Chapter 12

RABIES AND CONTINUED MILITARY CONCERNS

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RABIES CONTROL IN FUTURE CONTIGENCY OPERATIONS

SUMMARY

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INTRODUCTION

A Historical Perspective

Rabies may be the oldest infectious disease known to humanity. First noted in Mesopotamian dogs around 2200 BCE,[1] the modern name, rabies, comes from the Latin word *rabere*, which means "to rage or rave." Aristotle later used the Greek word *lyssa*, which means "madness" to describe the symptoms of rabid dogs in his book, the *Natural History of Animals*, in 400 BCE. Although Aristotle incorrectly concluded that humans were immune to rabies infections, the scientific community continues to honor the Greek description, classifying rabies' etiologic agent as one of several related viruses from the genus *Lyssavirus* and its disease name, lyssa.[2] Rabies is sometimes also called hydrophobia.

For as long as warriors have turned to dogs as protectors and companions during conflicts worldwide, rabies has been a notable concern of military forces and their respective societies around the world. One of the first battle references to rabies may be found in Homer's *The Iliad*; in this poem, Homer compares the frenzied fighting style of the Trojan warrior Hector to a "raging dog."[3] The Roman writer Cardanus later expresses his concerns about rabies regarding public safety and canine–human contact, given the "infectivity of the saliva of rabid dogs."[2(p1)] He further describes the canine saliva's highly infectious material as "a poison (for which the Latin [word] was 'virus')."[2(p1)]

Still other Roman writers (ie, Pliny and Ovid) describe rabies as "dog tongue worm" and list a common canine rabies prevention procedure used up until the 19th century: cutting the dog's tongue attachment and removing its fold (some practitioners erroneously believed that a worm lived in this mucous membrane and that this worm caused rabies). Numerous Old World Syrian and Arabic doctors note rabies as well, usually characterizing it as an incurable hydrophobic disease. By the 18th century, rabies was also recognized within certain wildlife populations in the eastern United States, namely skunks. However, in the years following the Civil War, this sylvatic virus traveled westward with the early pioneers, spreading rabies across the United States.[2]

The US Military's Involvement

After the Civil War, US military veterinarians played an important role in controlling rabies on installations through vaccination and education. Burlin C. Bridges, Ft Bliss veterinarian in 1927, described the decreasing threat posed by canine rabies in El Paso, Texas, during the early 20th century:

> …there were 300 cases of rabies reported during 1925, 40 cases during 1926, and 12 cases during the first 6 months in 1927. …The decrease in number of rabies cases can only be accounted for by the education of the owners of dogs relative to preventive vaccination, by annual dog shows where only vaccinated dogs are shown, and by the capture of stray dogs on the reservation [Ft Bliss] with no tags of vaccination.[4 (p262)]

During 1930, prevention efforts continued with similar success on all Army posts: 4,012 dogs were vaccinated for rabies; only seven positive rabies cases were reported; of these, four were in stray dogs.[5]

During World War II, rabies again became an active threat, but its risk varied by theater location.[6] For example, during World War II, rabies was present in all operational sites, including the Middle East, China, Burma, India, Austria, Germany, northwestern Europe, North Africa, and Italy.[7] However, of the 65 laboratory samples from the United States tested for rabies by the 4th Service Command Medical Laboratory at Ft McPherson, Georgia, only 37% were positive. In theaters outside of the United States, such as China, Burma, and India, positive results approached 75%.[8] Seven US service members died from the disease while serving in the United States, the Philippines, Panama, and Italy.[6]

The danger posed by rabies to US military in Italy increased throughout the war. From June 1944 through June 1945, over 2,000 people suffered animal bites, and 400 suspected cases and 58 confirmed cases of rabies occurred in dogs. A shortage of rabies vaccine thwarted initial efforts to mitigate the outbreak; control was eventually achieved via impounding strays and leashing and muzzling pets. The Army Veterinary Service was well established by World War II, and it provided additional rabies prevention and control services such as animal vaccination, detection of rabies in military-owned and civilian animals, laboratory testing of animal specimens, and oversight of animal quarantine and country reentry procedures.

