysin (TRH), *V. vulnificus* cytolytic toxin (VVC), cholera toxin (CT), and zona-linked toxin (Zot) (Huang et al., 2021).

Thermostable direct hemolysin (TDH) is a proliferative toxin seen in *Vibrio parahaemolyticus* species and is one of the primary causes of diarrhea in vibriosis infections. TDH is responsible for creating pores along the membrane of eukaryotic cells, resulting in cell damage and ultimately death (Huang et al., 2021). Due to the pore forming nature of the TDH toxin, TDH secretion will successfully cause diarrhea in the host by altering intracellular iron levels (Huang et al., 2021). TDH-Related Hemolysin (TRH) is a heat sensitive toxin seen in *V. parahaemolyticus* that also alters intracellular iron levels within host cells, this is achieved by the activation of chloride channels (Huang et al., 2021). Both TDH and TRH cytotoxins are responsible for causing diarrhea within the host due to iron fluctuations within host cells; in addition, TDH and TRH are used as markers when identifying *Vibrio parahaemolyticus* infections.

Vibrio vulnificus Cytolytic Toxin (VVC) is a cytotoxin that is only found in *Vibrio vulnificus* species and is one of the key virulence factors. VVC is an exotoxin that can be secreted out of cells, and according to Huang et al., is part of the cholesterol-dependent cytolysin of the pore-forming protein family (2021). VVC is responsible for generating an ion channel that allows intracellular ions to flow out of the cell, leading to the lysing of cells.

Cholera toxin (CT) is a cytotoxin only found in *Vibrio cholerae* species and is the primary pathogenic factor of *V. cholerae* strain O1/O139 (Huang et al., 2021). In addition to cytotoxin CT, *V. cholerae* also utilizes cytotoxin zona-linked toxin (ZOT). ZOT is essential for the adherence of mucosal cells to increase permeability of intestinal mucosa, allowing other toxins to seep into the intestine (Huang et al., 2021). Both ZOT and CT are virulence markers used for identifying *V. cholerae* infections.

Vibriosis Infections

Vibrio spp. can cause various types of infections ranging in degrees of severity and locations throughout the body. Before exploring the types of vibriosis infections, vibriosis is first broken down into two different categories: Cholera infections and non-Cholera infections. Cholera infections are particularly caused by the species, *Vibrio cholerae* strain O1/O139, which has been responsible for various endemics throughout history (Janda et al., 2015). Common non-Cholera *Vibrio* spp. infections are caused by all other species of *Vibrio*. These infection types include mild to severe gastroenteritis, invasive soft tissue infections that can lead to necrotizing fasciitis, and septicemia. Over 8,000 cases of vibriosis occur in the United States annually, and 75% of these cases are related to the consumption of raw or undercooked shellfish (Janda et al., 2015). This statistic is expected to rise, however, as Janda et al. explain that there has been an observed increase in foodborne related vibriosis infections in recent years. Nonfoodborne cases of vibriosis, however, although less common overall, are more prevalent along the coasts of the United States. According to Janda et al., around 97% of nonfoodborne related vibriosis infections have been narrowed down to the Gulf and Atlantic coasts of the United States (2015).

Gastroenteritis Related Vibriosis

Gastroenteritis caused by *Vibrio* species is the most common type of *Vibrio* related infection. GI related vibriosis infections are classified as non-cholera infections and the *Vibrio* species that are responsible for gastroenteritis related vibriosis include *V. parahaemolyticus, V. vulnificus, V. cholerae* non-O1 and non-O139,

Corresponding Author: natalie.prosser@students.jefferson.edu

and *V. fluvialis* (Janda et al., 2015). The most common causative species of GI vibriosis is *V. parahaemolyticus*, a commonly encountered species along coastal water. This species of *Vibrio* is related to foodborne illness, as *V. parahaemolyticus* is transmitted via ingestion of contaminated raw seafood or shellfish. Symptoms of GI related vibriosis include watery diarrhea, cramps, nausea, vomiting, fever and chills (CDC, 2024). Due to the symptoms of GI related vibriosis being similar to all other enteropathogenic infections, a proper vibriosis diagnosis is unlikely unless patient recreational history is considered, and specific laboratory tests are ordered. Gastroenteritis related vibriosis infections are typically mild to moderate, and do not require any medications or treatment; the only suggested treatment regarding GI related vibriosis is to drink extra fluids to prevent dehydration.

