Zoonosis Update

Animal bites

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Animal bites continue to pose major public health challenges. Since publication of the previous report[1] on this topic for this series in 1988, much has been researched and reported regarding animal bites among populations of humans. The intent of this article was not to exhaustively review all literature published since 1988, but to focus on aspects of animal bites (dog and cat bites in particular) that were novel or noteworthy with respect to previously unrecognized injuries or cause of death[2–7] or bite-wound pathogens,[8–10] the role of individual organisms in polymicrobial infections,[11] risk factors for infection of a bite,[12] and controversies in medical or surgical management of bite injuries (eg, wound closure and antimicrobial prophylaxis).[13,14] Therefore, reports describing new empiric data and prospective studies were given attention, rather than new compilations of previously reported material. Online abstracting and indexing databases (ie, Medline and PubMed) were searched by use of the key words dog bite, cat bite, and animal bite. In addition, the bibliographies of pertinent publications were reviewed to identify additional relevant publications.

Epidemiology

Species—Recent reports from the United States,[15] Australia,[16] and Italy[17] are consistent in that dogs represent the species most frequently responsible for bite-related injuries associated with vertebrate animals, followed by cats (approx 80% and < 20%, respectively). Wildlife, farm animals, rodents, and other pets are responsible for the remainder of those reported bite-related injuries; such injuries are comparatively infrequent. Results of a multicenter, prospective study of 2,026 persons evaluated at 11 geographically diverse university-affiliated urban emergency departments across the United States because of animal-related injuries during the period of July 1996 through July 1998 indicated that dogs (n = 1,528) were the predominant animal exposure for adults (70% [931/1,339] of patients) and children (87% [597/687] of patients).[18] Among the 2,026 persons, there was a much smaller proportion (13%) of cat exposures, of which 7.1% (49/687) were children and 16% (218/1,339) were adults. Furthermore, 87.7% (1,777/2,026) of affected persons received bites, rather than scratches, body fluid exposure, or other injuries

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ABBREVIATIONS	
ED	Emergency Department
PEP	Postexposure prophylaxis
Psi	Pounds per square inch

for which people might come to an emergency department for care.

Frequency—Accurate incidence data for dog (or any other animal) bites and exposure-related injuries are not available because, in part, of the lack of a national system for reporting animal bites. Among studies[15,19–27] for which the rate of bites/100,000 persons was reported, depending on the population sampled and sampling methods, the estimated incidence of dog bites and bite-related hospital visits is quite variable (**Appendix**). Most bite statistics likely underestimate the true incidence. For example, in a capture-recapture study[21] conducted in Pittsburgh, it was estimated that only approximately 36% of dog bites were reported. A similar study[26] in 3 counties in Georgia revealed that health department surveillance systems for dog bites have sensitivities ranging from 44.3% to 82.5%. Extrapolation of data from Kansas City, Mo, suggests that as few as 10% of dog bites were reported to Animal Control Authorities.[22] It is also recognized that there is likely to be a strong bias toward reporting more serious bites or vicious attacks.[15]

Hospital visits and costs—Animal-related exposures account for approximately 0.2% of all ED visits.[18] In a previous study[27] of 333,687 dog bite–related injury visits to EDs in the United States from 1992 through 1994 (based on the National Hospital Ambulatory Medical Care Survey), it was estimated that only approximately 4% of affected persons required hospitalization or transfer to another facility. Overall, among the 94% of cases assigned a calculated injury severity score, 99% were of low severity (injury severity score = 1).[27] The injury severity score is a standardized assessment of trauma-related injuries; scores range from 0 to 75, with a low score indicating a less severe injury.[28] Nationally, the incidence of dog bite–related hospitalizations has been reported as 2.1/100,000 persons[20] and 1.6 to 2.0/100,000 adults ≥ 20 years old.[29] Incidence in California has been reported as 2.6/100,000 persons,[30] whereas incidence in Kansas City, Mo, has been reported as 4.3/100,000 persons.[22]

Notwithstanding the minor nature of most bites, the cost of dog bites remains substantial. From data collected from 904 hospitals in 17 states, it was estimated

that there were at least 330,000 ED visits nationally and 5,991 hospital discharges related to dog bite injuries in 1994.[29] Combined with other ED survey data from the period 1992 through 1994,[27] the estimate for direct medical care for dog bites was US$164.9 million, with a total cost of $235.6 to $253.7 million. In a study[22] of 3,467 ED visits for dog bites in Kansas City, Mo, in 1998 through 2002, charges totaled $1,452,845 (median cost, $300/visit). Approximately 2.8% (96/3,467) of bites resulted in hospitalization of the patient, for which the median charge was $4,698; in some instances, the costs were notably higher. In a retrospective review[31] of medical records for 111 individuals who received a dog (n = 71) or cat (40) bite to the hand, approximately two-thirds of patients required hospital admission, and one-third required at least 1 surgical procedure. Thirteen persons required IV administration of antimicrobials long term, multiple surgeries, or both, and estimated cost of care exceeded $77,000/patient.

