

## *Shewanella algae* Infections in United States Naval Special Warfare Trainees

Matthew J. Bauer,<sup>1</sup> Kristi K. Stone-Garza,<sup>1</sup> Daniel Croom,<sup>2</sup> Cheryl Andreoli,<sup>3</sup> Peter Woodson,<sup>2</sup> Paul C. F. Graf,<sup>4</sup> and Ryan C. Maves<sup>1</sup>

<sup>1</sup>Division of Infectious Diseases, Department of Internal Medicine, Naval Medical Center, San Diego, California, USA, <sup>2</sup>Naval Special Warfare Center, Naval Amphibious Base Coronado, California, USA, <sup>3</sup>Navy Environmental and Preventive Medicine Unit FIVE, San Diego, California, USA, and <sup>4</sup>Division of Microbiology, Department of Laboratory Medicine, Naval Medical Center, San Diego, California, USA

*Shewanella* infections are uncommon in immunocompetent hosts. We report 6 cases of *Shewanella algae* infection in young, healthy Naval Special Warfare trainees in San Diego during 2 consecutive El Niño seasons, defining a unique population at risk and adding to the epidemiologic understanding of this potentially virulent organism.

**Keywords.** Naval Special Warfare; necrotizing fasciitis; *Shewanella algae*; *Shewanella* bacteremia; *Shewanella* species.

*Shewanella algae* is a Gram-negative, motile bacillus found ubiquitously in salt water reservoirs of warmer climates. It is an uncommon cause of human disease but may produce bacteremia, skin and soft tissue infections, or otitis media [1]. Infections rarely occur in colder marine climates or in healthy subjects. Naval Special Warfare (NSW) trainees undergo unique physiologic stresses during Basic Underwater Demolition/SEAL training (BUD/S), most notably during a continuous 5-day operational exercise on land and sea with minimal sleep, prolonged immersion in marine water, and limited hygiene known as “Hell Week.” We report 6 cases of infection with *Shewanella algae* in the NSW community that occurred over a 3-year period from 2014 and 2016 in Coronado, California. The NSW community may be at unique risk for infection with this pathogen, particularly during years with warmer water temperatures, and mitigation strategies are necessary to prevent further morbidity.

### CASE DESCRIPTION

A 26-year-old man on active duty in the US Navy presented to the emergency department with 5 days of watery diarrhea, 3 days of cramping right-sided abdominal pain, nonproductive cough with dyspnea on exertion, myalgias, left lateral thigh

pain, and bilateral lower extremity swelling with intertriginous abrasions of the groin and axilla. His symptoms developed on the last day of Hell Week and progressively worsened until the time of presentation. His vital signs were notable for a temperature of 38.1°C, blood pressure of 115/53 mmHg, respirations of 20/minute, heart rate of 99 beats/minute, and oxygen saturation of 95% while breathing room air. On examination, he had tender anterior cervical adenopathy, reduced bibasilar breath sounds, tenderness to palpation in the right lower quadrant, anasarca with scrotal edema, and bilateral inguinal and axillary abrasions with superficial ulceration, surrounding erythema, and purulent discharge. Labs were notable for a white blood cell (WBC) count of  $6.2 \times 10^3$  cells/ $\mu$ L with 82% neutrophils and 2% bands, hemoglobin 11.4 g/dL, lactate 2.4 mmol/L with an anion gap of 10 mmol/L, venous pH 7.34, albumin 2.6 g/dL, creatinine kinase 560 U/L, alanine aminotransferase 147 U/L, aspartate aminotransferase 82 U/L, and lactate dehydrogenase 445 U/L. Blood, sputum, and inguinal wound cultures were obtained. A respiratory virus panel was negative for influenza. Urinalysis demonstrated concentrated urine without pyuria or bacteriuria.

The patient underwent abdominal computed tomography (CT), which demonstrated an irregular wedge-shaped hypodense focus in the right kidney, gallbladder wall thickening, and bilateral pleural effusions with atelectasis, but no evidence of appendicitis. Chest radiography again demonstrated bilateral pleural effusions and bilateral linear opacities. He was admitted for further evaluation and started on vancomycin and piperacillin-tazobactam.

