Relative Frequency, Characteristics, and Antimicrobial Susceptibility Patterns of *Vibrio* spp., *Aeromonas* spp., *Chromobacterium violaceum*, and *Shewanella* spp. in the Northern Territory of Australia, 2000–2013

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Abstract. *Vibrio*, *Aeromonas*, *Chromobacterium violaceum*, and *Shewanella* (VACS) are water-associated Gram-negative organisms that can cause a variety of infections. The frequency, patient characteristics, and antimicrobial susceptibilities for 468 isolates from 442 patients from the Northern Territory were reviewed. *Aeromonas* spp. (312 of 468; 67%) were most commonly isolated followed by *Vibrio* spp. (71 of 468; 15%), *Shewanella* spp. (61 of 468; 13%), and *C. violaceum* (24 of 468; 5%). A strong male predominance was found (male to female ratio of 2.3:1). Skin and soft tissue isolations (373 of 468; 80%) from lower limb infections (222 of 371; 60%) were the most common clinical manifestation. The episodes were usually polymicrobial (281 of 468; 60%). Coisolates included *Staphylococcus aureus* (137 of 468; 29%), β -hemolytic streptococci (74 of 468; 16%), enterobacteriaceae (111 of 468; 24%), non-fermentative Gram-negative bacilli (35 of 468; 7%), and other VACS organisms (37 of 468; 8%). Antimicrobial resistance of VACS organisms to ciprofloxacin (0–4%), cefepime (0–3%), and gentamicin (0–0.8%) and *Vibrio* spp., *Aeromonas* spp., and *Shewanella* to cotrimoxazole (0–3%) was rarely shown. For water-associated lower limb skin and soft tissue infections in the tropics, clinicians should consider empirical antimicrobial therapy with agents active against *S. aureus* and VACS organisms.

INTRODUCTION

Vibrio spp., *Aeromonas* spp., *Chromobacterium violaceum*, and *Shewanella* spp. (VACS) are a group of oxidase-positive, Gram-negative organisms that occur naturally in aquatic environments.

Conditions that favor their survival include the warm ambient temperatures of the tropics, subtropics, and summers in more temperate regions. *Aeromonas* is the most ubiquitous, with a worldwide distribution, whereas *C. violaceum* reports have come exclusively from within 35° latitude of the Equator, including Florida and Louisiana in the United States.

Relative salinity also has a bearing on the prevalence of the organisms, with *Vibrio* spp., *C. violaceum*, and *Shewanella* spp. generally requiring estuarine or marine conditions, whereas *Aeromonas* spp. are also present in fresh water, including the drinking water of some countries.^{1–4}

These organisms can cause a variety of illnesses, including severe skin and soft tissue infections, gastroenteritis, and bacteremia: *V. vulnificus*⁵ and *Shewanella* spp.¹ are particularly associated with severe fulminant disease, especially in immunocompromised patients or those with underlying liver disease, and *Aeromonas* has been recognized as an important cause of infections in the aftermath of natural disasters, such as tsunamis.⁶

C. violaceum is the rarest of these organisms, with published literature restricted to case reports or small case series. It is thought to usually confer severe disease with poor outcomes when isolated.³ The best antimicrobial therapy has not been determined.

The Northern Territory comprises a land area of 1.2 million km², the majority of which is north of the Tropic of Capricorn. The region has a sparse population of 230,000. There are two climate zones: tropical in the north with distinct wet (November to April) and dry seasons (May to October) and semiarid in the far south.

The aim of this study was to compare the relative frequencies, characteristics, and antimicrobial susceptibilities of the VACS organisms isolated from patients presenting to the Northern Territory public hospital system.

