

## BACTERIOLOGIC ANALYSIS OF INFECTED DOG AND CAT BITES

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## ABSTRACT

**Background and Methods** To define better the bacteria responsible for infections of dog and cat bites, we conducted a prospective study at 18 emergency departments. To be eligible for enrollment, patients had to meet one of three major criteria for infection of a bite wound (fever, abscess, and lymphangitis) or four of five minor criteria (wound-associated erythema, tenderness at the wound site, swelling at the site, purulent drainage, and leukocytosis). Wound specimens were cultured for aerobic and anaerobic bacteria at a research microbiology laboratory and, in some cases, at local hospital laboratories.

**Results** The infected wounds of 50 patients with dog bites and 57 patients with cat bites yielded a median of 5 bacterial isolates per culture (range, 0 to 16) at the reference laboratory. Significantly more isolates grew at the reference laboratory than at the local laboratories (median, 1; range, 0 to 5;  $P < 0.001$ ). Aerobes and anaerobes were isolated from 56 percent of the wounds, aerobes alone from 36 percent, and anaerobes alone from 1 percent; 7 percent of cultures had no growth. *Pasteurella* species were the most frequent isolates from both dog bites (50 percent) and cat bites (75 percent). *Pasteurella canis* was the most common isolate of dog bites, and *Past. multocida* subspecies *multocida* and *septica* were the most common isolates of cat bites. Other common aerobes included streptococci, staphylococci, moraxella, and neisseria. Common anaerobes included fusobacterium, bacteroides, porphyromonas, and prevotella. Isolates not previously identified as human pathogens included *Reimerella anatipestifer* from two cat bites and *Bacteroides tectum*, *Prevotella heparinolytica*, and several porphyromonas species from dog and cat bites. *Erysipelothrix rhusiopathiae* was isolated from two cat bites. Patients were most often treated with a combination of a  $\beta$ -lactam antibiotic and a  $\beta$ -lactamase inhibitor, which, on the basis of the microbiologic findings, was appropriate therapy.

**Conclusions** Infected dog and cat bites have a complex microbiologic mix that usually includes *pasteurella* species but may also include many other organisms not routinely identified by clinical microbiology laboratories and not previously recognized as bite-wound pathogens. (N Engl J Med 1999;340:85-92.)

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**E**ACH year, several million Americans are bitten by animals, resulting in approximately 300,000 visits to emergency departments, 10,000 hospitalizations, and 20 deaths, mostly among young children.<sup>1</sup> Ninety percent of these bites are from dogs and cats, and 3 to 18 percent of dog bites and 28 to 80 percent of cat bites become infected, with occasional sequelae of meningitis, endocarditis, septic arthritis, and septic shock.<sup>2-13</sup> Bacteriologic analyses of these wound infections have focused on certain zoonotic and potentially invasive pathogens such as *Pasteurella multocida*, *Capnocytophaga canimorsus* (DF-2), and *Weeksella zoohelcum* (IIj).<sup>4-6,14-19</sup>

Previous microbiologic studies have been limited to case series of small numbers of selected patients at single centers that used inexact infection criteria and variable techniques of specimen collection and pathogen isolation. To delineate the complicated bacteriology of these common infections and to improve the accuracy of empirical therapy for cat bites and dog bites, we conducted a prospective, multi-center study of dog bites and cat bites that met specific criteria for infection and that included culturing of specimens for aerobic and anaerobic bacteria at a research laboratory.

## METHODS

This prospective case series was conducted from April 1994 through December 1995 at 18 university-affiliated emergency departments in the United States. The study was approved by each institutional review board.

Patients were included if they had a cutaneous wound caused by a dog bite or cat bite that was large enough for at least a miniswab to be inserted in order to obtain a deep culture and met one of three major criteria — fever (temperature of more than 38.0°C), abscess, and lymphangitis — or four of five minor criteria: wound-associated erythema that extended more than 3 cm from the edge of the wound, tenderness at the wound site, swelling at the site, purulent drainage, and a peripheral white-cell count of more than 12,000 per cubic millimeter. These criteria were established by consensus before the study in order to distinguish clinically infected wounds from wounds that were contaminated but

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not infected. Patients who had taken antimicrobial agents within 72 hours before presentation, who were likely to require amputation as a result of the infection, or who had radiographically confirmed osteomyelitis or fracture were excluded. No patient was enrolled more than once.

The following data were obtained: age, sex, associated medical conditions, the time of the bite, the time a specimen was obtained for culture, the interval between the bite and the onset of infection, the type of local wound care given, the type of wound (puncture wound, laceration, or both) and infection, and the antimicrobial agents and any other types of therapy that were given. We assessed the outcome of the infections by reviewing the patients' medical records and by repeated telephone calls to the patients or their parents or guardians until the infection resolved. Infections were classified as abscesses (i.e., fluctuant lesions requiring incision and drainage), purulent wounds, or nonpurulent wounds, with cellulitis, lymphangitis, or both. The treating physicians directed clinical care.