In the Pacific theater, Army Veterinary Service personnel developed plans for quarantine and other rabies control procedures. However, Korea also experienced a vaccine shortage during World War II, which caused rabies to reemerge and become widespread in animals by 1946. Although documentation exists of at least one US service member contracting and dying from rabies during the Korean War, lyssa was not a major human threat in Korea at this time. Nonetheless, during this time period, laboratories regularly tested animal specimens that were suspect for rabies and potentially exposed laboratory personnel were treated with immune serum and vaccine.[9]

During the Vietnam War, rabies was the most widespread zoonotic disease hazard to American forces and Vietnamese nationals. Although the government of South Vietnam did not track rabies statistics, the Pasteur Institute in Saigon surveyed Saigon, Na Trang, and Da Lat in 1966 and estimated that, in just these three cities, at least 10,122 Vietnamese were potentially exposed to the virus; 4,845 received postexposure prophylaxis (PEP) treatment (a detailed overview of this treatment plan appears later in this chapter); and six people died. Of the 470 animal specimens examined during this time, 51% were positive for rabies.[10]

The danger rabies posed to US military forces during 1966 was also substantial. In 1966 alone, some 1,506 US military personnel were potentially exposed to rabies; 628 were treated with rabies PEP; and 21.5% of rabies specimens submitted to military laboratories tested positive.[10]

Several factors led to increasingly significant numbers of animal bites and exposures, with a correlative increase in the use of rabies PEP, including growing troop numbers; the lack of rabies and stray animal control measures for the large number of stray dogs that roamed the Vietnamese villages; and the large number of mammalian mascots and pets (eg, tigers, cheetahs, bears, roe deer, monkeys, dogs, and cats) maintained by US troops.[11] (Eagles, snakes, and other reptiles were also cared for as pets and mascots but did not pose a rabies threat because these are nonmammalian species; only warm-blooded mammals are susceptible to *Lyssavirus*.[10])

The primary threat for rabies infection in Vietnam came from one specific mammal: dogs, especially young puppies. In fact, over 25% of the dogs' rabies cases were diagnosed in puppies 8 to 16 weeks of age. These puppies posed a particularly insidious threat to humans because they were almost always asymptomatic when they died.[10] However, the veterinary advisor to the Military Assistance Command, Vietnam, soon recognized the canine rabies threat and initiated a vaccination campaign to protect US and Vietnamese troops. This campaign targeted dogs in villages near US military installations and used a proven, US-manufactured vaccine.

In 1966 through 1967, the US Army Veterinary Service also started vaccination campaigns for mascots and pets of US service members. Unfortunately, these programs were difficult to implement and did not reach enough targeted dogs because of numerous logistical problems. For example, in 1967, only an estimated 7,000 dogs owned or maintained by US service members (ie, only about half) were vaccinated; the majority of these vaccinations were for rabies, although other vaccinations such as canine distemper vaccination were also given.[12] Other rabies control efforts implemented by US Army veterinarians included registration and control of military mascots and pets, quarantine of rabies suspects, and tracking of rabies statistics.[10]

In 1969, there were 2,967 potential rabies exposures within the US Army forces in Vietnam, resulting in 1,628 patients receiving rabies PEP. By 1970, these numbers had decreased to 1,905 and 1,039, respectively. From January to June 1969, 17.8% of dog specimens submitted to the laboratory tested positive for rabies. This was a small decrease from the 21.5% positive samples reported by US military laboratories in 1966. Additionally, none of the cat, monkey, bat, or rodent samples submitted tested positive.[13]

During the withdrawal of US forces from Vietnam, both the stray dog population and rabies incidence increased as mascots and rabies control efforts on US installations were abandoned. In fact, in 1972, rabies reached near epidemic proportions. Forty percent of suspect rabies samples submitted to laboratories tested positive throughout South Vietnam, and nearly 60% tested positive in Saigon. Over 7,000 Vietnamese were treated with rabies PEP, and at least twelve people died.[10]

Despite the difficulties encountered in implementation and the limited numbers of dogs vaccinated, rabies control efforts performed by the US Army Veterinary Service during the Vietnam War were considered successful. The magnitude of the rabies threat was considered so enormous that even though up to five American deaths occurred from rabies (the actual number of rabies deaths is disputed), limiting the disease to only up to five deaths was considered a great accomplishment.[10,13]

Following the Vietnam War, rabies was again recognized as a disease threat during Operations Desert Shield and Desert Storm; however, protocols for rabies control and treatment, similar to those used today, may have diminished the threat to US forces.[14] In Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF), rabies also proved to be a menacing zoonotic disease; its effects during these conflicts and lessons learned are discussed later in the chapter.