Within 15 hours, all 4 blood cultures were positive for Gram-negative rods. Groin wound culture showed mixed Gram-negative and Gram-positive organisms. Surveillance blood cultures cleared within 24 hours. He was continued on broad-spectrum antibiotics.

By the fifth day of hospitalization, his blood cultures were identified as *Shewanella algae*, sensitive to fluoroquinolones. His wound culture was growing *S. algae* in addition to *Streptococcus agalactiae*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, and methicillin-susceptible *Staphylococcus aureus* (MSSA), all sensitive to fluoroquinolones. Despite clearance of blood cultures, the patient had worsening left lateral thigh pain and fevers. Examination showed swelling, warmth, induration, and erythema in this area. Magnetic resonance imaging (MRI) of the left leg revealed a 6-centimeter, poorly defined fluid collection with adjacent muscle enhancement. Orthopedic consultation was obtained; drainage was not recommended at that time. The patient defervesced, his pain improved with supportive measures, and he was switched to oral levofloxacin after having received a total of 6 days of intravenous therapy. He was discharged to complete an additional 8 days of levofloxacin for a total antibiotic course of 14 days for *S. algae* bacteremia.

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Correspondence: Ryan C. Maves, MD, Naval Medical Center San Diego, 34800 Bob Wilson Drive, San Diego, CA 92134 (ryan.c.maves.mil@mail.mil).

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Six days after initial discharge, the patient had worsening left lower extremity pain and swelling in the area of his previously identified fluid collection. Examination revealed a palpable and fluctuant area at the left distal thigh with pain upon knee flexion. He underwent incision and drainage (I&D), where purulence and necrotic tissue were identified and debrided. He received vancomycin and piperacillin-tazobactam postoperatively for 5 days and was transitioned back to oral levofloxacin for an additional 10 days. Wound cultures obtained on antibiotics did not grow *Shewanella*; only coagulase-negative staphylococci were identified. Repeat blood cultures were negative. Within 2 weeks, he reported complete clinical resolution.

## METHODS

We identified 6 cases of *Shewanella algae* infection in our institution from 2014 to 2016. All 6 were male NSW trainees. The characteristics of each case are described in Table 1. During the time period in question, there were between 2500 and 3000 Navy trainees who entered BUD/S training, of whom approximately one-third generally complete training; the remainder are returned to other Navy assignments consistent with their prior training. All cases had their acute onset during Hell Week, although no 2 cases occurred in the same training cohort. No cases were admitted to hospitals other than our institution. All of the patients' exposures occurred in open coastal waters of the Pacific Ocean in Coronado, California. Regular water quality testing does take place in those waters; *Shewanella* was not identified during those periods of surveillance, however.

Bacterial identification was performed in all isolates by conventional overnight panels on MicroScan (Beckman Coulter) and API 20E and APE 20 NE (Biomerieux). Antimicrobial susceptibility testing was performed by Etest (Biomerieux) on Mueller-Hinton agar and interpreted using M100-S25 or S26 (Clinical and Laboratory Standards Institute) for non-*Enterobacteriaceae*.

At the time of these cases, *Shewanella algae* was not in the database of MicroScan or API. The isolate from the first case was initially identified as *Shewanella putrefaciens* by the MicroScan panel. The others initially failed to grow adequately on MicroScan for identification, possibly due to the lack of sufficient salt in the inoculum [2]. Similarly, both API 20E and API 20NE yielded identification of all isolates as *Shewanella putrefaciens* when inoculated with a suspension prepared in 0.85% saline. To differentiate between *S. putrefaciens* and *S. algae*, the isolates were grown at 42°C and in 6.5% NaCl broth [1]. All isolates were ultimately identified as *S. algae* and were susceptible to ciprofloxacin, piperacillin-tazobactam, ceftriaxone, gentamicin, meropenem, trimethoprim-sulfamethoxazole, and minocycline. The isolate from case #6 was additionally identified as *Shewanella algae* by matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry on Vitek MS (Biomerieux).