Another cost associated with animal bites is rabies PEP. In 4 New York counties, cat and dog bite exposures accounted for 46.1% of 2,216 persons who receive rabies PEP from 1995 through 2000.[32] In a study[33] of bite reports in Pennsylvania, humans that had cat exposures were 6 times as likely as those that had dog exposures to require rabies PEP. Finally, it should be noted that the number of insurance claims for dog bites appears to be escalating, with the total cost of claims in 1995 estimated at $2 billion.[34]

Propensity of dogs to bite—Whether particular breeds of dogs are more prone to bite or to cause serious injury is a subject of great debate, a debate that has been fueled by errors or misrepresentations in reports. For example, in the introduction of a report[31] of a case series of patients with dog or cat bites to the hand, Benson et al stated that Jack Russell Terriers, German Shepherd Dogs, Chow Chows, and pit bull–type dogs are breeds more prone to attack without provocation. This blanket statement was not supported by the data in the references cited.[35,36] Unfortunately, once such claims are inserted into the biomedical literature, they become almost impossible to extract.

There has been considerable focus on fatal attacks. One study[37] evaluated 109 dog bite–related deaths from 1989 through 1994. Fatalities were identified by use of an online search service, records of deaths from multiple causes held by the National Center for Health Statistics, and a registry maintained by the Humane Society of the United States. For the 84 cases for which breed of dog was reported, pit bull–type dog was the most commonly reported breed (involved in 24 [28.6%] deaths), followed by Rottweilers (16 [19.0%]) and German Shepherd Dogs (10 [11.9%]).[37] A subsequent study[38] used media reports to supplement the fatal attack data and further described the circumstances of the attacks and breed of dog involved. At least 25 different breeds of dogs were involved in the 238 human deaths reported, and again, pit bull–type dogs and Rottweilers were involved in more than half the fatal attacks.

Interpretation of these data is difficult because of biases in how dog bite victims are identified and how dog bite information is obtained and reported.[39] These include challenges in identification of all human deaths attributable to dog bites, accuracy of dog breed determination, and lack of reliable denominators for individual breeds in the population.[38] With respect to nonfatal bites, there may also be a media bias in reporting bite incidents involving certain breeds. For example, purportedly within the same 3-day period, a severe attack by 2 pit bull–type dogs on a 59-year-old woman was mentioned in several hundred media reports including television coverage, whereas a fatal bite from a mixed-breed dog received by a child, a serious attack by a Labrador mix on a 70-year-old man, and an attack by a mixed-breed dog on a 6-year-old child received only limited mention in local press.[40]

One anecdotal report[41] argues for reevaluation of this previous breed-specific fatal attack data. On the basis of their study[38] of dog attacks between 1979 and 1998, Sacks at al reported a total of 327 deaths, but no news reports could be located for 89 of these deaths; thus, breed data were omitted from the tabulations in the original report. However, further efforts resulted in obtaining information about 40 additional deaths, 37 of which involved breeds other than pit bull–type dogs.[41]

Although there is increasing recognition of the limitations of breed data[38,39] and of the fact that breed per se is an unreliable indicator of potential danger and propensity to bite, it does seem indisputable that physically larger, more powerful dogs have a much greater ability to inflict more serious injury that is associated with long-term functional and cosmetic sequelae than small dogs. Nevertheless, in rare instances (particularly in the context of a pack attack), even physically small dogs can inflict fatal injuries.[42] Dogs that may pose little danger when acting as individuals may become far more dangerous when acting in concert.[42] Among 109 fatal dog attacks from 1989 through 1994, for those 85 events where the number of dogs was known, incidents involving 2 dogs resulted in 18 (21.2%) deaths, and those involving 3 or more dogs resulted in 5 (5.9%) deaths.[37] Lack of human social interaction, social feeding behavior, and prey stimuli from the victim appear to be risk factors for pack attacks.[43]

The fact that fatal bites inflicted by a small number of dogs have far-reaching consequences has been duly noted.[37,38] However, reports of medically attended nonfatal bites, which can be associated with serious and permanent injury, increased by more than 33% from 1986 to 1994.[38]

Setting—The greatest risk of dog bites continues to be from dogs that are familiar to the victim and in the home setting. For example, in 1 pediatric case series[44] of severe bites, dogs known to the family attacked the victim at home in 75% of 31 cases. In another case series[45] of 100 pediatric patients brought to a hospital ED, 65% were bitten at home; most (93.8%) of the biting dogs were familiar to the bitten children. In yet another survey[36] of 146 patients referred to a plastic surgery unit for treatment of dog bites, 91 of 107 (85%) bites occurred in the home. A prospective case series[18] of 2,026 ED visits revealed that approximately three-fourths of dog bites to children occurred in the home or private yard. Furthermore, a retrospective review of 341 charts of children who sought medical attention for dog bites indicated that 82% of the biting dogs were familiar to the children.[7]

Victim profile—Animal bites continue to have particular importance for children. In data collected in Indiana, children were substantially overrepresented as victims of reported animal bites; compared with the annual incidence of 81 bites/100,000 persons > 60 years of age, there were 475 bites/100,000 persons < 5 years old, 613 bites/100,000 persons 5 to 9 years old, and 462 bites/100,000 persons 10 to 14 years old.[15] Similar age-related patterns for bite-related hospitalization have been identified in California (data collected from 1991 through 1998[30]), New York City,[19] and Kansas City, Mo.[22] Boys also appear to be bitten at greater frequency than girls.[15,19,20,22] Dog bites take on particular importance for children because data consistently indicate that children are typically bitten on the face, head, and neck.[7,13,18,33,45–47] Injuries in these body locations are often complex, involving bony tissue injuries, intracranial complications, and ophthalmologic lesions.[47] Because of frequent postsurgical complications in these cases, children may frequently require multiple revision procedures such as skin grafting, scar revision, and ear reconstruction.[48]