ETIOLOGY AND EPIDEMIOLOGY

Rabies Virus Variants and Distribution

Rabies can infect any mammal, although it is primarily a disease of carnivores (eg, dogs, skunks, raccoons, and cats) and bats, and the rabies virus exists on every continent except Antarctica. The etiologic agents that usually cause "classic" rabies in humans and animals are bullet-shaped RNA viruses: genus, *Lyssavirus*; family, Rhabdoviridae (Figure 12-1).[15]

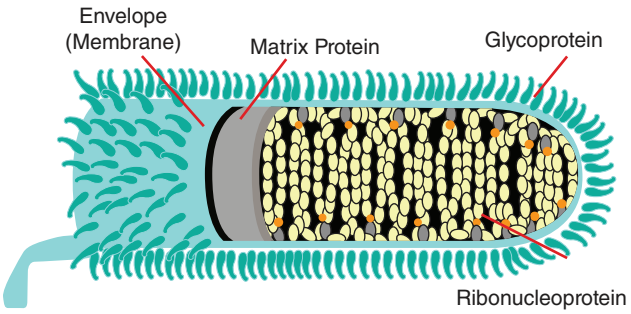

Figure 12-1. The structure of the rabies virus, genus *Lyssavirus*.
Reproduced from the Centers for Disease Control and Prevention Rabies website. http://www.cdc.gov/rabies/transmission/virus.html. Accessed January 23, 2014.

Several variants of rabies virus are also maintained in different host species that are often used to characterize the strain of virus. The canine variant of rabies causes the most human rabies cases on a global basis, but other strains are of particular concern in certain animals in certain parts of the world (eg, the coyote in Texas). Raccoon, skunk, and fox variants are widespread in the United States (Figure 12-2) and can infect other wildlife.[15] The red fox variant is the primary cause of rabies in Europe. The United States, Europe, Central and South America, and Canada also have widely distributed bat rabies.

Spillover of variants into other species is common, and frequent interaction between hosts can result in adaptation of one variant to species-specificity in the spillover host. For example, in the United States, genetic testing has determined that the canine variant of rabies is the ancestor to the fox variant of rabies in Texas, and the skunk variant of rabies originated in raccoons.[16] Although not documented to have species-specific strains, mongooses in the Caribbean, South Africa, and parts of Asia; jackals in Africa; and wolves in northern Europe also play an important part in transmitting the virus.[17] A puzzling feature of the rabies virus is that no feline strain of the virus has ever been detected, nor has any documented cat-to-cat transmission of the virus occurred, although the number of rabid cats has outpaced that of rabid dogs in the United States every year since 1988.[16,17]

Historically, the canine variant of rabies was the primary strain in the United States; however, this variant was almost entirely eradicated by a robust animal vaccination campaign and other control efforts that began in the late 1940s and continued through 1970. In 1938, there were 8,452 rabies cases diagnosed in dogs; by 1965, this number was only 412. A similar drop is found in human cases: in 1938, there were 47 rabies cases; by 1965, there was only one.[2] In the past 10 years, the bat variant caused most of the human cases in the United States, although canine variant rabies still occasionally appears along the Mexican border.[18]

A new variant of the lyssaviruses, first identified in 1996 in several species of flying foxes and bats in Australia, has been associated with two human deaths from rabies-like illness. This virus, provisionally named Australian bat lyssavirus, is closely related, but not identical to, the classic rabies virus.[18]

Rabies-free Definition and Areas

Although rabies is present almost everywhere in the world, certain areas are considered virus-free. The World Health Organization (WHO) confers "rabies-free" status on countries that have had no indigenously acquired cases of rabies in humans or animals over the previous 2 years. Rabies-free areas include the United Kingdom, Sweden, Norway, Iceland, Japan, New Zealand, Singapore, Papua New Guinea, the Pacific Islands (including Hawaii), most of Malaysia, and some of Indonesia. These countries have strict animal import requirements to help maintain their rabies-free status. Countries that are not rabies-free have varying degrees of rabies risk as defined by the WHO.[19]

Rabies Transmission Process and Conditions

Rabies is transmitted between mammals, typically through introduction of infected saliva through broken skin, which usually occurs during a bite incident.

