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Bacteriology of the Teeth from a Great White Shark: Potential Medical Implications for Shark Bite Victims†

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Bacteria were cultured for the first time from the teeth of a great white shark (*Carcharodon carcharias*). Isolates included *Vibrio alginolyticus*, *Vibrio fluvialis*, *Vibrio parahaemolyticus*, and other genera. All are common in the marine environment and some may be associated with wound infections in humans. Shark bite lacerations may serve as a source of these potentially infectious bacteria, particularly *Vibrio* spp., and should be treated immediately. Antibiotic susceptibility patterns are shown for representatives of *Vibrio* isolates and indicate that a variety of new agents may be appropriate chemotherapy for shark bite victims.

About three-fourths of present-day victims of shark attack survive (2). In a high percentage of attacks, there is no significant amount of tissue missing from the victims; instead, laceration patterns indicate that bites are most likely caused by open-mouth raking that results in severe cuts and slashes without much loss of tissue.

The literature yields only a few references on the treatment of shark bites relative to infection. It has been suggested that some marine bacteria may be virulent and resistant to antibiotics and that wound cultures should be taken and antibiotic susceptibilities determined before chemotherapy (13, 17). Because of infection potential, however, early treatment has been indicated even when wounds are relatively minor (3, 10). It is believed also that shark bites can become infected quickly and severely from bacteria present on the teeth of the shark (11). An individual severely bitten by a white shark in Australia survived after extensive medical treatment that included the use of unspecified antibiotics; bacteria on the teeth of the shark were considered a threat (18). Use of oxytetracycline was credited in the first recorded instance of recovery from major abdominal injury caused by a shark bite in South Africa (11). Chloramphenicol was used successfully in another case, in which the victim suffered extensive superficial lacerations and the loss of an arm. Prophylaxis against tetanus and gas gangrene was recommended also because infections caused by *Clostridium* spp. have been reported. (13).

A hemolytic paracolon ("*Paracolobactrum*") bacillus was isolated from wounds of a victim attacked by a ragged-toothed shark (*Odontaspis taurus*) and from the teeth of living sharks in South Africa (8). With the exception of reports that discuss chemotherapy (12, 14, 31) and refer to the early study and course of antibiotic treatment (8), no additional reports are available on bacteria from shark teeth. Consequently, there are no contemporary data on antibiotic susceptibility of these potentially dangerous bacteria.

The white shark (*Carcharodon carcharias*) looms prominently among documented shark attacks on humans (1, 2, 15, 21, 28, 29). The availability of a white shark offered the opportunity to culture bacteria for the first time from the teeth. We report results of this study and antibiotic susceptibilities of some bacteria isolated for an updated assessment of appropriate chemotherapy for treating shark bite victims.

MATERIALS AND METHODS

The shark was harpooned by sportfishermen southeast of Block Island, R.I., on 5 August 1983. The shark remained in the water and was towed back to Noank, Conn. The elapsed time between capture and examination was approximately 6 h. The shark was male and presumably mature (the claspers were 67 cm long). Its standard length was 442 cm and its weight was 1,227 kg. Separate swabs (Culturette II; Marion Scientific, Kansas City, Mo.) were taken from three different front teeth of the shark immediately after it was removed from the water. Opinions differed as to whether the animal was actually dead, and therefore no object had been placed in the mouth before our samples were collected. Plates of tryptic soy agar (Difco Laboratories, Detroit, Mich.) containing 5% horse blood and tubes of tryptic soy broth were inoculated directly from the swabs within 30 min. After incubation at 37°C for 36 h, blood plates were streaked from broth tubes. Cultures were recovered from all plates, restreaked for purity, and maintained on tryptic soy agar slants. Gram-negative bacteria were identified by use of the API 20E system (Analytab Products, Plainview, N.Y.). It has been noted that diluent may influence the identification of marine vibrios when this procedure is used (20). Our cultures were confirmed by using both 0.85% saline and 20‰ marine salts (Instant Oceans; Aquarium Systems, Mentor, Ohio) and independently with the Micro-ID system (General Diagnostics, Morris Plains, N.J.). Flagella staining and reactions in salt-containing media, thiosulfate-citrate-bile salts-sucrose agar (Difco), and triple sugar iron agar (Difco) further supported the identification of *Vibrio* spp.

The Kanagawa test (22) was performed on all isolates of *Vibrio parahaemolyticus*. Because of the emerging recognition of marine *Vibrio* species as potential human pathogens (6, 7), antibiotic susceptibilities of representatives of the three *Vibrio* species were determined by standard procedures (5).

RESULTS

A total of 24 cultures were recovered and included *Vibrio alginolyticus* (nine isolates), *V. parahaemolyticus* (six isolates), *Vibrio fluvialis* (two isolates), *Pseudomonas putrefa-*

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ciens (two isolates), golden-pigmented *Staphylococcus* sp. (two isolates), *Pseudomonas* sp. (one isolate), *Citrobacter* sp. (one isolate), and *Micrococcus* sp. (one isolate). The Kanagawa test was performed on all isolates of *V. parahaemolyticus* because of the correlation between hemolytic activity and gastrointestinal illness in humans (7). Although all cultures were strongly hemolytic on blood agar, they were Kanagawa negative, which is consistent with results from environmental isolates (7). Extraintestinal infections, however, can be caused by Kanagawa-negative strains (7).