Circumstances of bites—Data about the circumstances of animal bites are frequently not included in bite reports, and when precipitating actions and victim behavior are reported, there is little consistency. For example, in data on 3,244 dog bites in Milwaukee from 1989 through 1991 reported by Ndon et al,[23] circumstances were characterized as playful (ie, victim and dog were acquainted and interacting in a friendly manner; 3.3%), unprovoked (ie, victim was bitten without interacting with the dog; 33%), provoked (ie, victim threatened the dog or invaded its territory; 19%), or unknown (45.3%). In another report,[13] Akhtar et al describe a provoked bite as teasing a dog with food, pulling a dog's ear, and pulling a leash. Other authors associate bites with circumstances such as invasion of dog's territory, the victim being seen as a threat to the family or dog, and jealousy.[36] By comparison, Patrick and O'Rourke[49] define provoked bites as the animal having been "picked up, petted, hit, kicked, or struck" or "any part of the animal's body having been pulled, pinched, or squeezed." In a case series[50] of all pediatric admissions for dog bites in Philadelphia from January 1986 through June 1998, 37 of 67 (55%) were characterized as unprovoked, yet in 12 (18%) cases, the children were reported to have been playing with the dog. In another study,[46] a bite was defined as provoked if the child was interacting (playing, petting, or other interactions) with the dog and as unprovoked if the patient was not interacting with the dog at the time of the bite. In another report,[45] investigators mention that playing with the dog, interacting with the dog while it was eating, entering a room occupied by the dog, surprising the dog while it was asleep, and trying to cuddle the dog were instigating factors.

Part of the reason for this inconsistency in reporting is that triggering circumstances for a bite or attack may be poorly understood. In 1 report,[51] Love and Overall emphasize how canine behavior may seem unpredictable to untrained observers. Therefore, what people perceive as nonprovocational behavior may, in fact, be highly stimulating to certain dogs. Furthermore, a variety of common canine behavioral problems, such as predatory or fear aggression, pain aggression, food aggression, protective or territorial aggression, dominance aggression, inappropriate herding behavior, inappropriate play, and possessive aggression, can also increase the risk of bites.[51] In other instances, seemingly innocent events may provide powerful triggers. Three cases of fatal dog mauling of infants left unattended in a mobile swing in the presence of the family dog have been reported.[52] However, fatal attacks have even occurred when infants were left (presumably) sleeping in their crib.[24] It has also been reported[48] that children with attention deficit disorder may be at higher risk of dog bites and may require particularly close supervision when in the presence of dogs.

Bite force—Claims about bite force are frequently exaggerated or unsupportable. For example, in a report[13] by Akhtar et al, it is stated that the bite force of an American Pit Bull Terrier can reach 1,800 psi, yet the cited reference[53] provides no indication of that particular pressure value. The referenced article[53] does provide an unreferenced statement that the jaws of a large dog can exert a pressure of 450 psi, which they classify as "enough to penetrate light sheet metal." In a report[54] by De Munnynck and Van de Voorde, an article by Miller et al[6] is cited in which another report by Chambers and Payne[55] is cited as stating that forces of 450 psi (ie, "sufficient to penetrate sheet metal") have been recorded in dog bite attacks. The latter report[55] is actually a discussion of treatment of bites inflicted by German Shepherd Dogs that were being trained at the United States Air Force Sentry Dog School. That article contains an uncorroborated statement that "[s]tudies by veterinarians at Lackland Air Force Base indicate that the bite power is 150 to 200 psi and as much as 400 to 450 psi by the end of training," which, at times, "is adequate to perforate the sheet metal gauntlet that is worn as a protective device." How bite pressure, either before or after sentry dog training, was determined was not described, but regardless, these results would clearly be limited to a specific population of dogs.

Bite force (and pressure, which is force per unit area) is technically difficult to measure in dogs. In the contrived environment of an experimental situation, it is presently almost impossible to recreate the arousal that drives a dog's biting behavior during a real-life attack[56]; thus, any investigation of that nature has considerable inherent limitations. Dog size, head shape, gape, tooth size,[a] training, and motivation to bite all interact to produce tremendous individual variation in bite force even within a breed.[56] Indeed, there is only moderate correlation between weight and bite strength, except at the extremes of size.[56] Thus, any claims about bite force should be interpreted with healthy skepticism. Beyond reaffirming the obvious finding that larger dogs have the potential to inflict greater damage than smaller dogs, discussion of bite force associated with particular breeds seems to have minimal clinical relevance and may only inflame and polarize the discussion.