Wound Related Vibriosis

Vibriosis infections are not only limited to the gastrointestinal tract, as open wounds and sores can also become infected with *Vibrio* species. Current wound infections can be accentuated by a secondary *Vibrio* infection due to wounds coming in contact with contaminated coastal or brackish waters; and or new wounds can become infected with *Vibrio* due to penetrating injuries by an object contaminated with *Vibrio* spp. Symptoms of vibriosis related wound infections include fever, redness, pain, swelling, warmth, discoloration, and discharge from the affected area (CDC, 2024). The most common species of *Vibrio* associated with wound infections include *V. vulnificus, V. parahaemolyticus, V. cholerae* non-O1 and non-O139, and *P. damselae*, a pathogen previously classified as *Vibrio damselae* (Janda et al., 2015). The most common and the most severe species associated with wound infections is *V. vulnificus.*

Necrotizing Fasciitis & *V. vulnificus*

Vibrio vulnificus is one of the most virulent species of *Vibrio* and is the most likely species to cause necrotizing fasciitis, septicemia, and death in as little as 24 to 48 hours of symptom onset (Janda et al., 2015). Necrotizing fasciitis is defined as, "...a subset of aggressive skin and soft tissue infections (SSTIs) that cause necrosis of the muscle fascia and subcutaneous tissues" (Wallace & Perera, 2023). According to Janda et al., 50% of patients who have been diagnosed with a previous condition and have contracted a vibriosis related wound infection will develop necrotizing fasciitis compared to 3% of healthy individuals (2015). Wound related vibriosis infections require intense treatment with antibiotics. Depending on the severity of the infection and the status of the patient, surgery to remove dead tissue or amputation accompanied with an ICU stay may be considered.

Cholera

The term "Cholera" has been described in historical texts within the last few centuries, along with lists of symptoms, mortality and morbidity rates, and how geographic areas and populations were devastated by Cholera outbreaks. Cholera has been described in ancient texts originating from India and Greece, with the first pandemic originating from the Ganges Delta in Jessore, India in 1817 due to contaminated rice (History.com, Cholera, 2017). The species of *Vibrio* responsible for Cholera illnesses is the bacteria *Vibrio cholerae*, but only the serotypes O1 and O139 are capable of causing Cholera outbreaks. According to the World Health Organization, the serotype O139 has only been seen in sporadic cases and has not been identified outside the continent of Asia (WHO, n.d., Cholera). There has been a total of six Cholera pandemics since the discovery of the disease, with current endemic outbreaks currently taking place in over 120 countries today (History.com Editors, Cholera, 2017).

With the stigmas and fear surrounding Cholera, the lack of medical knowledge, and the concept of germ theory not being implemented until later, Cholera epidemics ravaged the globe since its discovery in the 1800s. Despite these limitations, physicians were able to present conclusions based on current evidence and previous knowledge from other outbreaks. Physicians at the time were able to narrow down how Cholera was transmitted and was able to conclude that Cholera is not contagious from person-to-person contact. This was confirmed via physicians discovering their lack of illness after tending to Cholera patients, as well as the father of epidemiology, John Snow, being able to trace endemic cases of Cholera to local wells and other public drinking sources in 1855 (Contagion, 2020). Due to lack of knowledge and public fear, there were harmful assumptions made by the population to excuse why individuals were getting sick with Cholera. It was unfortunately believed that those who contracted Cholera were engaging in physical and morally devious behaviors, had inferior cultural beliefs and practices, and were those who were of lesser social status (Contagion, 2020). These beliefs were further idealized as Cholera primarily spread in densely populated areas with low income.