Microbiologic specimens were collected by needle aspiration for abscesses and with standard cotton swabs for open lacerations. For puncture wounds, calcium alginate-treated miniswabs were inserted deeply after the skin surrounding the wound had been cleaned with alcohol or povidone-iodine solution. Specimens were placed in an anaerobic transport tube containing a deep column of anaerobic transport medium (Anaerobe Systems, Morgan Hill, Calif.) and shipped by overnight courier to R.M. Alden Research Laboratory (Santa Monica, Calif.). A second specimen was sent to the microbiology laboratory at the hospital and processed according to the facility's standard procedures.

On receipt at the research laboratory, transport tubes were opened inside an anaerobic chamber and the specimen was suspended in 1 ml of brucella broth and processed according to standard methods.<sup>20,21</sup> The following mediums were used for anaerobes: supplemented brucella agar, laked-blood kanamycin-vancomycin agar, phenylethyl alcohol-blood agar, bacteroides bile esculin agar (Anaerobe Systems), and Rose agar (Hardy Diagnostics, Santa Monica, Calif.). Anaerobic plates were incubated for five days before being examined for the first time, and all plates were incubated for two weeks to allow growth of fastidious strains.

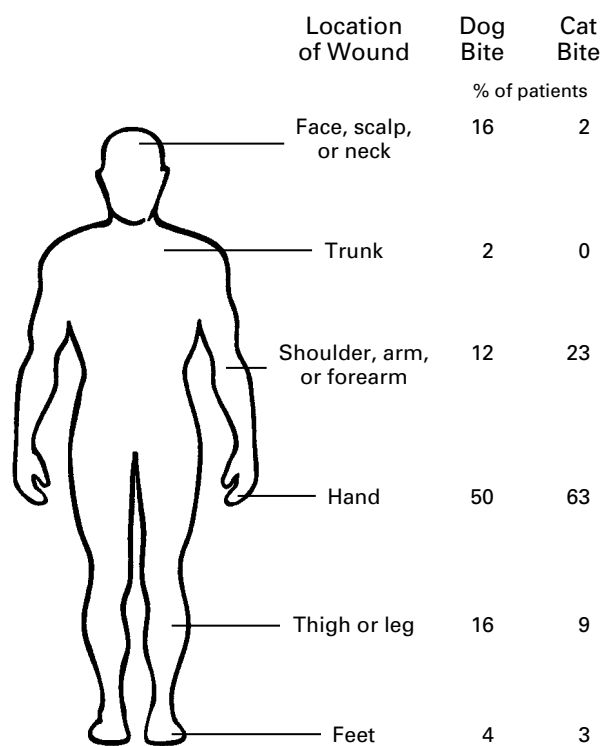
The following mediums were used for aerobic and facultative organisms: trypticase soy agar supplemented with 5 percent defibrinated sheep's blood, chocolate agar, Rose agar, and MacConkey agar. All specimens except those on MacConkey agar were incubated in 5 to 7 percent carbon dioxide for 24 hours before being examined for the first time and reincubated for up to five days to allow growth of slowly growing organisms.

A combination of identification methods was used. Many isolates were strains found in animals and thus were not included in test-kit data bases; therefore, such strains were partially identified (i.e., according to genus) on the basis of reactions to standard kit components. For the identification of aerobes, biochemical tube tests (Hardy Diagnostics) were frequently used in conjunction with other standard methods.<sup>20,22,23</sup> Anaerobes were identified with the use of standard methods including special-potency antibiotic disks, which are used to group organisms into categories.<sup>21,24-26</sup> Some strains were classified on the basis of the analysis of long-chain fatty acids and comparison of the results with veterinary data bases (performed by Spencer Jang, Veterinary Microbiology Laboratory, University of California at Davis, Sacramento), and others, such as porphyromonas species, were identified by arbitrarily primed polymerase-chain-reaction fingerprinting and comparison of the results with type strains.<sup>27</sup>

The data were summarized with the use of descriptive statistics. The Mann-Whitney U test was used to compare data on time and the numbers of isolates. A P value of less than 0.05 was considered to indicate statistical significance.

### RESULTS

A total of 110 patients were enrolled in the study; 2 patients who had received antibiotics within 72



**Figure 1.** Location of Wound Infections in 50 Patients Bitten by Dogs and 57 Patients Bitten by Cats.

hours before presentation and 1 patient with a tiger bite were subsequently excluded. Results are reported for 50 patients with infected dog bites and 57 patients with infected cat bites.