METHODS

Using the common database of the public laboratory system, unique isolations of any VACS organism in the laboratories of Royal Darwin, Katherine, Tennant Creek, Alice Springs, and Gove Hospitals in the Northern Territory of Australia between January 1 2000 and December 31, 2013 were identified. Isolations of these bacteria are not all notifiable to public health. Studies with other pathogens suggest that the public hospitals' laboratories detect the majority (> 90%) of microbiological pathogens in the Northern Territory.⁷ Population prevalence was derived from Australian Bureau of Statistics data for the Northern Territory. Rainfall data were the average Northern Territory rainfall over the period from 2007 to 2013 (Australian Bureau of Meteorology).

Laboratory and clinical information was extracted from electronic databases. Isolates were originally identified by biochemical and phenotypic methods, including API 20NE (bioMérieux, France), MicroScan WalkAway (Dade MicroScan, Inc.), and Vitek 2 (bioMérieux, France), over the 14 years of the study.

Antimicrobial susceptibilities were interpreted using Clinical and Laboratory Standards Institute (CLSI) criteria where available (*Aeromonas* spp. and *Vibrio* spp.). For *Shewanella* spp. and *C. violaceum*, CLSI and The European Committee on Antimicrobial Susceptibility Testing (EUCAST) criteria are not available; therefore, *Pseudomonas aeruginosa* susceptibility criteria were used as indicative susceptibilities for the following antibiotics: piperacillin-tazobactam, meropenem, ceftazidime, cefepime, ciprofloxacin, and the aminoglycosides.

Statistical analysis was performed using χ^2 or Fisher exact tests where appropriate. This study was registered with the Human Research Ethics Committee (HREC) of the Northern Territory Department of Health and Menzies School of Health Research (HREC reference number QAAR 2014-2163).

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RESULTS

During the study period, 468 VACS isolates from 446 episodes involving 442 patients were identified. The median age of patients was 41 years (range = 0–81 years). Men accounted for 312 of 446 (70%) of the episodes (male to female ratio of 2.3:1).

Aeromonas spp. (67%; 9.9 of 100,000 population/year) were the most commonly isolated of the four organisms followed by *Vibrio* spp. (15%; 2.2 of 100,000 population/year), *Shewanella* spp. (13%; 1.9 of 100,000 population/year), and *C. violaceum* (5%; 0.76 of 100,000 population/year). Characteristics of the isolates and the patients are presented in Table 1.

Patients with *Vibrio* spp., *Shewanella* spp., and *C. violaceum* more commonly resided in coastal regions, particularly East Arnhem Land and the Tiwi Islands (Figure 1). Isolation of these organisms occurred rarely in patients attending Alice Springs (1.3%) and Tennant Creek (0.6%) Hospitals, which are both in arid Central Australia, where year-round rainfall is low and salt water is absent. *Aeromonas*, however, was isolated at all hospital locations, including Alice Springs (8%) and Tennant Creek (2.2%).

The highest number of *Aeromonas* infections occurred in April, and a reduction in isolates was observed during the

months of May to July. In contrast, year-round infection with less variability occurred with other VACS organisms (Figure 2).

The *Vibrio* spp. isolated were *V. parahaemolyticus* (25), *V. alginolyticus* (23), *V. vulnificus* (11), *V. fluvialis* (6), *V. cholera* (4), *V. metschnikovii* (1), and *V. mimicus* (1). *Aeromonas* spp. identified to species level were *A. caviae* (2), *A. hydrophilia* (103), *A. salmonicida* (3), and *A. sobria* (14). *Shewanella* spp. identified to species level were *S. algae* (29) and *S. putrefaciens* (31).

VACS organisms were primarily isolated from skin and soft tissue (80%) specimens. Other sites included blood (5.2%), feces (5.4%), intra-abdominal (1.3%), respiratory (3.6%), eye (1.7%), and urine (1.9%). The site of skin and soft tissue isolates was most commonly the lower limb (222 of 373; 60%).

Infections in men were more likely with *Vibrio* and *Shewanella* (77% and 84%, respectively) than with *Aeromonas* (68%) and *C. violaceum* (46%). Bacteremia was more common with *Vibrio* (particularly *V. vulnificus*) and *Shewanella* species (9.9% and 9.8%, respectively) than other VACS organisms. *Aeromonas* skin and soft tissue infections (83%) were more common than gastrointestinal infections (5%; $P < 0.01$).