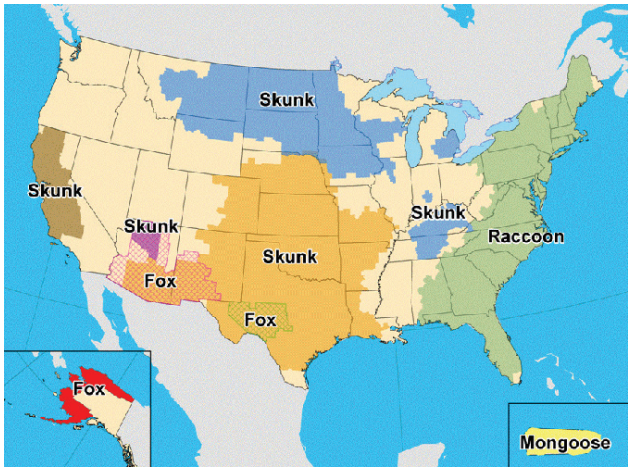

Figure 12-2. A map of terrestrial rabies reservoirs in the United States, 2010.
Reproduced from Centers for Disease Control and Prevention website. http://www.cdc.gov/rabies/resources/publications/2010-surveillance/reservoirs.html. Accessed January 23, 2013.

Rabies virus can also be transmitted through mucous membrane contact with infected saliva. In extremely rare cases, aerosolized virus can be inhaled, resulting in infection. Two documented human cases of rabies occurred through this type of exposure when spelunkers spent time in a cave where a large colony of bats resided.[1] (Bats can also pass the virus to other members of the colony under these conditions, although bites are still the primary method of intraspecies transmission among bats.) Other aerosolized virus infections have occurred in laboratories, resulting in at least two known human rabies cases.[20]

During a bite from a rabies-infected animal, a particular set of conditions determine whether virus transmission results in victim infection, including time and wound depth. Because the rabies virus is encapsulated by an envelope (see again Figure 12-1), the virus is extremely susceptible to inactivation by drying and, therefore, is incapable of surviving outside the host for any extended period. Viral contamination of only the skin surface or superficial wounds is unlikely to result in infection.

Saliva from the infected animal also must carry an appropriate viral load to cause disease.[21] (A study in Africa showed that a bite from a rabid dog to another dog carried only a 49% probability that the victim would become rabid.[22]) Additionally, the species of biting animal and volume of saliva introduced into the wound affect whether the victim develops clinical signs of disease, and bites nearer to the head result in rabies symptoms developing more often and more quickly than bites on extremities.[2]

Once rabies is introduced into the body, the virus replicates locally for a variable period of time and then proceeds along peripheral nerves toward the central nervous system (CNS). The duration between inoculation and arrival at the CNS varies widely between cases and depends on factors such as the proximity of the inoculation site to the CNS (ie, the distance of the bite from spinal cord and brain) and the viral load delivered. In animals, the incubation period varies from 14 days to several months, with an average of 3 weeks.[18] In humans, the average incubation period is 3 to 8 weeks, although one documented case of rabies occurred more than 6 years after the man was exposed to the virus.[17] Fortunately, the relatively lengthy incubation period for humans allows an adequate amount of time for people exposed to rabies to receive postexposure treatment and prevent clinical disease development.

After rabies reaches the CNS, the virus produces paralysis consistent with spinal cord involvement and mania from brain involvement. The virus continues to replicate in the brain and travels down peripheral nerves to the salivary glands, where rabies can be transmitted to new hosts through bites or licks from the infected animal.[19]

CLINICAL REVIEW

Clinical Signs of Rabies in Animals

Signs of rabies in animals are consistent with derangement of the CNS and are characterized into two syndromes or forms: (1) furious rabies and (2) dumb or paralytic rabies, which are actually two phases of a three-part disease process that includes the prodromal, excitatory, and paralytic phases. The first 2 to 3 days of infection in either form is the prodromal phase. In this early symptom phase of the disease, animals exhibit minor temperament changes, often subtle enough to go unnoticed.[17]

The next stage, the excitatory phase, is either so transient that symptoms continue to go unrecognized or is so prominent that symptoms are obvious. The label "furious rabies" describes animals exhibiting a pronounced excitatory phase; the label "dumb rabies" typifies animals with a transitory excitatory phase but a marked paralytic phase. During the excitatory phase, animals' pharyngeal muscles become more and more paralyzed, resulting in drooling and frothy saliva when they pant heavily. Animals also become restless, vocalize, attack inanimate objects, lose their fear of people, swallow foreign objects, and eventually experience ataxia and severe, often fatal, convulsions.[19]

Animals that do not die during seizures enter the paralytic phase. In this final stage, muscular incoordination advances into total body paralysis, causing animals to lapse into a coma and die from respiratory failure. Death occurs 2 to 6 days after the onset of clinical signs for animals exhibiting the dumb form of rabies and 4 to 8 days after onset of the furious form.[19]

Any species can exhibit either of the forms of rabies. However, cats most often manifest with furious rabies, while livestock species and dogs commonly exhibit the dumb form of rabies.[17]