Patients ranged in age from 1 to 82 years (median, 33; interquartile range, 20 to 46). Twenty-four patients (22 percent) were younger than 18 years of age, and five (5 percent) were younger than 3 years. The median age of the patients with dog bites was 28 years (interquartile range, 15 to 40), and the median age of those with cat bites was 39 years (interquartile range, 28 to 51). Thirty-eight percent of the patients with dog bites were female, as compared with 72 percent of the patients with cat bites. Fifteen patients had one or more associated medical conditions, including diabetes (five patients), glucocorticoid use (three), alcoholism (five), chronic renal disease (three), and chronic liver disease (one).

Sixty percent of the dog-bite wounds were punctures, 10 percent were lacerations, and 30 percent were a combination of both. Eighty-five percent of cat-bite wounds were punctures, 3 percent were lacerations, and 12 percent were a combination. Nineteen wounds involved tendons, and one wound involved both a tendon and a metacarpal-phalangeal joint. Most wounds involved the arms, especially the hands (Fig. 1).

Patients or their parents or guardians administered

the following local wound care: soap and water (73 percent), iodine (10 percent), peroxide (46 percent), sterile saline (5 percent), isopropyl alcohol (15 percent), and other topical care, such as epsom salts, garlic, and mouthwash (21 percent). Nine patients (8 percent) had been seen by a physician, of whom two underwent wound débridement and one received sutures.

Twelve patients (11 percent) had temperatures of more than 38.0°C at presentation, and 21 of 47 patients (45 percent) had peripheral white-cell counts of more than 12,000 per cubic millimeter.

The median interval between the bite and the collection of the specimen was 25 hours (interquartile range, 18 to 54; range, 8 to 410). The interval was significantly shorter after cat bites than after dog bites (median, 23 vs. 35 hours; P=0.04). The median interval between the collection of the specimen and culture was 35 hours (interquartile range, 24 to 43; range, 1 to 120) and was not significantly different between dog bites and cat bites.

The median number of isolates per culture was 5 (interquartile range, 2 to 9; range, 0 to 16); approximately 3 were aerobes and 2 were anaerobes (Table 1). Wound infections were characterized as abscesses in 16 percent of cases, purulent in 48 percent, and nonpurulent, with cellulitis, lymphangitis, or both, in 36 percent (Table 1). Lymphangitis was present in 22 percent of dog bites and 28 percent of cat bites. Nonpurulent wounds were more frequent among patients with cat bites.

Mixed aerobic and anaerobic infection was present in 56 percent of all wounds (48 percent of dog bites and 63 percent of cat bites), only aerobes grew in 36 percent (42 percent of dog bites and 32 percent of cat bites), and only anaerobes (*Bacteroides tectum* and *Porphyromonas gingivalis*) grew in 1 percent (one dog bite) (Table 2). Seven wound cultures (7 percent) had no bacterial growth (median interval between the collection of the specimen and culture, 25 hours).

The bacteria isolated from the dog bites and cat bites are listed in Table 3. Pasteurella species were

**TABLE 1.** NUMBER OF BACTERIAL ISOLATES OBTAINED FROM CULTURES OF 50 DOG BITES AND 57 CAT BITES, ACCORDING TO THE TYPE OF INFECTION.

VARIABLE	ABSCESS		PURULENT WOUND		NONPURULENT WOUND	
	DOG BITE	CAT BITE	DOG BITE	CAT BITE	DOG BITE	CAT BITE
	(N=6)	(N=11)	(N=29)	(N=22)	(N=15)	(N=24)
No. of bites (%)	6 (12)	11 (19)	29 (58)	22 (39)	15 (30)	24 (42)
No. of isolates						
Median	7.5	7.0	5.0	6.5	2.0	5.0
Interquartile range	3-10	5-11	2-11	3-10	1-4	2-6
Range	2-11	3-13	0-16	0-13	0-9	0-12

**TABLE 2.** TYPES OF MICROORGANISMS ISOLATED FROM 50 DOG BITES AND 57 CAT BITES, ACCORDING TO THE TYPE OF INFECTION.\*

TYPE OF MICROORGANISMS	ABSCESS		PURULENT WOUND		NONPURULENT WOUND	
	DOG BITE (N=6)	CAT BITE (N=11)	DOG BITE (N=29)	CAT BITE (N=22)	DOG BITE (N=15)	CAT BITE (N=24)
	number of bites (percent)					
Aerobes only	1 (17)	3 (27)	10 (34)	7 (32)	10 (67)	8 (33)
Anaerobes only	1 (17)	0	0	0	0	0
Aerobes and anaerobes	4 (67)	8 (73)	18 (62)	14 (64)	2 (13)	14 (58)
No growth on culture	0	0	1 (3)	1 (5)	3 (20)	2 (8)

\*Because of rounding, not all percentages total 100.