C. violaceum epidemiology differed significantly with respect to sex, age, and site of isolation compared with the other

TABLE 1
Demographics, hospital location, and site of isolation of VACS bacteria

Parameter	Number of samples (% of total)				Total	P value
	<i>Vibrio</i> spp.	<i>Aeromonas</i> spp.	<i>C. violaceum</i>	<i>Shewanella</i> spp.		
No. of bacterial isolates	71 (15)	312 (67)	24 (5)	61 (13)	468 (100)	
Sex*						
Male	47 (77)	203 (68)	11 (46)	51 (84)	312 (70)	0.004
Age (years)*						
0–15	8 (13)	27 (9)	5 (21)	2 (3)	42 (9.4)	0.046
16–60	43 (70)	223 (74)	14 (58)	51 (84)	331 (74.2)	
> 60	10 (16)	50 (17)	5 (21)	8 (13)	73 (16.4)	
Total episodes	61	300	24	61	446 (100)	
Hospital location						
Darwin	51 (72)	216 (69)	20 (83)	54 (89)	341 (73)	
Gove	9 (13)	20 (6.4)	2 (8.3)	3 (4.9)	34 (7.3)	
Katherine	8 (11)	44 (14)	2 (8.3)	4 (6.6)	58 (12)	
Tennant Creek	1 (1.4)	7 (2.2)	0 (0)	0	8 (1.7)	
Alice Springs	2 (2.8)	25 (8)	0 (0)	0	27 (5.8)	
Total	71	312	24	61	468	
Specimen site						
Skin and soft tissue	52 (73)	260 (83)	11 (46)	50 (82)	373 (80)	< 0.001
Blood	7 (9.9)	11 (3.5)	0 (0)	6 (9.8)	24 (5.2)	0.031
Feces	6 (8.5)	16 (5.1)	3 (12.5)	0 (0)	25 (5.4)	0.032
Respiratory	2 (2.8)	4 (1.3)	7 (29)	4 (6.6)	17 (3.6)	< 0.001
Peritoneal	1 (1.4)	3 (1.0)	0 (0)	0 (0)	4 (0.9)	
Bile	0 (0)	2 (0.6)	0 (0)	0 (0)	2 (0.4)	
Bone	0 (0)	1 (0.3)	0 (0)	0 (0)	1 (0.2)	
Eye	1 (1.4)	6 (1.9)	0 (0)	1 (1.6)	8 (1.7)	
Urine	1 (1.4)	5 (1.6)	3 (12.5)	0 (0)	9 (1.9)	0.018
Genital tract	0 (0)	3 (1.0)	0 (0)	0 (0)	3 (0.6)	
Ear	1 (1.4)	1 (0.3)	0 (0)	0 (0)	2 (0.4)	
Total	71	312	24	61	468	
Skin and soft tissue site of lesion						
Lower limb	29 (56)	157 (60)	7 (64)	29 (58)	222 (60)	
Upper limb	8 (15)	38 (15)	2 (18)	10 (20)	58 (15.8)	
Torso	0 (0)	20 (7.7)	2 (18)	1 (2)	23 (6.3)	0.035
Head	2 (3.8)	14 (5.4)	0 (0)	2 (4)	18 (4.9)	0.035
Not recorded	13 (25)	31 (12)	0 (0)	8 (16)	52 (13.9)	
Total	52	260	11	50	373	
Additional focus	2 (3)	1 (0.3)	0 (0)	2 (3)	5 (1.1)	

In patients with coexistent VACS isolates, ages were assigned to *C. violaceum* initially and then *Shewanella* spp., *Vibrio* spp., and *Aeromonas* spp. isolates to avoid duplication counting of patient ages. Four patients had two discrete temporally separated episodes of VACS isolations during the time period of the study. Two patients had two episodes of a *Shewanella* sp. and an *Aeromonas* sp. isolation. One patient had two episodes: one *Vibrio* sp. and one *Shewanella* sp. One patient had two episodes of *Aeromonas* sp. detection.