Results of antibiotic susceptibility tests are summarized in Table 1. Studies in 1961 (8) indicated that the hemolytic paracolon bacillus is susceptible to chlortetracycline, oxytetracycline, and chloramphenicol and resistant to penicillin and the sulfonamides. Because a complete description of this bacterium is not available, we cannot compare it with our isolates. Table 1 indicates that potentially infectious bacteria found on the teeth of the white shark in this study are susceptible to several antibiotics, including some not yet developed in the 1960s.

DISCUSSION

The marine vibrio group is important in human health (6, 7). *V. alginolyticus* has been recovered from a variety of infections, some of which were wound induced (24, 26, 27). *V. parahaemolyticus* is considered as an autochthonous pathogen in the marine development (9) and has been associated with septicemia, usually from wounds acquired in seawater (4, 25). *V. fluvialis* occurs commonly in marine material (30) and possesses extracellular toxins (23), although at present the organism has not been associated with wound infections. One cannot dismiss the presence on shark teeth of *P. putrefaciens*, which is found in seawater and may be an opportunistic pathogen associated with septicemias (19), and pigmented staphylococci, which can cause bacter-

TABLE 1. Response to antibiotics of *P. putrefaciens* and five *Vibrio* strains isolated from the teeth of *C. carcharias*

Antibiotic[a]	Response (MIC [μg/ml]) of following organism (no. of isolates)[b]:			
	V. alginolyticus (2)	*V. fluvialis* (1)	*V. parahaemolyticus* (2)	*P. putrefaciens*
Aminoglycosides				
Amikacin	S (2)	S (≤1)	S (≤0.5–4)	S (2)
Gentamicin	S (≤0.5)	S (≤0.5)	S (1)	S (≤0.5)
Tobramycin	S (≤0.5–1)	S (≤0.5)	S (1)	S (<0.5)
Cephalosporins				
Cephalothin (1st generation)	R	R (>16)	R (8)	R (>16)
2nd generation				
Cefoxitin	S (4–8)	S (4)	S (4)	S (2)
Cefamandole	S (≤1)	R (>16)	S (2)	R (8)
3rd generation				
Cefoperazone	S	R	S	S
Cefotaxime	S	R	S	S
Moxalactam	S	S	S	S
Macrolide (lincomycin)	R	R	R	ND[d]
Penicillins[c]	R (8–256)	R (8–>16)	R (16–32)	R (0.5–8)
Sulfas				
Triple sulfa	R	R	R	ND
Sulfamethoxazole	S (≤0.5)	S (≤0.5)	S (≤0.5)	S (≤0.5)
Tetracyclines				
Doxycycline	S	S	S	ND
Tetracycline	S (≤0.25)	S (≤0.5)	S (≤0.5)	S (≤0.25)
Others				
Chloramphenicol	S (≤0.5)	S (≤0.5)	S (≤0.5)	S (≤0.5)
Nalidixic acid	S	S	S	ND
Nitrofurantoin	S	S	S	ND
Novobiocin	R	R	R	ND
Vancomycin	R	R	R	ND

[a] Several other antibiotics were tested also; all bacteria were intermediate in susceptibility.
[b] R, Resistant; S, susceptible.
[c] Amoxicillin, ampicillin, carbenicillin, cloxicillin, penicillin G, pipericillin.
[d] ND, Not done.

emias in humans via wounds and may be overlooked in marine waters (16).

All of the bacteria recovered in this study have been reported previously in the marine environment, and thus we cannot be certain that the isolates are unique to the teeth of a white shark. All three *Vibrio* species are common in water near where the shark was caught (R. C. Tilton and R. W. Ryan, Abstr. Annu. Meet. Am. Soc. Microbiol. 1984, N15, p. 181). It has been reported also that *Vibrio vulnificus* was recovered from Long Island Sound water beginning in July when water temperatures were above 69.5°F (ca. 21°C). The temperature of the water in the vicinity of where the shark was caught was 59°F (15°C), and that of Noank coastal water was 68°F (20°C). This probably accounts for the lack of *V. vulnificus* isolated from the animal. Another study, however J. D. Buck, Fish. Bull., in press), reported the recovery of *V. alginolyticus* from the teeth of sandbar (*Carcharinus plumbeus*), tiger (*Galeocerdo cuvieri*), and Atlantic sharpnose (*Rhizoprinodon terraenovae*) sharks from the Gulf of Mexico. Whatever the origin of the bacteria, the observations herein confirm that the teeth of several species of sharks from different geographic areas are a source of infectious bacteria including *Vibrio* species.

Increased awareness of the occurrence of these potential pathogens in various environments will allow more appropriate treatment. Although shark attacks are rare, they are frequently dramatic in degree of induced trauma; more importantly, however, bites are not often fatal. Victims must be treated rapidly and effectively. Fortunately, infections resulting from shark bites have lesser significance with use of antibiotics and allows limited, more conservative excisional surgery of wounds. Our data provide an updated description of potentially infectious bacteria associated with shark teeth, particularly of the white shark. In addition, the antibiotic susceptibility patterns reported here, especially those shown to the new cephalosporins and aminoglycosides, expand the therapeutic options for the treatment of shark bites. Antibiotic choice should, of course, include coverage of the microflora of tissues involved in the injury, i.e., enteric organisms in the case of abdominal wounds. We encourage microbiological isolation and susceptibility testing for all shark bite injuries.

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