TABLE 3. AEROBIC AND ANAEROBIC BACTERIA ISOLATED FROM 50 DOG BITES AND 57 CAT BITES.\*

BACTERIA	DOG BITE	CAT BITE	BACTERIA	DOG BITE	CAT BITE	BACTERIA	DOG BITE	CAT BITE
	no. of patients (%)			no. of patients (%)			no. of patients (%)	
<b>Aerobes</b>			<b>Aerobes (cont.)</b>			<b>Aerobes (cont.)</b>		
<i>Pasteurella</i>	25 (50)	43 (75)	<i>Moraxella</i>	5 (10)	20 (35)	<i>Actinobacillus</i> †	0	2 (4)
<i>Past. canis</i>	13 (26)	1 (2)	Other†	5 (10)	18 (32)	<i>Alcaligenes</i>	0	2 (4)
<i>Past. multocida</i> ssp. <i>multocida</i>	6 (12)	31 (54)	<i>Morax. catarrhalis</i>	1 (2)	6 (11)	<i>Alcal. faecalis</i>	0	1 (2)
<i>Past. stomatis</i>	6 (12)	2 (4)	EF-4b	5 (10)	9 (16)	<i>Alcal. odorans</i>	0	1 (2)
<i>Past. multocida</i> ssp. <i>septica</i>	5 (10)	16 (28)	<i>Enterococcus</i>	5 (10)	7 (12)	<i>Enterobacter cloacae</i>	0	2 (4)
<i>Past. dagmatis</i>	2 (4)	4 (7)	<i>Ent. faecalis</i>	3 (6)	2 (4)	<i>Erysipelothrix rhusiopathiae</i>	0	2 (4)
<i>Past. multocida</i> ssp. <i>gallicida</i>	1 (2)	0	<i>Ent. avium</i>	1 (2)	0	<i>Reimerella anatipestifer</i>	0	2 (4)
Other†	1 (2)	0	<i>Ent. malodoratus</i>	1 (2)	0	<i>Rothia dentocariosa</i>	0	2 (4)
<i>Streptococcus</i>	23 (46)	26 (46)	<i>Ent. durans</i>	0	5 (9)	<i>Aeromonas hydrophila</i>	0	1 (2)
<i>Strep. mitis</i>	11 (22)	13 (23)	<i>Bacillus</i>	4 (8)	6 (11)	<i>Pantoea agglomerans</i>	0	1 (2)
<i>Strep. mutans</i>	6 (12)	6 (11)	<i>Bac. firmus</i>	2 (4)	2 (4)	<i>Rhodococcus</i> †	0	1 (2)
<i>Strep. pyogenes</i>	6 (12)	0	<i>Bac. circulans</i>	1 (2)	1 (2)	<i>Streptomyces</i> †	0	1 (2)
<i>Strep. sanguis</i> II	4 (8)	7 (12)	<i>Bac. subtilis</i>	1 (2)	0			
<i>Strep. intermedius</i>	3 (6)	2 (4)	Other†	0	3 (5)	<b>Anaerobes</b>		
<i>Strep. constellatus</i>	2 (4)	2 (4)	<i>Pseudomonas</i>	3 (6)	3 (5)	<i>Fusobacterium</i>	16 (32)	19 (33)
<i>Strep. equinus</i>	1 (2)	3 (5)	<i>Pseud. aeruginosa</i>	1 (2)	0	<i>Fuso. nucleatum</i>	8 (16)	14 (25)
<i>Strep. sanguis</i> I	1 (2)	3 (5)	<i>Pseud. vesicularis</i>	1 (2)	1 (2)	Other†	6 (12)	4 (7)
<i>Strep. agalactiae</i>	1 (2)	1 (2)	<i>Pseud. diminuta</i>	1 (2)	0	<i>Fuso. russii</i>	1 (2)	8 (14)
<i>Strep. sanguis</i>	1 (2)	1 (2)	<i>Pseud. putida</i>	0	1 (2)	<i>Fuso. gonidiaformans</i>	1 (2)	1 (2)
β-Hemolytic, group G	1 (2)	0	<i>Pseud. stutzeri</i>	0	1 (2)	<i>Fuso. aloisii</i>	1 (2)	0
<i>Strep. dysgalactiae</i>	1 (2)	0	<i>Actinomyces</i>	3 (6)	2 (4)	<i>Bacteroides</i>	15 (30)	16 (28)
β-Hemolytic, group F	0	1 (2)	<i>Act. viscosus</i>	2 (4)	1 (2)	<i>Bact. tectum</i>	7 (14)	16 (28)
<i>Staphylococcus</i>	23 (46)	20 (35)	<i>Act. neuui</i> ssp. <i>anitratius</i>	1 (2)	0	<i>Bact. forsythus</i>	2 (4)	0
<i>Staph. aureus</i>	10 (20)	2 (4)	Other†	0	1 (2)	<i>Bact. gracilis</i>	2 (4)	0
<i>Staph. epidermidis</i>	9 (18)	10 (18)	<i>Brevibacterium</i> †	3 (6)	2 (4)	<i>Bact. ureolyticus</i>	2 (4)	0
<i>Staph. warneri</i>	3 (6)	6 (11)	<i>Gemella morbillorum</i>	3 (6)	2 (4)	<i>Bact. tectum</i> group E	1 (2)	2 (4)
Other†	3 (6)	0	EF-4a	3 (6)	0	<i>Bact. fragilis</i>	1 (2)	1 (2)