Unfortunately, even though rabies produces well-characterized clinical stages in animals, behavior is not a reliable indicator of whether an animal is shedding virus in its saliva. An animal can act normally and still be shedding virus, which can have significant implications for human exposures. Studies have documented that virus can be recovered from skunk saliva up to 14 days prior to any clinical signs and 1 to 5 days prior to clinical

signs in dogs and cats. Moreover, viral shedding may be intermittent once clinical signs occur, or the animal may never shed virus in its saliva, despite the onset of rabies behavior that ultimately ends with the animal's death.[2] Also, since animals can demonstrate a variety of clinical signs along the entire spectrum of the disease, rabies should be a differential diagnosis for any animal exhibiting behavioral changes or unexplained paralysis.[19]

Diagnosis of Rabies in Animals

Diagnostic testing of animals is performed for two purposes: (1) verification of disease status for animals that have exposed humans or other animals and (2) rabies surveillance. All non-human diagnostic tests for the presence of the virus are performed postmortem on brain tissue because antibodies are not produced until the terminal stages of the disease. (See also Chapter 10, Army Veterinary Laboratory Service.)

When submitting samples to diagnostic laboratories, medium-sized animals' heads such as dogs and cats are decapitated by disarticulating the vertebrate and shipped (in accordance with state and federal guidelines) with the brain vault intact. For large animals such as cattle or horses, the brain is removed from the brain vault prior to shipping. Small animals such as bats or rodents are shipped whole.

All samples should be shipped chilled, but not frozen. Dry ice should never be used because it can inhibit the rabies testing process and is considered a hazardous substance to ship.[15] All personnel involved in handling rabies specimens should receive the preexposure rabies vaccination series and proper training on preparation, packing, and shipping of samples.

Currently, few tests are available to expediently verify rabies infection in operational environments. The direct fluorescent antibody (DFA), considered the "gold standard" for rabies diagnosis, is a highly sensitive and specific microscopic test that is 98% to 100% reliable.[19] DFA protocol is dictated by the Centers for Disease Control and Prevention (CDC). However, because specialized equipment, trained personnel, and a controlled environment are necessary to perform this testing, DFA is difficult to use in a field or combat environment. Animal samples obtained in these environments must be airlifted back to fixed facility military laboratories (ie, in Germany or the United States) for DFA testing.

Other tests being developed for rabies surveillance include the direct rapid immunohistochemical test (dRIT) on brain or brainstem tissue. This test, which is also regulated by the CDC, requires a minimal amount of equipment and expertise and has a sensitivity and specificity similar to that of the DFA. However, the dRIT is not yet a prescribed test approved for use in field environments as a replacement for the DFA, according to the World Organization for Animal Health,[23,24] even though the US Army Veterinary Service participated in field trials of the dRIT during OIF.

Animal Management After Bites from Rabies Suspects

Because rabies is nearly always fatal once symptoms appear, no treatment is attempted for animals showing clinical signs of rabies, and no PEP is available for animals that have just been bitten by another rabid animal. However, when combined with canine rabies vaccination requirements (see the section on animal vaccination below), legally mandated quarantine procedures (also described below) have resulted in the near eradication of canine variant rabies within the United States. These quarantine procedures are recommended by the National Association for Public Health Veterinarians and are used uniformly throughout the United States, although each state does have the ability to implement unique criteria.[15]

When a nonvaccinated animal is bitten by a rabid animal, the exposed animal should be euthanized immediately. If the owner is unwilling to euthanize the animal, the exposed animal must be quarantined for 6 months in a secure location where it will not have contact with other animals or pose a risk to humans. Should the animal shows signs consistent with rabies during quarantine, it must be euthanized and tested. If the animal shows no signs of rabies during its 6-month seclusion, the animal can be released after a licensed veterinarian certifies it is healthy and vaccinates it for rabies.[15]

On US military installations, when a vaccinated animal is bitten by a rabid animal, the exposed animal remains under observation for 45 days, usually in the owner's home. During quarantine, it should not have contact with other animals and should be revaccinated immediately. (These aforementioned guidelines used on military installations are standard protocol throughout the veterinary profession as recommended by the National Association of State Public Health Veterinarians, so they also apply to military family pets that are bitten off-base or receive treatment from a civilian veterinarian.[15])

Animals with overdue vaccinations are dealt with on a case-by-case basis, often relying on the professional opinion of the treating veterinarian.[15] For example, if the animal had multiple vaccinations and is a month overdue, the veterinarian may choose to vaccinate the animal and put it under 45-day quarantine or run an antibody test to determine the animal's immune

status. If the animal had an inconsistent vaccination history, the veterinarian may treat the animal as if it were unvaccinated and require a 6-month quarantine followed by proper vaccination.