Clinical Features and Evaluation

Clinical features—Animal bite wounds have been categorized into 3 groups on the basis of the type of injury: avulsions, lacerations, or punctures. Avulsions occur when the skin is torn away from underlying tissue and bone. Lacerations are tears in the skin; in more severe instances, these include tears in the underlying tissue that result in irregular edges. Punctures result from teeth penetrating the skin and possibly the underlying structures.[57]

Avulsions and lacerations are associated more with dog bites than with cat bites because of the physical design of the mouth of canids and the strength of the canine masseter-pterygoid complex muscles.[55] The characteristic lesion is that of a hole with corresponding tearing of the surrounding tissue.[54] This along with bite force explains why dog bites may cause crushing injuries with direct structural damage to underlying vasculature, tendons, nerves, or joints.[31,58] Such blunt force can also lead to considerable morbidity that may not be immediately evident (eg, depressed skull fractures, chest wall deconstruction, and vascular injury).[3] Although all breeds are capable of severe damage, large brachycephalic dogs have a greater biting force, compared with that of small dolichocephalic dogs.[a]

Cats first bite and then hold their prey until they are motionless.[11] As such, cat bites more often result in puncture wounds.[10–12] The long, pointed teeth of cats can readily pierce underlying structures, including ligaments, bone, joint capsule, tendon sheath, neurons, and vascular structures.[10,58,59] Additionally, puncture wounds inflicted by felids typically involve deep penetration of tissue and preservation of a largely closed wound.[11]

Ferret bites deserve mention because this species has become more commonly kept as a pet. Attacks on infants, particularly attacks to the face, may be particularly severe, resulting in the loss of ear and nose tissue as well as multiple punctures on the face, lips, and eyelids. Children who have recently finished feeding from a bottle have been bitten, suggesting that the attacks may have been prompted by the scent of milk or formula.[60,61]

Bites from bats found in the United States rarely cause major tissue damage; thus, the victim often does not seek medical care. Although rabies in humans is rare in the United States, bats are the primary vector for transmission of rabies virus to humans in this country. It is important to note that bats infrequently yield positive test results for rabies virus infection and that any bite or other type of potential rabies virus exposure should be fully evaluated to determine the need for rabies PEP, especially if the bat is not available for testing.

Bite wound evaluation—The initial evaluation is considered to be a vital part of managing and treating bite wounds. It should include a thorough assessment of the wound itself and the patient's medical history and status, determination of the amount of time elapsed before treatment was initiated, and identification of the animal responsible and the circumstances under which the bite occurred.[58,62] During the evaluation, information documented should include details such as wound location, type, and depth; degree of contamination or edema; and evidence of infection. It has been suggested that collection of this information is important for follow-up comparisons as well as for any potential legal actions.[58]

In some instances, severe damage from a bite wound is not always evident on visual inspection. To help identify more extensive problems, wounds should be fully explored, and depending on the location of bites, range of motion of potentially affected joints should be assessed. For example, puncture wounds may appear superficial, but in some instances, deeper structures may be involved, particularly with regard to wounds to the hand. Additionally, crushing wounds may potentially damage vessels, nerves, or internal organs. Detection of signs of pain during stretching or contracting muscles that control a joint or paresthesia or hypoesthesia of nerves in the area of a bite may be indicative of a compartmental injury or necrotizing infection.[58,62] Attacks to the trunk should warrant evaluation for rib fractures, pneumothorax, or internal organ injury.[58]

Dog bites to the head require special consideration, particularly in children. Children often receive dog bites to the head and neck because of their small stature, proximity to a dog's mouth, and uninhibited interactions with dogs. In a case series[63] of 18 dog bites referred to an oculoplastic specialty practice, patients were predominantly children < 12 years old. It has been reported that the most common bite site among children is the face (59% [81/137]).[13] On the basis of findings in 3 retrospective studies[64–66] of bites to the head, the most frequently affected sites on the face were the cheek (28%,[64] 45%,[65] and 24%[66]) and the lips (41%,[64] 28%,[65] and 19%[66]). Most bites are not serious in nature but require medical attention for cosmetic reasons; typically, approximately half (48%) of the wounds are superficial and do not involve the musculature.[64]

It is important to expect that children with bites to the head may require multiple surgical procedures. A retrospective study[48] of dog bites to the scalp, face, and neck in 44 children revealed that 11 of the 16 hospitalized patients developed postsurgical complications, including hypertrophic scarring and facial nerve injuries. Nine of the 26 children with injuries such as simple lacerations or eyelid repair that did not require hospitalization also developed complications.[48]

Less often, such bites may result in severe damage to the skull because the calvarium of children is often thin and readily crushed.[4,5] In a case series[3] of children with severe dog bite wounds, 8 of 35 (23%) children sustained life-threatening injuries that were mostly attributable to blunt force or penetration from the bite; these injuries included skull fractures as well as pneumothorax, stroke, spinal cord transection, and tracheal or esophageal lacerations. Deep puncture wounds to the head provide a direct route for bacteria to enter the intracranial space. There have been several pediatric cases of penetrating injuries resulting in development of brain abscesses and meningitis.[4,5] If the scalp is displaced at the time of the bite, punctures to the bones of the skull may be overlooked because they are covered by the scalp after it resettles in position. Radiography of the skull is recommended for all children that receive a

dog bite wound to the head.[5] Periocular injuries should be assessed for damage to the delicate bones, tissues, and structures that comprise the orbital area.[63]

Although rare, most fatal dog attacks are a result of lesions to the head and neck of children. Death is usually a result of crushing of the larynx or damage to large vessels with subsequent severe hemorrhage.[54]

With regard to bites to the hand, cat bites are often more difficult to treat than dog bites.[31] It has been reported that a higher proportion of persons with cat bites to the hand are referred for more invasive treatment, compared with the proportion of persons with dog bites to the hand.[31] In 1 study,[67] the middle and index fingers were the most common cat bite sites on the hand. In a prospective study[68] of 78 patients with cat bite wounds primarily of the hand and arm, 19 (24%) were hospitalized for severe disease or for surgical repair; complications occurred in 14 (18%) of the patients, including development of arthritis. In addition to complications arising from cat bites to the hand, other complications associated with cat bites in general that have been reported in the literature include cellulitis, osteomyelitis, tenosynovitis, bacteremia, and brain abscesses.[11,58,68,69]