<i>Staph. intermedius</i>	1 (2)	1 (2)	<i>Escherichia coli</i>	3 (6)	0	<i>Bact. ovatus</i>	1 (2)	0
<i>Staph. hominis</i>	1 (2)	1 (2)	<i>Weeksella</i>	2 (4)	4 (7)	<i>Porphyromonas</i>	14 (28)	17 (30)
<i>Staph. auricularis</i>	1 (2)	0	<i>W. virosa</i>	0	1 (2)	<i>Porph. macacae</i>	3 (6)	4 (7)
<i>Staph. colnii</i>	1 (2)	0	<i>W. zoohelcum</i>	2 (4)	4 (7)	<i>Porph. cansulci</i>	3 (6)	1 (2)
<i>Staph. xylosus</i>	1 (2)	0	<i>Klebsiella</i>	2 (4)	1 (2)	<i>Porph. gingivalis</i>	2 (4)	6 (11)
<i>Staph. sciuri-lentus</i>	0	2 (4)	<i>K. oxytoca</i>	1 (2)	1 (2)	<i>Porph. canoris</i>	2 (4)	5 (9)
<i>Staph. capitis</i>	0	1 (2)	<i>K. pneumoniae</i>	1 (2)	0	<i>Porph. cangingivalis</i>	2 (4)	2 (4)
<i>Staph. haemolyticus</i>	0	1 (2)	<i>Lactobacillus</i>	2 (4)	1 (2)	Other†	2 (4)	0
<i>Staph. hyicus</i>	0	1 (2)	<i>L. lactis</i>	1 (2)	0	<i>Porph. circumdentaria</i>	1 (2)	3 (5)
<i>Staph. saprophyticus</i>	0	1 (2)	Other†	1 (2)	1 (2)	<i>Porph. levii-like</i>	1 (2)	0
<i>Staph. simulans</i>	0	1 (2)	<i>Citrobacter</i>	2 (4)	0	<i>Prevotella</i>	14 (28)	11 (19)
<i>Neisseria</i>	8 (16)	11 (19)	<i>Citro. amalonaticus</i>	1 (2)	0	<i>Prev. heparinolytica</i>	7 (14)	5 (9)
<i>N. weaverii</i>	7 (14)	8 (14)	<i>Citro. koseri</i>	1 (2)	0	<i>Prev. intermedia</i>	4 (8)	0
<i>N. subflava</i>	1 (2)	1 (2)	<i>Flavobacterium</i>	2 (4)	0	Other†	1 (2)	4 (7)
Other†	1 (2)	0	Group IIa	1 (2)	0	<i>Prev. zoogloformans</i>	2 (4)	1 (2)
<i>N. cinerea-flavescens</i>	0	1 (2)	<i>Flavo. brevis</i>	1 (2)	0	<i>Prev. melaninogenica</i>	1 (2)	1 (2)
<i>N. mucosa</i>	0	1 (2)	<i>Micrococcus</i>	2 (4)	0	<i>Prev. denticola</i>	1 (2)	0
<i>Corynebacterium</i>	6 (12)	16 (28)	<i>Micro. lylae</i>	1 (2)	0	<i>Propionibacterium</i>	10 (20)	10 (18)
Group G	3 (6)	3 (5)	Other†	1 (2)	0	<i>Prop. acnes</i>	7 (14)	9 (16)
<i>Coryne. minutissimum</i>	2 (4)	4 (7)	<i>Proteus mirabilis</i>	2 (4)	0	<i>Prop. acidi-propionicus</i>	1 (2)	0
<i>Coryne. aquaticum</i>	1 (2)	8 (14)	<i>Stenotrophomonas maltophilia</i>	2 (4)	0	<i>Prop. freudenreichii</i>	1 (2)	0
<i>Coryne. jeikeium</i>	1 (2)	1 (2)	<i>Capnocytophaga</i>	1 (2)	4 (7)	Other†	1 (2)	0
<i>Coryne. afermentans</i>	1 (2)	0	<i>Cap. ochracea</i>	1 (2)	2 (4)	<i>Prop. avidum</i>	0	1 (2)
Group E	1 (2)	0	Other†	0	3 (5)	<i>Prop. lymphophilum</i>	0	1 (2)
<i>Coryne. pseudodiphtheriticum</i>	1 (2)	0	<i>Eikenella corrodens</i>	1 (2)	1 (2)	<i>Peptostreptococcus</i>	8 (16)	3 (5)
Other†	1 (2)	0	<i>Flavimonas oryzihabitans</i>	1 (2)	1 (2)	<i>Pept. anaerobius</i>	4 (8)	3 (5)
Group B	0	1 (2)	<i>Dermabacter hominis</i>	1 (2)	0	Other†	3 (6)	0
Group F-1	0	1 (2)	<i>Oerskovia</i> †	1 (2)	0	<i>Pept. asaccharolyticus</i>	1 (2)	0
<i>Coryne. kutscheri</i>	0	1 (2)	<i>Pediococcus damnosus</i>	1 (2)	0	<i>Eubacterium</i> †	2 (4)	1 (2)
<i>Coryne. propinquum</i>	0	1 (2)	<i>Stomatococcus mucilaginosus</i>	1 (2)	0	<i>Lactobacillus jensenii</i>	1 (2)	0
<i>Coryne. striatum</i>	0	1 (2)	<i>Acinetobacter</i>	0	4 (7)	<i>Filifactor villosus</i>	0	3 (5)
			<i>Acine. baumannii</i>	0	2 (4)	<i>Clostridium sordellii</i>	0	1 (2)
			<i>Acine. hwoffii</i>	0	2 (4)	<i>Veillonella</i> †	0	1 (2)