Diagnosis

Proper diagnosis of vibriosis in patients is not as direct and simple as one would assume despite the advances in diagnostic techniques within the last century. However, studies have shown that cases of vibriosis are often misdiagnosed, or not considered a potential cause of illness in patients at all. According to Janda et al., only 31% of patients who contracted vibriosis were treated with the proper antimicrobial therapies at any point during their treatment and only 14% of vibriosis patients were treated correctly upon initial evaluation (2015). The misdiagnosis rate of vibriosis is so severe that statistics being published and discussed from hospitals are falsely decreased. Janda et al., states that due to the lack of proper diagnosis and care, laboratory confirmed cases are lower than the actual infection rate of *Vibrio* (2015). This essentially means that *Vibrio* is more common than what statistics and laboratories see. Lack of physician awareness and education about *Vibrio* species is one of the primary driving forces behind this large misdiagnosis gap. It is essential to consider the presence of *Vibrio* based on presenting symptoms and recent patient history.

Clinical Diagnostic Approach

Diagnosing a patient with a vibriosis infection requires two critical steps to rule in *Vibrio* species being a possible causative agent. The first step involves obtaining a patient history, this involves getting information about the patients' diet over the last few days, any recreational activities or recent vacations, any recent injuries both minor and major, and if the patient has been in an area where there was a recent natural disaster. The most important element regarding

patient history is whether or not the patient has had any recent contact with coastal or brackish waters or if the patient has eaten any raw shellfish within the last few days. According to Janda et al., 70% of *Vibrio* exposure has been linked to recreational activities in coastal or brackish water (2015). The second most vital step in catching a *Vibrio* related infection is recognizing clinical presentation of *Vibrio* specific diseases in patients. Being able to recognize the signs and symptoms and correlating it with the possibility of a vibriosis infection is critical in ruling out the pathogen and the subsequent disease.

Laboratory Diagnostic Approach

Diagnosis of vibriosis via laboratory methods can be tedious and difficult. *Vibrio* is very difficult to cultivate and requires specific agar, or enrichment media, to enhance growth for detection and testing. One medium commonly used to isolate and grow *Vibrio* species is thiosulfate-citrate-bile salts-sucrose agar (TCBS). TCBS specifically cultivates and differentiates *Vibrio* species. TCBS agar can differentiate various species of *Vibrio* based on whether the colony utilizes sucrose. The fermented sucrose will result in pigment production of the colonies for easy differentiation of species without molecular methods (Janda et al., 2015). Additional media can be used to cultivate *Vibrio* species as well, including gram-negative selective MacConkey (MAC) agar, or the enriched Blood Agar Plate (BAP). Despite cultivation and isolation of *Vibrio* being notoriously difficult, there are still no rapid diagnostic tests approved by the US Food and Drug Administration (FDA) for clinical diagnosis (Janda et al., 2015). However, there are rapid tests available for *V. cholera* strains O1 and O139, due to the severity and the capability of this species to cause epidemics. Rapid test methods include latex agglutination for serotype *V. cholerae* O1, as well as immunochromatographic and colorimetric tests to detect *V. cholerae* O1 and O139 serotypes (Janda et al., 2015). Additional rapid methods of *Vibrio* testing are available and approved for research only by the FDA.

At Risk Populations

Vibrio species is a commonly contracted pathogen that is seen throughout the United States and within various populations. However, there are certain populations that are more at risk for developing more severe vibriosis infections compared to the average healthy individual. Patients who have a history of being immunocompromised, liver disease or cirrhosis, cancer, diabetes, human immunodeficiency virus (HIV), and thalassemia are at higher risks of developing severe vibriosis infections (CDC, 2024). In addition to prior health conditions, patients who have recently had stomach surgery and who are actively taking stomach acid reducing medications are at a higher risk as well (CDC, 2024). Those who have had recent stomach surgery and those on stomach acid reducing medications are more likely to contract vibriosis due to the compromised state of the organ itself. With the stomach being compromised, *Vibrio* can more easily escape host defenses and head towards the intestine to cause disease. A recent study has found a direct correlation to specific patient populations and *Vibrio vulnificus* infection. According to Baker-Austin & Oliver, around 86% of patients who contracted *V. vulnificus* infections were male and over the age of 40, with these groups displaying a mortality rate of over 50% (2017). This study also noted that *V. vulnificus* infections were very rarely seen in younger populations aged 0 to 30 years old (Baker-Austin & Oliver, 2017).