*Data from 441 patients and 446 patient episodes. One patient with *Vibrio* spp. detected was of unknown age.

FIGURE 1. Prevalence by geographic distribution of salt water bacterial (*Vibrio* spp., *Shewanella* spp., and *C. violaceum*) infections in the Northern Territory from 2000 to 2013. Prevalence of 10,000 population per year.

organisms: patients were more evenly matched for sex (male to female ratio of 0.85); infections occurred more commonly in children (25%); and isolates from feces (12.5%), respiratory samples (29%), and urine (12.5%) were more frequent. *C. violaceum* was also more commonly isolated from patients in the intensive care unit (ICU) (6; 25%) than *Vibrio* spp. (3; 4.1%), *Aeromonas* spp. (13; 4.2%), or *Shewanella* spp. (4; 6.6%; all $P < 0.05$).

Coisolation of other bacteria (Table 2) was present in 281 of 468 (60%) VACS isolations and included *Staphylococcus aureus* (137 of 468; 29%), β -hemolytic streptococci (74 of 468; 16%), non-fermentative Gram-negative bacilli (35 of 468; 7%), enterobacteriaceae (111 of 468; 24%), anaerobes (22 of 468; 5%), enterococci (8 of 468; 2%), and other VACS organisms (42 of 468; 8.9%).

Gram positives (56; 72%) were more commonly coisolated than aerobic Gram negatives (17; 25%) and other VACS organisms (13; 23%) for *Vibrio* spp. and *Shewanella* spp., whereas aerobic Gram negatives (39%) and Gram positives

(42%) were both commonly isolated with *Aeromonas* spp.; other VACS organisms were uncommon (4%). *S. aureus* was less commonly coisolated with *Aeromonas* spp. (24%) and *C. violaceum* (8%) than with *Shewanella* spp. (51%) and *Vibrio* spp. (41%). Anaerobes were coisolated with *Aeromonas* spp. (4%) and *Shewanella* spp. (7%).

The antimicrobial susceptibilities for the VACS organisms against a range of antibiotics are shown in Table 3.

For *Vibrio* spp., *Aeromonas* spp., and *Shewanella* spp. isolates, resistance was rarely detected to the oral agents ciprofloxacin (0–4%) and cotrimoxazole (0–3%). Only small numbers of isolates were tested against the tetracyclines. Resistance to gentamicin was rare (0–0.8%) but occasionally found for tobramycin (0–5%). All isolates were susceptible to amikacin. *In vitro* resistance to ceftazidime (0–5%), piperacillin-tazobactam (0–11%), cefepime (0–3%), and meropenem (0–8%) was uncommon. Of a subgroup of *Aeromonas* isolates, 80 of 144 (56%) showed inducible ampC β -lactamases, and 5 of 93 (5%) showed inducible carbapenem resistance.

For *C. violaceum*, all isolates had inferred susceptibility to ciprofloxacin, gentamicin, and meropenem. Resistance to ceftazidime (62%), amikacin (17%), tobramycin (29%), and cotrimoxazole (14%) was found, though the numbers were small.

DISCUSSION

In this comparative study, we found *Aeromonas* spp. to be the most frequently isolated of the VACS organisms (67%). *Vibrio* spp. (15%), and *Shewanella* spp. (13%) were more commonly isolated than *C. violaceum* (5%), a rarely reported but important pathogen. The rates of *Aeromonas* (9.9 of 100,000 population/year) and *Vibrio* (2.2 of 100,000 population/year) found in this study are higher than those reported in France⁸ (*Aeromonas*: 0.25 of 100,000 population/year) and the United States⁵ (*Vibrio*: 0.42 of 100,000 population/year), although true rates are difficult to determine in the absence of

FIGURE 2. Seasonal isolation of VACS organisms in the Northern Territory from 2000 to 2013.