\*Some patients were infected with more than one type or species of bacteria. The abbreviation ssp. denotes subspecies.

†The isolate could not be identified beyond the genus level.

the most common isolates from both dog bites (50 percent) and cat bites (75 percent). *Past. canis* predominated among dog bites, and *Past. multocida* subspecies *multocida* and *septica* were the most common isolates of cat bites. Streptococci, staphylococci, moraxella, and neisseria were common aerobic isolates, and fusobacterium, bacteroides, porphyromonas, and prevotella were common anaerobic isolates. *Erysipelothrix rhusiopathiae* was found in two cat bites. *Reimerella anatipestifer*, *Bact. tectum*, *Prevotella heparinolytica*, and several porphyromonas species (*Porph. macacae*, *Porph. canoris*, *Porph. circumdentaria*, *Porph. cangingivalis*, and *Porph. cansulci*) — zoonotic strains that to our knowledge have not been previously identified as human pathogens — were also isolated. In addition, *Bact. forsythus*, isolated from two dog bites, to our knowledge has not been previously described as part of the oral flora of animals.

Anaerobes were isolated more frequently from abscesses (77 percent) than from the other types of infections. Streptococci (59 percent) and staphylococci (52 percent) were isolated more frequently from non-purulent wounds with lymphangitis than from the other types of infections. Pasteurella species were common in both abscesses (83 percent) and non-purulent wounds with lymphangitis (63 percent).

Bacteriologic results did not appear to be related to the interval between the bite and the collection of the specimen or the interval between collection of the specimen and culture. Pasteurella species or anaerobes were more commonly isolated from bites of the arms than from bites of the legs and from puncture wounds than from lacerations.

Fifty-five wound cultures were also sent to the local microbiology laboratories; significantly fewer organisms grew in these cultures than in cultures sent to the reference laboratory (median, 1; range, 0 to 5;  $P < 0.001$ ). Ten of these cultures (18 percent) had no growth. The prevalences of all species except *Past. multocida* (49 percent), staphylococci (25 percent), streptococci (25 percent), and bacteroides (6 percent) were less than 5 percent. Of the 14 patients with blood cultures, 1, who had been bitten by a dog, had *Staphylococcus aureus* and *Streptococcus pyogenes* bacteremia; these were the sole wound isolates grown at the reference laboratory.

Approximately 2 percent of all isolates were grown only at the local laboratories (staphylococcus, 5; streptococci, 3; pasteurella, 2; weeksella, 2; moraxella, 1; prevotella, 1; and fusobacterium, 1). There was occasional discordance in species identification between local and reference laboratories; for example, four *Past. multocida* isolates were identified as *Past. canis*, *Past. dagmatis*, and *Past. stomatis*, and one *Staph. aureus* isolate was identified as *Staph. intermedius*.

The median time from the bite to the appearance of the first symptoms of infection (the latency period) was significantly shorter for cat bites than for dog

bites (12 hours; interquartile range, 7 to 18; as compared with 24 hours; interquartile range, 12 to 48;  $P < 0.001$ ). For wounds from which pasteurella (68 patients), streptococci (49 patients), and staphylococci (43 patients) were cultured (many wounds yielded more than one type of microorganism), the median latency periods were 12, 15, and 18 hours, respectively ( $P$  not significant).