## DISCUSSION

*Shewanella* spp. are ubiquitous nonfermenting Gram-negative, motile bacilli that typically inhabit warm water and uncommonly cause human disease. Approximately 80% of human isolates contributing to disease are *Shewanella algae* [1]. Primary clinical syndromes typically develop after exposure to marine environments and include otitis media, skin and soft tissue infections (SSTIs) following local trauma, and uncomplicated bacteremia, which is usually benign but may be fulminant in immunocompromised hosts [3, 4]. There are rare reported cases of necrotizing fasciitis (including this series), discitis, meningitis, biliary infection, pneumonia, and endocarditis [3, 5]. Many infections, especially skin infections, are polymicrobial—a finding reflected in our patients—but prior reports of monomicrobial infections with *Shewanella* spp. have established the organism as causal in many cases, confirming its pathogenicity [3, 6].

Its pathogenicity is presumed secondary to the presence of beta-hemolysins [1], virulence factors such as siderophores, biofilm production, and iron chelating compounds [7]. *Shewanella* spp. are also considered a possible reservoir and/or vehicle for antimicrobial resistance. Although they are typically susceptible to aminoglycosides, carbapenems, and fluoroquinolones, they have variable resistance to ampicillin and cephalosporins, and carbapenem resistance has been reported. Recently, identification of genes for carbapenem and quinolone resistance (*bla*<sub>OXA</sub> and *qnr*, respectively), and even for colistin (*eptA* gene), has been reported in some *S. algae* isolates [7]. In conjunction with several cases of multidrug-resistant isolates of *S. algae*, this combination of factors is concerning [8].

Traditionally, those at risk for infection include men over 50 with malignancies or underlying cardiovascular, hepatobiliary, renal, respiratory disease who have been exposed to marine environments. Infections have also been identified recently in a cohort of migrants traveling via boat to the Canary Islands, in premature neonates, and in healthy individuals in areas of high seafood consumption [6, 8]. Infection in healthy hosts is uncommon; in a recent literature review, only 10% of patients lacked comorbid medical conditions [8]. Nearly all infections occur in warmer climates, including the Mediterranean, Southeast Asia, and the Caribbean, although extension outside of these traditional boundaries is increasingly recognized, including in our 6 cases reported in San Diego [1, 3, 5, 9].

In this case series, all patients were young men, had extensive exposure to the marine environment, experienced harsh conditions of sleep deprivation and environmental exposure, and had no underlying comorbidities. Of the 6 patients, all of them made full recoveries and returned to active duty in the Navy, including case #5, a 26-year-old man with necrotizing fasciitis of the left lower extremity complicated by septic shock, who ultimately completed BUD/S training following a protracted recovery and extensive extremity reconstruction. There were no