TABLE 2
Presence of coexistent bacterial isolates

Copathogen	Number of isolates (%)				P value
	<i>Vibrio</i> spp.	<i>Aeromonas</i> spp.	<i>C. violaceum</i>	<i>Shewanella</i> spp.	
Total	40 (56)	188 (60)	12 (50)	41 (67)	
More than one organism	21 (27)	129 (41)	7 (29)	24 (39)	
<i>S. aureus</i>	29 (41)	75 (24)	2 (8)	31 (51)	< 0.001
β-Hemolytic streptococci	11 (15)	48 (15)	2 (8)	13 (21)	
Non-fermentative Gram negatives	3 (4)	23 (7)	4 (16)	5 (8)	
Enterobacteriaceae	6 (8)	100 (32)	1 (4)	4 (7)	< 0.001
Anaerobes	0 (0)	18 (6)	0 (0)	4 (7)	
Enterococci	0 (0)	8 (3)	0 (0)	0 (0)	
<i>Acinetobacter</i>	0 (0)	5 (2)	0 (0)	0 (0)	
Other VACS organisms	14 (23)	14 (4)	2 (8)	12 (20)	< 0.001

Twenty-four isolates of *C. violaceum* came from 24 episodes of *C. violaceum* detection. One patient had a coexistent *Vibrio* sp. detected, and one patient had a coexistent *Aeromonas* sp. detected. Sixty-one isolates of *Shewanella* spp. came from 61 episodes of *Shewanella* spp. isolation. Six episodes had a coexistent *Vibrio* sp. detected, five episodes had a coexistent *Aeromonas* sp. detected, and one episode had both an *Aeromonas* sp. and *Vibrio* sp. Seventy-one isolates of *Vibrio* spp. came from 61 episodes where *Vibrio* spp. were detected. Six episodes were with coexistent *Shewanella* spp., four episodes included coexistent *Aeromonas* sp., two episodes had a coexistent different *Vibrio* sp. detected, and one episode had both an additional *Vibrio* sp. and an *Aeromonas* sp. isolated. One episode coexisted with *C. violaceum*. Three hundred twelve *Aeromonas* spp. isolates arose from 300 episodes of *Aeromonas* spp. detection. In four episodes, *Vibrio* sp. was coexistent. In five episodes, *Shewanella* sp. was coexistent. In one episode, *C. violaceum* was coexistent. Two episodes included isolation of two distinct *Aeromonas* spp. Two additional episodes included multiple mixed VACS organisms.

mandatory laboratory reporting. The number of *C. violaceum* isolates that we report (24) is also the largest to date.

Consistent with their similar environmental and phenotypic characteristics, we found that individual VACS organisms share several epidemiological features. They occur with a striking predominance in adult males; skin and soft tissue sites are most likely to be involved, usually involving the lower limb, which is consistent with exposure during water-associated activities.⁹

Because this is the first study to compare the epidemiological characteristics of this group of organisms, the general applicability of our findings needs to be addressed. We believe, for the following reasons, that this study has generalizable validity. These features have previously been noted individually for all VACS organisms over wide geographical areas,^{1,3,9-14} and in the closest study available for comparison, similar proportions of *Aeromonas*, *Vibrio*, and *C. violaceum* were found in skin and soft tissue infections in Thailand.⁶

The male predominance, however, is not a feature of other skin infections, such as community-acquired, methicillin-resistant *S. aureus*.¹⁵ Possible reasons include a combination of factors, such as exposure-prone activities and contributing comorbidities, including alcoholism.¹⁶ Estrogen also has been postulated to play a protective role against the effects of *V. vulnificus* endotoxin.¹⁷

Infections are usually polymicrobial, particularly involving *S. aureus*, β-hemolytic streptococci, enterobacteriaceae, and other VACS organisms. Non-fermentative Gram negatives and anaerobes may also be present. This likely reflects wound inoculation with both the patient's own flora and those bacteria present in the aquatic environment.⁶

Aeromonas spp. were the most commonly isolated organisms, consistent with its global distribution and ability to survive in all forms of environmental water at a wide range of temperatures. The salt water organisms *Vibrio* spp., *C. violaceum*, and *Shewanella* spp. were more common in coastal areas, where estuarine activities are more likely to bring individuals into contact with these organisms.