Thirty-three patients (31 percent) were hospitalized and were initially treated with intravenous antibiotics; 37 patients (35 percent) received one intravenous or intramuscular dose of antibiotics followed by an oral regimen; and 37 patients (35 percent) received only oral antibiotics. Intravenous regimens for hospitalized patients included a combination of a  $\beta$ -lactam antibiotic and a  $\beta$ -lactamase inhibitor, typically ampicillin and sulbactam (19 patients); penicillin (4); cefazolin (3); cefazolin and a combination of a  $\beta$ -lactam antibiotic and a  $\beta$ -lactamase inhibitor (1); cefazolin and penicillin (1); cefazolin and gentamicin (1); cefotaxime (1); ceftriaxone (1); nafcillin (1); and doxycycline (1). The single-dose parenteral regimens that preceded oral therapy included a combination of a  $\beta$ -lactam antibiotic and a  $\beta$ -lactamase inhibitor (15 patients), ceftriaxone (9), cefazolin (9), ceftriaxone and penicillin (1), ceftriaxone and cefazolin (1), penicillin and cefazolin (1), and penicillin (1). Oral regimens included amoxicillin and clavulanic acid (40 patients), a first-generation cephalosporin (12), penicillin and a first-generation cephalosporin (7), penicillin (5), penicillin and dicloxacillin (3), tetracyclines (2), azithromycin (1), loracarbef (1), dicloxacillin (1), clindamycin (1), and clindamycin and doxycycline (1).

Complete follow-up data were available for 93 patients (87 percent), who received a median of 10 days (range, 3 to 24) of antimicrobial therapy until symptoms resolved. Among the 33 patients who were hospitalized, the median length of stay was 3 days (range, 1 to 11). Incision and drainage were performed in 23 patients (21 percent), débridement in 18 (17 percent), and both procedures in 9 (8 percent). Gangrene developed in one patient for whom medical therapy was thought to have been successful, and amputation of a finger was required. Initial medical treatment was unsuccessful in four patients because of worsening infection: three of these patients were infected with pasteurella species (as well as moraxella, staphylococcus, EF-4b, porphyromonas, bacteroides, or fusobacterium in some cases) and were initially treated orally with a first-generation cephalosporin. Their conditions subsequently improved with oral amoxicillin and clavulanic acid, penicillin, or penicillin with doxycycline. The fourth patient was infected with actinomyces species and *Propionibacterium acnes* and was initially treated with oral penicillin. The patient was hospitalized and treated successfully with ampicillin and sulbactam followed by amoxicillin and clavulanic acid.

## DISCUSSION

Previous investigations of infected dog bites and cat bites have been limited by the small numbers of patients enrolled, skewed patient populations, a retrospective design, the inclusion of patients who were receiving systemic antibiotics, and the use of inexact definitions of infection. A precise definition of a wound infection is critical, since several series have documented bacterial growth, including growth of zoonotic bacteria, in specimens from fresh wounds and clinically uninfected wounds.<sup>9,14</sup> Our study addressed these limitations and as a consequence was able to provide a more complete description of the broad range of pathogens, including many zoonotic isolates, associated with these infections.

We identified cases from among patients who sought treatment for their dog bites or cat bites at emergency departments, so the patients had more severe illness than would be seen among patients in other settings. Since we do not know whether all consecutive patients were enrolled, there may have been selection bias. However, because of the bias toward enrolling patients with more serious infections, the patients selected were more likely to have infections and thus more prone to complications for which microbiologic analyses would be most relevant. The fact that we used strictly defined and prospectively applied criteria for wound infection and the number and diversity of infections in this study make the possibility of important selection bias unlikely.

The microbiologic specimens collected from the wounds were transported by courier to a research microbiology laboratory specializing in the isolation of microorganisms from bite wounds. Several observations suggest that the microbiologic techniques were optimal. Few specimens exhibited no growth, and an average of five isolates were cultured per specimen, even among specimens from nonpurulent wounds. One previous study that used methods for the recovery of anaerobic bacteria found only 2.8 isolates per specimen.<sup>15</sup> The results of the local microbiology laboratories and the findings of the research laboratory were in agreement in terms of the frequency of the predominant aerobic pathogens; however, the number and diversity of other aerobic and anaerobic isolates were much greater in the research laboratory.