Antibiotic Resistance

The severity of *Vibrio* spp. infections has led to physicians opting to last resort treatments such as antibiotics; however, the usage of antibiotics has led to resistant strains becoming more prevalent in clinical settings. According to Kitaoka et al., *Vibrio* species are normally susceptible to antibiotics commonly used in veterinary practice and strong antibiotic treatments in humans (2011). Additionally, Kitaoka et al. explains how there are several sources that have identified ampicillin resistance in both *V. vulnificus* and *V. parahaemolyticus* (2011). Aside from ampicillin resistance being commonly found in most species of *V. vulnificus* and *V. parahaemolyticus*, there are antibiotics that are still effective in reducing infection. The recommended antibiotics used to treat vibriosis caused by either species include doxycycline, cephalosporin, fluoroquinolone, trimethoprim/sulfamethoxazole, and aminoglycosides; additionally, tetracycline or ciprofloxacin are often used in cases of prolonged or severe *V. parahaemolyticus* infections (Kitaoka et al., 2011).

Regulation & Management

With infections caused by *V. vulnificus* being some of the most severe, each state that has seen vibriosis infections has developed an action plan. These action plans are to manage and regulate the infection prevalence within a community or area This is accomplished via public alerts, signs in heavy traffic areas in multiple languages, and shutting down areas where the bacteria is prevalent. It is recommended by the CDC that public health officials report all vibriosis cases through the National Notifiable Diseases Surveillance System (NNDSS) and inform residents and tourists in communities local to where *Vibrio* species has been isolated (CDC, 2023). In addition to action plans, the CDC has an accessible emergency preparedness and response plan for laboratories and healthcare professionals in the event of an outbreak. It is essential for state and local officials to take the threat of a *Vibrio* outbreak seriously to protect the population.

Summary of Conclusions

Vibrio species is a prominent oceanic and brackish water bacteria that is responsible for causing a wide spectrum of illnesses among various populations. *Vibrio* species infections range in pathogenicity and virulence, from gastroenteritis to necrotizing fasciitis, to non-Cholera to Cholera infections. Vibriosis can be debilitating and a potentially life-threatening illness without the proper treatment. It is vital for physicians to be aware of *Vibrio* species in general, what clinical signs to look for, and how patient history can be a key part in ruling in or ruling out a vibriosis infection. It is essential for federal systems to maintain awareness in the general population as well, provide educational material to the public regarding risk behaviors and symptoms of a potential infection, as well as notifying local areas of outbreaks to prevent illness. Public, physician, and laboratory awareness of *Vibrio* species and their subsequent infections is an essential component to keeping communities healthy and safe.

Corresponding Author: natalie.prosser@students.jefferson.edu

References

Baker-Austin, C., & Oliver, J. D. (2017). *Vibrio vulnificus*: New insights into a deadly opportunistic pathogen. Environmental Microbiology, 20(2), 423–430. https://doi.org/10.1111/1462-2920.13955

Bonnin-Jusserand, M., Copin, S., Le Bris, C., Brauge, T., Gay, M., Brisabois, A., Grard, T., & Midelet-Bourdin, G. (2017). *Vibrio* species involved in seafood-borne outbreaks (*V. cholerae*, *V. parahaemolyticus* and *V. vulnificus*): Review of microbiological versus recent molecular detection methods in seafood products. Critical Reviews in Food Science and Nutrition, 59(4), 597–610. https://doi.org/10.1080/10408398.2017.1384715

Centers for Disease Control and Prevention. (2024). About *vibrio* infection. Centers for Disease Control and Prevention. https://www.cdc.gov/vibrio/about/index.html

Centers for Disease Control and Prevention. (2023, August 31). Health Alert Network (HAN) - 00497. Centers for Disease Control and Prevention. https://emergency.cdc.gov/han/2023/han00497.asp