**Table 1. Cases of *Shewanella* Infection in Naval Special Warfare Trainees**

Case	Age, y	Clinical Syndromes	Site of <i>Shewanella</i> Isolation	Treatments (Listed Consecutively)
1	26	First admission <i>Shewanella algae</i> bacteremia; polymicrobial intertriginous groin wound infection ( <i>S. algae</i> , <i>Streptococcus agalactiae</i> , <i>Pseudomonas aeruginosa</i> , <i>Enterococcus faecalis</i> , <i>Staphylococcus aureus</i> )  Second admission - Left distal thigh abscess	- Blood culture - Groin wound culture  - <i>Shewanella</i> not identified (culture obtained on antibacterial therapy)	- Moxifloxacin for 1 d - Piperacillin-tazobactam + vancomycin for 6 d - Levofloxacin for 8 d  - I&D - Piperacillin-tazobactam + vancomycin for 5 d - Levofloxacin for 10 d
2	21	- <i>S. algae</i> and <i>P. aeruginosa</i> suppurative otitis media following ruptured right tympanic membrane	- Wound culture from right otic canal	- Failed oral amoxicillin and ciprofloxacin ear drops - Switched to oral ciprofloxacin for 14 d
3	21	- Multiple right lower extremity pretibial abscesses growing <i>S. algae</i> and <i>S. aureus</i>	- Wound culture from abscesses	- I&D with wound VAC - Cefazolin and vancomycin following I&D - Switched to oral clindamycin to finish a 14-d course
4	20	- Groin and bilateral lower extremity SSTI, polymicrobial ( <i>S. algae</i> , <i>S. aureus</i> , group G streptococci, <i>Acinetobacter haemolyticus</i> )	- Wound culture from lower extremity wound drainage	- Local wound care - 4 d of vancomycin and ceftriaxone - Switched to oral dicloxacillin for an additional 3 d
5	26	Polymicrobial necrotizing fasciitis of left lower extremity ( <i>S. algae</i> , <i>E. faecalis</i> , <i>Vibrio harveyi</i> ); <i>V. harveyi</i> bacteremia	- Operative wound cultures from debrided necrotic soft tissue	- Wide excisional debridement with split thickness skin graft of left lower extremity - Linezolid and meropenem for 7 d while in the ICU - Ceftazidime for 14 d
6	24	- <i>S. algae</i> , <i>S. aureus</i> , and <i>E. faecalis</i> polymicrobial bacteremia secondary to extensive SSTI involving the groin and bilateral lower extremities	- Blood culture - Groin and lower extremity wound cultures	- 14 d of IV daptomycin and ceftriaxone

Abbreviations: I&D, incision and drainage; ICU, intensive care unit; SSTI, skin and soft tissue infection; VAC, vacuum-assisted closure.

deaths or significant health sequelae in our patients, likely due in part to their excellent underlying health status.

Interestingly, these infections occurred in the normally colder waters of San Diego, which has an average ocean temperature of between 15.5°C and 20°C from April to October, but it should be noted that temperatures in the more protected San Diego Bay, where NSW trainees complete part of their training, are warmer, with average temperatures of 17.2°C to 21.7°C [10] from April to October. Additionally, review of weather data shows that the years 2014–2016 were host to consecutive El Niño seasons with water temperatures 2°C above the average [11]. We hypothesize that these environmental conditions, combined with a uniquely caustic training environment and the physiologic stress it creates, created ideal conditions for *S. algae* infection. In most cases, patients responded well to early wound debridement, if necessary, and to targeted antibacterial therapy.

NSW trainees undergo regular medical evaluations during training by on-site clinical staff, including wound checks;

surveillance programs track the incidence of SSTI, diarrhea, and respiratory disease. Following these cases, antimicrobial prophylaxis with oral doxycycline (administered as 100 mg daily, beginning 2 days before Hell Week and continuing for 7 days after its conclusion) has been implemented, as well as improvements in hygienic practices.

It is noteworthy that there have been no further cases of *Shewanella* infection in this population since these 6 cases, although the impact of these measures on all-cause SSTI incidence is as yet undetermined.

Our institution is the principal referral center for US military personnel in southern California and is in the same metropolitan area as NSW training; as such, it is unlikely that any cases of *Shewanella* infection in this population requiring hospital care were unrecognized in this study. We were unable to systematically evaluate the infecting strains and cannot comment on whether a single clone of *Shewanella* is responsible or whether there are unique pathogen-specific features that could account

for the syndromes seen in our series. The generalizability of our data is further limited by our study population; all NSW trainees are young, overwhelmingly male (and entirely male at the time of this series), and have high levels of baseline health; these individuals are then subjected to uniquely severe stresses and exposures.

Given global trends toward warmer water temperatures, *Shewanella* spp. may be considered an emerging pathogen in warming coastal climates. Conventional microbiologic diagnostics may have difficulty distinguishing *S. algae* from *S. putrefaciens*; high-saline media and MALDI-TOF may be necessary to improve diagnosis. For the NSW community, *Shewanella* may have special implications, as physiologic stress, water exposure, and injury to the skin barrier are commonplace. Novel strategies to reduce risk in this population will require further study.

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