Poor outcomes have been associated with contamination of wounds of closed spaces; within the hand, such closed spaces include the digital pulp space, nail bed, flexor tendon sheath, any of the deep spaces of the palm or thenar regions (group of 3 muscles that control the thumb), and many of the joint spaces of the fingers or wrist. If any of these areas become infected, debridement is usually indicated and may need to be done on several occasions along with IV administration of antimicrobials.[31] Complications involving the bone and or periosteum are not typically visible immediately following a bite; thus, radiography should be considered when such complications are clinically evident.[67]

In the biomedical literature, there are case reports of bizarre complications associated with dog and cat bites. An attack to the head of a 50-year-old man by 2 Rottweilers resulted in a pseudoaneurysm.[6] In a child < 3 years old that was attacked by a dog, a stroke developed secondary to occlusion of the left internal carotid.[3] Pericardial tamponade and meningoencephalitis developed in a patient that had *Pasteurella multocida*–associated septicemia as a result of a cat bite; that patient was successfully treated with pericardiocentesis, administration of antimicrobials, and appropriate medical management.[2] *Pasteurella multocida* was also responsible for meningitis and septic arthritis in a 78-year-old with multiple myeloma who had been bitten by a cat.[69]

Microorganisms—Early work suggested microbes recovered from a bite wound abscess would be representative of the oral flora from the biting animal.[70] This has been subsequently confirmed; anaerobes (including gram-positive anaerobic bacteria) and gram-negative asaccharolytic bacteria have been identified in cat abscess wounds and in oral swab samples collected from the respective biting cats.[11] In a study[68] in Sweden, oral swabs collected from cats that had bitten humans were cultured. Of the samples collected from 38 cats, microbial culture yielded *Pasturella* spp in 30 (79.9%); 27 of the 30 (90%) samples yielded *P multocida* (1

sample yielded *Pasteurella haemolytica*, and 2 microbial growths were not speciated). Additional isolates included *Prevotella oris-buccae* and *Enterobacter cloacae* (from 1 sample each).[68] Cultures of samples collected via gingival scraping from a group of 25 control cats all yielded *P multocida*; member of the Enterobacteriaceae family and viridians group streptococci were detected in samples from 2 and 1 control cat, respectively.

Bacteria from the skin of the bite victim or the environment may contaminate the bite wound, thereby contributing to the polymicrobial composition of an infection or becoming the sole source of an infection. Because methicillin-resistant *Staphylococcus aureus* has become more common as a community-acquired pathogen, it may be identified in bacterial cultures of samples from bite wounds, although this has not yet been reported in the literature to our knowledge. Thorough and timely wound care of a bite lesion and the surrounding skin should nearly eliminate the risk for such infections.

In 1999, a comprehensive evaluation of microorganisms that are responsible for infections of dog and cat bite wounds in a multicenter study[10] was performed in which samples were collected from bite sites in 107 patients at 18 university EDs. The detailed study design and the meticulous methods used to collect and transport samples for microbial culture in that investigation resulted in the most extensive assessment of bite wound–associated bacteria to date. Cultures of 56% (60/107) of bite wound samples yielded a mix of aerobic and anaerobic bacteria; the median number of isolates/sample was 5 (range, 0 to 16), 3 of which were typically aerobes and 2 of which were typically anaerobes.[10] An anaerobe is rarely the sole organism cultured (sole organism in 1% of dog bites and in 0% of cat bites[10]); such anaerobes are typically part of a mixed infection (detected in 56%[10] to 80%[68] of infected dog and cat bite wounds). In cultures of wound samples that yielded a single isolate, the isolate was almost always an aerobe rather than an anaerobe.[10,68]

Among the aerobes, *Pasturella* spp are most frequently detected in bite lesions (detected in samples from 50% of 50 dog bites and from 75% of 57 cat bites in 1 study[10]). *Pasturella multocida* is predominantly found in cat bite wounds, and *Pasturella canis* is predominantly found in dog bite wounds.[10,67,68] The next most commonly identified aerobes are species of *Streptococcus, Staphylococcus, Moraxella, Corynebacterium*, and *Neisseria*. The most commonly identified anaerobes are species of *Fusobacterium, Bacteroides, Posphuomonoa*, and *Prevotella*.[10]

Cat bites to the hands have garnered particular attention because of the high potential for infection and complications. Two studies[67,68] that investigated cat bites to the hand specifically revealed that the most common isolate cultured from wound samples was *P multocida*. Additional aerobes that were cultured included *S aureus* and *Streptococcus* group C; anaerobes included *Prevotella* and *Bacteroides* spp, which were usually part of a mixed infection with *P multocida*. From the findings of those studies,[67,68] the investigators concluded that an onset of cellulitis, lymphangitis, and serosanguineous or purulent discharge from a hand wound accompanied by severe pain within a 12- to 24-hour period was

suggestive of infection with *P multocida*, which has a shorter incubation period than that of *Staphylococcus* or *Streptococcus* spp. In contrast, in samples from 30 wounds in patients treated for animal bites in another study,[64] *Pasturella* spp were not detected; cultures most commonly yielded *Streptococcus* organisms (n = 15 wounds), *E coli* (10), *S aureus* (8), and *Staphylococcus epidermis* (7).