Choi, G., & Choi, S. H. (2022). Complex regulatory networks of virulence factors in *Vibrio vulnificus*. Trends in Microbiology, 30(12), 1205–1216. https://doi.org/10.1016/j.tim.2022.05.009

Cholera epidemics in the 19th century. Contagion - CURIOSity Digital Collections. (2020, March 26). https://curiosity.lib.harvard.edu/contagion/feature/cholera-epidemics-in-the-19th-century

Conner, J. G., Teschler, J. K., Jones, C. J., & Yildiz, F. H. (2016). Staying alive: *Vibrio cholerae*'s cycle of environmental survival, transmission, and dissemination. Microbiology Spectrum, 4(2). https://doi.org/10.1128/microbiolspec.vmbf-0015-2015

Gao, S., Jin, W., Quan, Y., Li, Y., Shen, Y., Yuan, S., Yi, L., Wang, Y., & Wang, Y. (1970, January 1). Bacterial capsules: Occurrence, mechanism, and function. PubMed Central (PMC). https://nam12.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.ncbi.nlm.nih.gov%2Fpmc%2Farticles%2FPMC10937973%2F&data=05%7C02%7CNatalie.Prosser%40students.jefferson.edu%7C887dd319c27c4371564608dcbc80ef63%7Ced4cf9769b924010a0b7a7222ba6cdef%7C0%7C0%7C638592509165885643%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=7dSSRORmQqHVlORvZSKdQ87trhUlnUn%2FqEXLamHgn4g%3D&reserved=0

Halophile. Halophile - an overview, ScienceDirect Topics. (n.d.). https://www.sciencedirect.com/topics/immunology-and-microbiology/halophile

History.com Editors. (2017). Cholera. History.com. https://www.history.com/topics/inventions/history-of-cholera

Huang, L., Gao, Q., Zhang, Y., Xu, W., & Yan, Q. (2021). Community change and pathogenicity of *vibrio*. Infections and Sepsis Development. https://doi.org/10.5772/intechopen.96515

Janda, J. M., Newton, A. E., & Bopp, C. A. (2015). Vibriosis. Clinics in Laboratory Medicine, 35(2), 273–288. https://doi.org/10.1016/j.cll.2015.02.007

Kitaoka, M., Miyata, S. T., Unterweger, D., & Pukatzki, S. (2011, April 1). Antibiotic resistance mechanisms of *Vibrio cholerae*. microbiologyresearch.org. https://www.microbiologyresearch.org/content/journal/jmm/10.1099/jmm.0.023051-0

National Centers for Coastal Ocean Science. (2018, April 26). NCCOS - *Vibrio* background. NCCOS | *Vibrio* Background. https://products.coastalscience.noaa.gov/vibrioforecast/#:~:text=Vibrio%20spp.,a%20high%20case%20fatality%20rate

Rezny, B., & Evans, D. (2023). *Vibrio parahaemolyticus* Infection. In StatPearls essay, StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK459164/.

Rodriguez, J., Hashmi, M., & Kahwaji, C. (2024) *Vibrio cholerae* infection. In StatPearls essay. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK526099/

Vezzulli, L., Grande, C., Reid, P. C., Hélaouët, P., Edwards, M., Höfle, M. G., Brettar, I., Colwell, R. R., & Pruzzo, C. (2016). Climate influence on *Vibrio* and associated human diseases during the past half-century in the coastal North Atlantic. Proceedings of the National Academy of Sciences, 113(34). https://doi.org/10.1073/pnas.1609157113

Wallace, H., & Perera, T. (2023) Necrotizing Fasciitis. In StatPearls essay, StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK430756/#:~:text=Necrotizing%20fasciitis%20is%20a%20subset,has%20a%20poor%20blood%20supply

World Health Organization. (n.d.). Cholera. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/cholera#:~:text=During%20the%2019th%20century%2C%20cholera,and%20the%20Americas%20in%201991.

Corresponding Author: natalie.prosser@students.jefferson.edu