We do not believe that shipment in transport medium and delayed plating significantly affected the growth of isolates. Only rarely were isolates grown only at the local laboratories, which may be due in part to the method of specimen collection, and the few discordant results in the identification of species could be explained by the fact that the reference laboratory performed more extensive testing. Before the study, we conducted experiments with bite-wound isolates of *Pasteurella*, *Eikenella*, *Strep. salivarius*, *Prevotella*, and *Peptostreptococcus* that indicated

that they remained viable in transport medium for one week. The ability of transport medium to maintain anaerobes has been established by other investigators.<sup>28</sup>

We found that *Pasteurella* species were the most common pathogen in dog bites and cat bites. Although found more often in cat bites, *Pasteurella* species were isolated from half of dog bites, contradicting the impression that this is an uncommon pathogen in dog bites.<sup>4-6,14,15</sup> *Pasteurella* species are among the most common canine and feline oropharyngeal isolates, present in 12.5 to 87 percent of such animals.<sup>29-31</sup> Our data support its reputation for pathogenicity and its association with infections with a more rapid onset.<sup>4-6,16</sup>

Non-multocida species of *Pasteurella* have been cultured from animals and have caused infections in humans.<sup>29-33</sup> Advances in molecular-biology methods have led to the identification of 11 genetically closely related taxa, which includes several new species; 3 subspecies of *Past. multocida*; and 11 related species with a low degree of homology.<sup>34</sup> As in other reports, in our study *Past. canis* was the predominant isolate from dog bites and *Past. multocida* subspecies *multocida* and *septica* were the predominant isolates from cat bites.<sup>32,33,35</sup> Other *Pasteurella* species (e.g., *Past. dagmatis* and *Past. stomatis*) were also occasionally present in both types of bites.

Streptococci, staphylococci, moraxella, corynebacterium, and neisseria were the next most common aerobic isolates. *Staph. aureus* and *Strep. pyogenes*, which are part of the normal flora of human skin, typical etiologic agents of cellulitis, and uncommon in canine oropharyngeal flora, were found relatively infrequently, especially in cat bites (*Staph. aureus* was present in 20 percent of dog bites and 4 percent of cat bites, and *Strep. pyogenes* was present in 12 percent and 0 percent, respectively). This may have resulted from the wounds' being more heavily contaminated with oral zoonotic bacteria than with human-skin flora, especially deep puncture wounds, which are characteristic of cat bites. *Staph. intermedius*, a zoonotic species frequently present in canine gingival flora,<sup>19</sup> was found in only 2 percent of dog bites and 2 percent of cat bites. *Eikenella corrodens*, which is associated with human-bite infections, was found in only one dog bite and one cat bite.

Anaerobes were rarely present alone; the majority of infections (56 percent) were mixed infections. Contrary to previous studies in which anaerobic cocci predominated, we found that fusobacterium, bacteroides, porphyromonas, and prevotella species were the predominant anaerobic isolates.<sup>14,15</sup> In a search of the literature we could find no previous reports of infections in humans with the anaerobes *Bact. tectum*, *Prev. heparinolytica*, and several porphyromonas species as a result of dog bites or cat bites. As was true for *Pasteurella* species, anaerobes were more often

isolated from cat bites than from dog bites, and from puncture wounds of the arms than from other parts of the body, perhaps reflecting more efficient transmission of oral flora because of the nature of the wound.

Two potentially invasive zoonotic pathogens, capnocytophaga species and *W. zoobeleum*, were uncommon isolates and may be opportunistic pathogens.<sup>17,18</sup> One cat bite was infected with *R. anatipestifer*, a pathogen related to weeksella and capnocytophaga and associated with septicemia in avian species; to our knowledge this pathogen has not been isolated previously from animal bites in humans.<sup>36</sup> *Erysip. rhusiopathiae* was isolated from two cat bites. Infection with this organism has occurred in humans after contact with a variety of animals, but it has not been associated with cat bites.

Our findings suggest that empirical therapy for dog bites and cat bites should be directed against pasteurilla, streptococci, staphylococci, and anaerobes. Pasteurella species are usually susceptible to ampicillin, penicillin, second-generation and third-generation cephalosporins, doxycycline, trimethoprim-sulfamethoxazole, fluoroquinolones, clarithromycin, and azithromycin.<sup>37-43</sup> Antibiotics typically used for routine infections of skin and soft tissue, such as antistaphylococcal penicillins, first-generation cephalosporins, clindamycin, and erythromycin, are less active against pasteurilla in vitro. In this study, treatment with first-generation cephalosporins alone was unsuccessful in three cases in which pasteurilla was cultured. Many species isolated from infected bites, including staphylococci and most anaerobes, are  $\beta$ -lactamase producers.

Approximately 20 percent of the infections in this study were treated empirically with penicillin, ampicillin, or a first-generation cephalosporin alone, choices that appear to be less than optimal. On the basis of our findings, we believe that empirical therapy should include a combination of a  $\beta$ -lactam antibiotic and a  $\beta$ -lactamase inhibitor, a second-generation cephalosporin with anaerobic activity, or combination therapy with either penicillin and a first-generation cephalosporin or clindamycin and a fluoroquinolone. When given alone, azithromycin, trovafloxacin, and the new ketolide antibiotics display in vitro activity against common aerobic and anaerobic isolates from bite wounds and thus may also be useful.<sup>40-43</sup>

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## APPENDIX

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