Uncommon microbial infections—*Capnocytophaga canimorsus* is seldom isolated from bite wounds, but in rare instances, it can cause severe wound infections and possibly death. Typical risk factors for infection with this organism include immunosuppression, liver disease, alcohol abuse, and asplenia. The incubation period can be as long as 2 to 4 weeks following exposure. A bite is the usual route for infection; however, humans may become infected via nonbite exposures, including through being licked by a dog.[71] Death as a result of infection with *C canimorsus* in 2 otherwise healthy individuals with no risk factors has been reported.[8,72] A 45-year-old woman died as a result of sepsis with gangrene after being bitten by a dog 3 weeks earlier while working at an animal shelter.[8] A 48-year-old man died from multiorgan failure following development of *C canimorsus*–associated septicemia approximately 4 days after receiving a fairly minor dog bite to the hand.[72] Patients with dog bites that have septicemia at the time of evaluation or that subsequently develop septicemia should be evaluated for possible *C canimorsus* infection and treated without delay.[8]

Capnocytophaga canimorsus, similar to asaccharolytic strains of *Acinetobacter*, was first identified in 1974 by the CDC; the organism was detected in a dog bite wound in an 8-year-old boy from Texas. Infection with this organism was described epidemiologically and clinically by Kaiser et al[9] in 2002. It is associated with dog and cat bites and can cause bite-related soft tissue infections such as abscesses or cellulitis. The most common clinical features of *C canimorsus* infection at the site of a bite wound include purulent drainage, worsening pain, erythema, and swelling. Of 12 persons with *C canimorsus*–infected bite wounds for whom records were available in the case series by Kaiser et al,[9] 1 developed systemic illness with symptoms consistent with septicemia; all were successfully treated with antimicrobials.

Infection rates and risk factors for infection—Infection rates differ significantly between cat and dog bites. Rates for cat bites have been reported to range from 30% to 50%,[12,73–75] whereas rates for dog bites are as low as 2% to 4%.[12] Most authors note that these figures are derived from studies with small sample sizes and limited standardization, suggesting that patient management should be approached on a case-by-case basis. A multitude of factors relating to both the bite recipient and the injury influences the potential development of infection; these include the type of injury, injury location, quantity of bacteria and presence of foreign particulates in the wound, delay of treatment, wound care, and other factors inherent to the patient.[12,14] Risk factors for infection cited in the literature include patient age > 50 years, puncture wounds, full-thickness wounds, and wounds requiring debridement.[12,76]

Hand and facial wounds have been specifically addressed in several reports.[31,49,63,64,66,67,77–79] The extensive blood supply to the face may explain why fewer infections develop in association with facial bite wounds.[77] In 1 study,[77] an infection rate of 2.5% among 40 patients with dog bite wounds to the face was reported; among 71 patients with bite wounds to the head who received prophylactic treatment with antimicrobials in another study,[64] 8 (11.2%) developed infections. Hand wounds are prone to development of complications and infections because of the extensive number of small compartments and the lack of substantive soft tissue.[79] It has been reported that 36% of all hand bites become infected.[80] Infection is the most common complication for cat bites to the hand, and complications from infected cat bites account for 1% of all patients hospitalized because of hand infections.[67,81]

Inadequate or delayed treatment can increase the chance for development of infection. Delay in care can result in infection and as a result lead to prolonged time to recovery as well as a requirement for more invasive treatments.[31] Among patients treated for head bites > 6 hours after injury, 59% (22/37) had signs of infection or went on to develop infection; in contrast, presence or development of infection was evident in only 8% (8/95) of patients who received treatment < 6 hours after injury.[64] A treatment delay > 24 to 48 hours is considered a risk factor for wound infection.[80] The infection rate for wounds that are or are not debrided is 2% and 62.5%, respectively.[80] In a study[77] of 40 persons with dog bites to the face for which initial treatment involved copious irrigation and debridement, infection rate was 2.5%.

Rates of wound infection are reduced in patients who receive antimicrobials IV.[48] In a retrospective study[48] of 44 children with bites to scalp, face, and neck, 34 were administered antimicrobials. Of the 16 who received antimicrobials IV, only 1 developed a wound infection, compared with 5 of the 18 children who were administered antimicrobials orally.

Treatment and management—Patients seeking treatment soon after the injury (usually within 8 hours) typically have severe injuries, cosmetic concerns, or pain or are concerned with the prevention of infectious diseases such as tetanus and rabies. Patients evaluated more than 8 hours after receiving a bite often seek treatment because of the development of infection or other problems at the bite site.[82]

Clinical illness associated with a local infection may include erythema, swelling, fever, or pain at the bite site as well as purulent discharge from the wound; however, a fever may not develop in patients with infections who are immunosuppressed.[58,68] Cat bites can result in pain, swelling, and erythema at the site with resulting inflammation of regional lymph nodes within 1 to 2 hours.[11,68] A high temperature, low blood pressure, and evidence of toxicosis may be indicative of a more severe or systemic infection.[58]

Appropriate and early management and treatment are essential to the successful management of bite wounds. Wound exploration will aid in defining the extent of the injury and detecting foreign bodies. Adjunctive procedures such as radiography, computed tomography, and arteriography may be indicated for

wounds to the hand and head or if there is suspicion of vascular, nerve, or compartment injury.[3,5,63,67]