Aeromonas and *Vibrio* were more commonly associated with skin infections than gastroenteritis in our setting, which has been previously reported⁸ in contrast to some other studies.¹⁶ Factors that may explain this are the high standards of safe drinking water available to our population and water temperatures that favor year-round growth of these organisms in recreational areas. It also likely that differing laboratory isolation practices for *Aeromonas* impact on the reported prevalence of gastroenteritis in a particular region.

Aeromonas infections were less common during the dry season months of May to July, when inland fresh water is scarce, but seem to peak at the end of the wet season, when

TABLE 3
Antibiotic susceptibility of VACS bacteria

Antibiotic	VACS bacteria isolates tested (% susceptible)			
	<i>Vibrio</i> spp.	<i>Aeromonas</i> spp.	<i>C. violaceum</i> *	<i>Shewanella</i> spp.*
Amikacin	34 (100)	164 (100)	6 (83)	17 (100)
Ampicillin	47 (26)	248 (0.4)	—	—
Amoxycillin-clavulanate	37 (92)	200 (40)	—	—
Ceftriaxone	37 (100)	198 (91)	—	—
Ceftazidime	43 (100)	182 (96)	8 (38)	22 (95)
Cefoxitin	33 (79)	171 (31)	—	—
Cephazolin	41 (27)	185 (9.7)	—	—
Ciprofloxacin	48 (100)	230 (99.1)	11 (100)	27 (96)
Cefepime	35 (97)	168 (99.4)	3 (100)	15 (100)
Gentamicin	53 (100)	272 (99.2)	11 (100)	28 (100)
Meropenem	44 (93)	201 (92)	8 (100)	24 (100)
Piperacillin-tazobactam	35 (100)	137 (82)	5 (100)	19 (89)
Tobramycin	40 (100)	197 (98)	7 (71)	20 (95)
Cotrimoxazole	49 (100)	256 (97)	7 (86)	22 (100)

*CLSI criteria were not available; results were inferred from *P. aeruginosa* breakpoints.

maximal groundwater is present. Other VACS infections occurred year-round in our setting in contrast to the pattern seen with *Vibrio* outside the tropics.⁹

We have not directly looked at clinical outcomes for these organisms, which is a limitation of this study. However, comparing rates of bacteremia gives an indication of whether illness severity differs between VACS organisms. *Vibrio* spp., particularly *V. vulnificus*, and *Shewanella* spp. are well-recognized to cause fulminant skin and soft tissue infections with bacteremia, and we found them to be more commonly associated with bacteremia than either *Aeromonas* spp. or *C. violaceum*.

We have found that *C. violaceum*, while sharing some characteristics of the VACS organisms, also exhibits differences in its epidemiology. Infections occur equally in both sexes, children are more commonly affected compared with those infected with other VACS organisms, and the organism is frequently isolated from urine, the respiratory tract, and feces as well as skin and soft tissue. Previous case series^{3,18} have shown a male predominance for this organism, but infections in immunocompromised and healthy females have also been reported.^{14,19} Children, often with underlying immunodeficiencies such as chronic granulomatous disease,^{3,20} are known to be at risk of developing disease.

Additionally, although not as likely to be associated with bacteremia as *Vibrio* spp. and *Shewanella* spp., we found that isolation of *C. violaceum* occurs more commonly in the ICU population compared with other organisms. This may be an indicator of severity of disease, but in the absence of clinical data, it could also suggest that compromised patients are more likely to be colonized with this organism.