Human Postexposure Treatment for Rabies

After a person is bitten by an animal, the wound should immediately be flushed and cleaned with soap and water. As previously noted, the rabies virus is surrounded by an envelope, so this virus can be inactivated by a mild detergent or soap. If available, povidone iodine can also be applied to the wound.[18] However, since it is impossible to determine if immediate wound care destroyed all of the virus introduced in the bite, the victim still must be assessed for the rabies PEP treatment regimen.

PEP is the cornerstone of medical treatment to interrupt the course of disease in people infected by rabid animals. The medicinal regimen consists of human rabies immunoglobulin and a series of four to five rabies vaccinations. Initially, as much immunoglobulin as possible at the dose of 20 IU/kg body weight is infiltrated around the wound site and, then, is given intramuscularly. The vaccine is also given intramuscularly, ideally in the deltoid muscle. In order to successfully abort rabies infections, the regimen generally must be given prior to the onset of clinical signs. As previously mentioned, the duration of the incubation period varies, depending on factors such as the distance of the bite from the CNS, the amount of saliva introduced into the wound, the viral load in the saliva, the species of biting animal, whether or not immediate local wound care was performed, and several biological factors within the victim, including immune competency and comorbidities.[20]

As recently as 2003, rabies was considered 100% fatal once clinical signs became apparent. However, in 2004, a high school student in Wisconsin was bitten by a rabid bat and became the first recorded survivor of a clinical manifestation of rabies. Physicians administered a novel treatment now known as the "Milwaukee protocol," which included a medically induced coma and artificial life support, allowing the body time to mount an effective immune response against the virus.[25] The Milwaukee protocol was used to treat 28 other rabies victims since 2005, four of whom have lived.[26] Despite this handful of survivors, rabies has the highest case fatality rate of any known infectious disease if PEP is not provided.[22]

Because there is a limited window after exposure—before symptoms appear and patients die—rabies poses a significant, pressing public health concern. Effective management requires rapid identification of all potential contacts or exposures to confirmed rabid animals or human rabies patients, including individuals who had mucous membrane contact with a rabid human patient's saliva (eg, after sharing utensils or drink containers with an infected patient).[20] Identification must be done as quickly as possible to abort potentially fatal clinical disease via treatment with PEP.

PREVENTION AND CONTROL

Animal Vaccination

As already noted, no PEP regimen exists to eliminate infections in animals; therefore, prevention in animals is entirely dependent on preexposure vaccination, which is usually administered as a "parenteral" or injectable vaccine. Several federally approved parenteral vaccines provide 1 to 3 years of immunity. In the United States, dogs and cats are given 1.0 mL of subcutaneously administered vaccine containing killed rabies virus and can be vaccinated as early as 12 weeks of age. Before that age, puppies and kittens may not be able to mount a sufficient immune response to the vaccine; maternal antibodies that the neonates ingest shortly after birth while nursing interfere with the antigen exposure to the animals' immune systems, negating the vaccine's effects.[15]

Regardless of the product label, the first rabies vaccination is only considered effective for 1 year; every dog and cat needs to be revaccinated 1 year after the first vaccination is administered. After the second vaccination, the product label can be followed for the frequency of revaccination, providing the state in which the animal resides recognizes 3-year rabies vaccinations. Although not all states have laws requiring rabies vaccination of owned dogs and cats,[15] all dogs, cats, and horses that reside on military installations are required to maintain current rabies vaccination status, regardless of whether the state mandates vaccination.[27] Dogs and cats are usually issued a rabies tag and certificate of vaccination.

Rabies vaccine is also licensed for horses; they receive double the feline or dog dose: 2.0 mL administered in the neck muscles. Other species for which certain parenteral rabies vaccines have been licensed include ferrets, cattle, and sheep, but most livestock are vaccinated routinely only in rabies-endemic areas or as a response to a local outbreak.[15]

Parenteral rabies vaccine is also often used off–label to vaccinate species for which no approved vaccine exists. This type of vaccination is generally considered

harmless and probably protects species other than those in which it has been tested. However, any animal other than those for which a specific rabies product is licensed, including wolf-hybrid dogs, must be considered as an unvaccinated animal for the purposes of rabies control. The National Association of State Public Health Veterinarians recommends that a licensed veterinarian administers (or supervises the administration of) all parenteral rabies vaccinations. Many states have included this provision in their laws relating to rabies vaccination.[15]