Thorough cleaning and high-pressure irrigation with sterile physiologic saline (0.9% NaCl) solution or lactated Ringer's solution is crucial to aid in removal of foreign bodies and blood and to reduce the number of potential pathogens.[58,62]

If an abscess is present, the standard of care includes incision and drainage to permit better cleaning along with corresponding cleansing of surrounding skin to eliminate risk for infection from skin flora.[31,58] Punctures can reseal and abscesses may reform, thereby putting the patient at potential risk for hematogenous or contiguous spread of pathogens.[11,31]

Devitalized or necrotic tissue should be debrided, but with an abundance of caution to avoid complications with wound repair.[11,62,83] For hand wounds, administration of corticosteroids can reduce wound swelling quickly. In addition, elevation of the hand and its immobilization in a splint is recommended for a 48- to 72-hour period.[62,67] For potential legal proceedings, injuries and repairs should be documented by use of nondigital photographs, which are not amenable to alteration.[63]

The need for rabies PEP can be assessed by identifying the circumstances in which the bite was received, the species of biting animal, and, if indicated, whether testing for rabies virus or observation of the biting animal is underway. Vaccination against tetanus may be indicated depending on the patient's prior vaccination history.

Primary versus delayed repair—The debate regarding primary versus delayed repair persists, although more recently, investigators who study bites to specific anatomic regions such as the hand or face have come to some consensus. Taplitz[62] recommends considering primary closure if the wound occurred within the preceding 8 hours, the care provider is confident that thorough irrigation of the site has been accomplished along with debridement if indicated, and there is no evidence of infection.

In a retrospective study[66] of dog bite injuries requiring surgical repair in 100 children, all patients were treated with primary surgical repair (within 1 to 10 hours of admission to the hospital), and all received antimicrobials IV. Most wounds (59%) did not involve underlying musculature, and only 1 child developed a wound infection. The authors favored the use of primary surgical repair because of the better cosmetic outcome. Additionally, primary surgical repair enables care providers to avoid repeated anesthesia of a patient for continued wound dressing and manipulation during delayed healing.[66]

In another study, 133 patients who received primary closure following lacerations from dog and cat bites were evaluated. The authors reported an infection rate of 6% but noted that wound care and antimicrobial administration were not standardized among patients.[84] Most patients presented to the ED in < 2 hours following the bite (range, 0 to 7 hours). Of the patients that did develop infections, 5 had received dog bites, and all had been administered antimicrobials orally.

If the wound was received more than 24 hours earlier or if there is an increased risk for complications or infection such as wounds to the hand, primary closure is not recommended. For bite wounds to the hand that require surgical repair, closure should not be performed at the time of surgery. Instead, wounds should be reevaluated at 24 to 48 hours after surgery; if improvement is evident at that time, delayed primary closure is recommended.[67]

Historically, the recommendation for treatment of facial wounds was to allow for delayed healing if more than 24 hours had elapsed since the injury. More recent data suggest that primary closure is always indicated when copious irrigation and debridement are accomplished.[77] In a retrospective study[77] of 40 patients receiving primary repair for bite wounds to the face, only 1 developed an infection. Most patients in that study sought treatment within an hour of the injury, although 2 were evaluated for treatment after 5 days. It has been proposed that eyelid injuries undergo primary closure because of the extensive vascularization to the area.[62]

Antimicrobial prophylaxis—Prophylactic administration of antimicrobials remains controversial. A well-designed, standardized prospective study is needed to examine the efficacy of prophylaxis and treatment for bite wounds. Most information to date has been derived from studies involving an inadequate number of patients and low infection rates. According to an estimate by Jones and Stanbridge,[85] 740 persons enrolled as cases and controls would be needed to effectively test the value of antimicrobial prophylaxis in the treatment of dog bite wounds.

Effective medical management of animal bite wounds includes the decision regarding whether to provide antimicrobials prophylactically and requires an understanding of the patient, awareness of the timing of treatment with respect to the bite incident, thorough evaluation of the wound, and knowledge of the normal flora of the biting animal and the skin of the patient.[62] Even though most research has been unable to provide general guidance for antimicrobial prophylaxis, useful findings have resulted. Authors of a review[86] of several articles in which the use of prophylactic antimicrobials in treating animal bite wounds was assessed inferred that the use of rigorous wound care and irrigation effectively decreases the risk for infection, suggesting that wound care is more effective than antimicrobial prophylaxis.

In a meta-analysis[14] of 8 studies (1982 through 1992) of mammalian bites, prophylactic administration of antimicrobials significantly reduced the rate of infection associated with human bites but overall did not appear to reduce the infection rate after cat or dog bites. Wound type and location were addressed independently. Wound type (laceration vs puncture) was not a factor, but antimicrobial prophylaxis was associated with a significant reduction in the rate of infection of hand bites. Infection rates for bites to the hand were 2% when treated, compared with 28% if not treated (odds ratio, 0.1; 95% confidence interval, 0.01 to 0.86). Only one of the studies[87] in the meta-analysis investigated cat bites, and results indicated that the infection rate was

67% among persons who did not receive antimicrobials versus 0% among persons who were treated. The sample size was extremely small (n = 11), thereby making it difficult to generalize the findings of that study.

Overall, in the reports included in the meta-analysis, most authors provided commentary similar to that of Kesting et al[64] and recommended consideration of antimicrobial prophylaxis for patients after assessing whether there had been a delay of treatment; identifying the type of animal that bit the person, the anatomic structures involved, and the extent of the bite; and taking into account patient's age and associated medical conditions.