This study shows in a tropical setting that *C. violaceum* is not commonly isolated and can occur in unexpected sites. Infection should be considered in patients with infections not responding to standard antimicrobial therapy in the setting of water exposure. Our antimicrobial susceptibility data are limited by small numbers but support the empirical use of meropenem, ciprofloxacin, and gentamicin for *C. violaceum* infections. These antibiotics have been used elsewhere in successful treatment regimens.^{12,13} Earlier *in vitro* studies have showed ciprofloxacin to be the most potent of these,²¹ and this should, therefore, be incorporated in first-line regimens targeting this organism.

Regarding our inferred antimicrobial susceptibility data for *Shewanella* spp. and *C. violaceum* from *P. aeruginosa* results, we believe that this is reasonable for the following reasons. (1) Relatively low numbers of *Shewanella* spp. and *C. violaceum* make it unlikely that independent standards will be developed. (2) *P. aeruginosa* is also an oxidase-positive environmental organism with some similar features to *Shewanella* spp. and *C. violaceum*. It is reasonable to argue that *Vibrio* spp. susceptibility criteria could be used as an alternative. Examining our data, the susceptibility results for the antimicrobials reported were similar using both *Vibrio* spp. and *Pseudomonas* spp. inferred susceptibility results. Moving forward, we believe that, when these organisms are isolated, they should have minimum inhibitory concentration (MIC) testing performed against clinically relevant antibiotics, which is currently the case for other tropical organisms, such as *Burkholderia pseudomallei*.

Our antimicrobial susceptibility data for *Vibrio*, *Aeromonas*, and *Shewanella* support the empirical use of aminoglycosides, cotrimoxazole, ciprofloxacin, and cefepime in fresh and salt

water-associated skin and soft tissue infections in our region. Although we do not have clinical outcome data to support this, similar susceptibilities and successful outcomes have been noted elsewhere with these antibiotics.^{1,16,22} Local antimicrobial susceptibility data are important, because cotrimoxazole resistance in Spain and Taiwan restricts its empirical use in *Aeromonas* infections.^{23,24} Additional empirical cover should target likely copathogens, particularly *S. aureus*. Anaerobes, non-fermentative Gram-negatives, and enterococci should be covered in life-threatening infections.

Caution is advised against reliance on third generation cephalosporins for the treatment of *Aeromonas* infections, because more than one-half of a subset of isolates showed inducible resistance, despite *in vitro* susceptibility. This is caused by inducible ampC cephalosporinases²⁵ and has been shown to occur during treatment of *Aeromonas* bacteremia.²⁶ Cefepime offers a potential alternative agent, because it is not affected by this enzyme. In contrast, all *Vibrio* isolates were susceptible to ceftriaxone, and *in vitro* studies have suggested a role for a combination of a β -lactam with ciprofloxacin for treatment of *V. vulnificus* sepsis.²⁷

Meropenem was not universally active against *Vibrio* and *Aeromonas* isolates, and inducible carbapenem resistance was additionally detected in a subset of *in vitro* susceptible *Aeromonas* isolates. Inconsistencies are also known to occur between antimicrobial susceptibility testing methods, such as disk diffusion and broth microdilution with carbapenems, for this organism.²⁸ It is notable that the most common carbapenemase present in *Aeromonas* (CphA) has a very narrow substrate profile that would not affect cefepime, although VIM metallo β -lactamases (MBLs) do also occur.²⁵ Treatment failure caused by the development of carbapenem resistance in *Shewanella* bacteremia has also been reported²⁹; therefore, carbapenem monotherapy in severe water-associated infections cannot be recommended.

In summary, VACS are a group of water-associated environmental organisms associated with skin and soft tissue infections in the tropics. They should be considered in lower limb infections after fresh or salt water exposure. Polymicrobial infections usually occur. Empirical antibiotic treatment with agents, such as ciprofloxacin, cotrimoxazole, and aminoglycosides, with appropriate *S. aureus* cover should be considered, and identification of organisms and antimicrobial susceptibility testing should be performed.

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