An oral rabies vaccine product has been developed for use in wild animals but has only been tested and approved for coyotes and raccoons. The vaccine (1.5 mL) is contained in a plastic sachet placed inside a hollow, edible shell made of fishmeal or dog food, commonly referred to as "bait." When the animal bites into the bait, the plastic sachet breaks and coats the inside of the animal's mouth with killed virus vaccine, which is absorbed through the animal's mucous membranes and lymphatic throat tissues. This product, most effective when distributed from the air, contributed greatly to controlling rabies outbreaks in raccoons along the eastern coast of the United States and in coyote and fox populations in Texas. In 2007, 18 states distributed over 12.5 million rabies baits.[28]

Human Vaccination

In humans, rabies prevention occurs before or after exposure to the virus. Preexposure measures consist of a series of three injectable vaccinations containing killed virus. All Army Veterinary Service veterinarians and animal care specialists must be vaccinated. Rabies titers are checked every 2 years to ensure effectiveness.[27] Other military (eg, special operations forces) and contract personnel are vaccinated based on occupational risk of rabies exposure. Preexposure vaccination does not negate the requirement for PEP if personnel are bitten by a rabies suspect, but it decreases the number of postexposure vaccinations required and the necessity for human rabies immunoglobulin administration during PEP treatment.[20]

Military Animal Bite Reports

Military physicians, veterinarians, and preventive medicine personnel follow specific reporting requirements after receiving a potential rabies case, based on Defense Department (DD) Form 2341: Report of Animal Bite-Potential Rabies Exposure.[27] This four-part form, commonly referred to as a "bite report," is used on military installations worldwide whenever an authorized beneficiary of the military healthcare system receives a bite from an animal or has a nonbite exposure to an animal that could potentially have rabies. Examples of events that would trigger the initiation of a DD Form 2341 include a bat found inside the barracks room of a sleeping soldier (ie, aerosolized exposure potential), a stray cat biting a child, and a vaccinated dog biting its owner.

The triservice animal bite report is the primary mechanism for detecting and documenting rabies risk, rabies cases in animals, and follow-up treatment in potentially exposed DoD personnel. From January 2001 through December 2010, these forms documented animal bites in 20,522 US active duty, reserve, and civilian contractor personnel.[29]

Normally, the DD Form 2341 is initiated in the emergency room of the DoD medical treatment facility or other military clinical setting. On Part I of the form, the treating physician and medical staff question the victim about the bite incident and document as much information as possible about the offending animal.

On Part II, the DoD physician records any wound treatment and characterizes the risk of rabies as low, medium, or high, depending on the circumstances of the exposure. The physician also documents whether or not rabies PEP treatment was initiated for the victim. Decisions about potential rabies risk and initiation of PEP are based on whether the bite was provoked or unprovoked, the rabies vaccination status of the animal (if known), the animal's behavior, the rabies risk in the area, and other factors such as the healthcare provider's professional judgment.

After the physician completes Part II, the form is forwarded to the servicing Army veterinary treatment facility, and attempts are made to track down the animal involved in the potential rabies exposure. Stray or wild animals may be located by the military police or installation wildlife officials; owned animals may be tracked back to their owners by the veterinary treatment facility staff. If the animal is located, it is brought into the facility to be examined by the military veterinarian, who determines its disposition. The animal is either quarantined for 10 days at the owner's home (for healthy, vaccinated animals) or at the veterinary treatment facility (for healthy, unvaccinated, or aggressive owned animals), or it is euthanized and submitted for rabies testing (for stray or wild animals or any animal demonstrating signs consistent with rabies).

Aggressive vaccinated animals may be quarantined at the veterinary clinic to prevent additional bite incidents during the quarantine period. The National Association of State Public Health Veterinarians defined the 10-day quarantine because animals—aggressive or not–can shed virus 1 to 5 days before exhibiting clinical signs.[15,17] Thus, the 10-day quarantine at the home or at the clinic allows enough time for the rabid animal to exhibit clinical signs and present back to the veterinarian

who will recognize those signs. If the animal develops any neurologic signs of disease during the 10-day period, it is euthanized and submitted for testing.[15]

At the end of the quarantine period, the animal is reexamined by the DoD veterinarian and released to the owner if it remains clinically healthy. Any overdue rabies vaccinations are administered at this time. Once the animal is released or the test results have been received from the laboratory, Part III of the DD Form 2341 is completed in detail and forwarded to the respective service's preventive medicine personnel.