Antimicrobials—Antimicrobial treatments should be directed against the typical pathogens associated with the oral flora of the biting animal and skin of the victim and those most likely to cause infection. Microbial culture of bite wound samples should be performed when signs of infection are detected, but it is important to recognize that results are not always fully reflective of the microbial composition of the infection. Amoxicillin-clavulanate potassium is the most commonly prescribed antimicrobial for oral administration in patients with animal bite wounds who are treated either prophylactically or because of infected wounds on an outpatient basis. The findings from a study[10] of infected dog or cat bite wounds in 107 patients at 18 EDs suggest that appropriate treatments are as follows: a β-lactam antimicrobial agent with a β-lactam inhibitor, a second-generation cephalosporin that has anaerobic activity, combination of penicillin with a first-generation cephalosporin, or combination of clindamycin and a fluoroquinilone. In another study,[64] amoxicillin-clavulanate potassium was recommended as the antimicrobial of choice for children with bites to the head. However, this recommendation was based on a small group in which all 6 children who were prescribed an antimicrobial other than amoxicillin-clavulanate potassium developed wound infections.[64]

Hospitalized patients are typically administered antimicrobials IV, which allows for rapid dissemination of the drug to the affected sites. The antimicrobials that are typically administered IV for treatment of animal bites include ampicillin sodium and sulbactam sodium.

For all persons with a bite wound to the head in which there is a suspicion or evidence of skull fracture, treatment with antimicrobials that have good CSF penetration is recommended; these include vancomycin for gram-positive microbes, cefotaxime for gram-negative microbes, and metronidazole for anaerobes.[5] Detailed guidance on appropriate antimicrobial treatments is available elsewhere.[58,83]

Dog Bite Prevention

Dog bite prevention continues to be a major public health challenge. One guideline for prevention may lie in the obvious—dogs and cats with a prior history of aggression or propensity to bite are in fact more likely to bite in the future. This was demonstrated in 1 study[88] of animal bites in a veterinary teaching hospital. Animals with a known propensity to bite (eg, warning sign on cage) were in fact at much higher risk (odds ratio, 5.0; 95% CI, 1.9 to 13.0) of inflicting a bite.

Despite a wealth of commonsense recommendations for bite prevention and injury mitigation,[7,19,20,37,39] controlled trials to evaluate the effectiveness of this plethora of suggestions are lacking. Indeed, to our knowledge, only 1 report[89] of a controlled trial of an educational intervention has been published. In that pilot study, the Prevent-a-Bite educational intervention increased the precautionary behavior of children 7 to 10 days after receiving the educational intervention.

Breed-specific laws have been the subject of great debate and, although opposed by the AVMA and other groups,[39] continue to be popular, despite any formal confirmation of their effectiveness. Indeed, in 1 study[90] of dog bite data collected before and after passage of a breed-specific Dangerous Dog Act in the United Kingdom in 1991, there was no discernible change in the frequency of dog bites by the implicated breeds. In contrast, Multnomah County, Oregon, passed a generic dangerous dog ordinance in 1986; data collected 3 years after its passage suggested that there had been a significant reduction in offenses by dogs classified as dangerous under the ordinance.[91]

If there is consensus in the discussion about dog bite prevention, it is that the importance of carefully and continually monitoring the interaction of children with dogs cannot be overstated. The contribution of both children's and dogs' behavior to bites has been the subject of 2 in-depth reviews.[51,92]

Overview

Animal bites continue to pose major public health challenges, and the clinical sequelae of bite injuries can extend far beyond simple wound management. Clinicians must be aware of the potential for occult trauma and be alert for the potential for serious infection and emergence of unusual microbial pathogens; such infections, if treated suboptimally, can be fatal. Identification of people bitten by animals remains incomplete, and among reported bites, inconsistencies in data collection preclude meaningful conclusions about bite circumstances and predisposition of specific breeds of dogs to bite or inflict severe bites. More consistent reporting and a more complete understanding of the circumstances of bites are needed to help target prevention and bite avoidance, particularly among children.

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Appendix

Reported rate of dog bites and dog-related hospital visits in the United States.*

Date	Data source	Location	Type of injury data	Rate/100,000 persons	Reference
1990–1992	State Health Department	Indiana	Animal bites	Approximately 220–360	15
1998	New York City DOH	New York City	Physician-reported dog bites	85	19
2001	NEISS-AIP survey of EDs	United States	Nonfatal injuries from dogs	129	20
1993	Allegheny County DOH surveillance	Pittsburgh, Pa	Reported dog bites	214	21
1998–2002	Hospital discharge records	Kansas City, Mo	ED visits for dog bites	157	22
1989–1991	Municipal animal bite reports	Milwaukee, Wis	Reported dog bites	171	23
1994	ICARIS telephone survey	United States	Self-reported dog bites	1,800	24
1986	NHIS survey of nonfatal injuries	United States	Self-reported dog bites	Approximately 240	25
2000	Various data	3 Georgia counties	Dog bites in children	460	26
1992–1994	ED records	United States	Dog bites in EDs	129	27

*For studies in which the rate/100,000 people was reported. DOH = Department of Health. NEISS-AIP = National Electronic Injury Surveillance System-All Injury Program. ICARIS = Injury Control and Risk Survey. NHIS = National Health Interview Survey.