Preventive medicine personnel advise the treating physician on the initiation or continuation of PEP based on the health of the animal during and at the end of the quarantine period or the results of rabies testing, if performed. If rabies PEP is indicated, the preventive medicine department is responsible for interviewing the victim and performing an investigation to ensure all possible human contacts of the rabid animal are identified and receive PEP. Actions taken by preventive medicine personnel and the results of their investigation are documented on Part IV of the DD Form 2341.

Once Part IV is completed, the report is forwarded to the Rabies Advisory Board (RAB) for review and discussion. The RAB's membership varies by installation but usually includes the installation veterinarian, representatives from the emergency room staff and hospital administration, preventive medicine personnel, and possibly military police and installation wildlife officials.

The RAB meets periodically to review each bite report and discuss the handling of each case. The board identifies any problems with the installation's bite reporting system and case follow-up and discusses methods to improve tracking and timely case closure. The RAB may also discuss general issues about rabies awareness in the area, individuals who should receive PEP, and any other issues pertaining to rabies and how it affects the local military community. The RAB chair, or another senior medical official from the treating facility, countersigns Part IV of each DD Form 2341 once the review and discussion are completed.

Surveillance

Rabies surveillance programs are a critical component of any successful rabies control effort. The majority of surveillance information comes from testing animals that have potentially exposed humans. In the United States, rabies—in either humans or animals—is a reportable disease. The CDC requires information on the species, location, and date of capture for animals testing positive for rabies. The agency uses this information to determine the annual incidence of rabies across the country and the most common vectors for human exposures.[16]

Active surveillance programs are also common elements of viable rabies control efforts within wildlife populations across the United States. For example, an epizootic of the coyote strain of rabies occurred in domestic dogs in southern Texas between 1988 and 1994.[30]

Concurrently, rabies in the fox population began expanding in west-central Texas. At the time, the associated human exposures cost to the state was projected to reach $63 million by the end of 2004. In an attempt to control the problem, the state initiated an oral rabies bait vaccine program that included surveillance efforts to target geographic bait distribution and postbaiting vaccine efficacy. Animals from the target area were trapped and tested to determine if they had an antibody titer against rabies. These efforts were successful; in fact, the epizootic spread of 72 to 80 km per year ceased after the program was implemented, and rabies cases fell from 142 in 1995 to 0 by 2000. Only one case was reported in 2001, and none were reported in 2003, so the bait distribution continued.[30] In 2012, Texas distributed 2 million doses of oral rabies baits statewide over a 2-week period.[31]

The US military assisted with such state rabies surveillance and control programs on several occasions. In 2004, the DoD Food Analysis and Diagnostic Lab, currently part of US Army Public Health Command Region-South, assisted with the oral bait surveillance laboratory testing in Texas.[31,32] Army veterinary personnel at Ft Huachuca, in southeastern Arizona, assisted with a skunk study and surveillance program run by the Arizona Wildlife Service between 1985 and 2004. During this time, 506 skunks tested positive for rabies in Arizona; all but 26 of these cases came from the southeastern area of the state.[33]

The DoD supports the National Cooperative Rabies Management Program, including skunk rabies surveillance efforts at Ft Riley, Kansas, and oral rabies baiting programs at Ft Drum, New York, and on the Navajo Army Depot, Arizona.[31,34] Personnel on Air Force and Navy installations also cooperate in support of this program.

RABIES IN AN OPERATIONAL ENVIRONMENT

The magnitude of potential rabies exposures in operational environments is often judged by the number of bite reports collected from these areas. From 1 January through 31 May of 2012, US military veterinarians tracked 242 reports of animal bites or potential rabies exposure using DD Form 2341 for US service members

in Afghanistan. Only four of these reports were initiated to track animals that were submitted for testing because they exhibited neurological signs of disease; the other 238 reports were initiated because of human contact with a potentially rabid animal that was not yet exhibiting signs of disease.

Of the 16 animals submitted to the laboratory for rabies testing, only four (25%) tested positive, and one was indeterminate. At least 189 of the victims received some form of rabies PEP, as indicated by attending officers' notations on the bite report or clinical notes in patient records (Lieutenant Colonel Derron Alves, Afghanistan Theater Veterinary Consultant, June 2011–January 2012; Lieutenant Colonel Greg Saturday, Afghanistan Theater Veterinary Consultant, December 2011–June 2012).

Unfortunately, rabies risk cannot always be accurately measured by the number of bite reports. The tragic story about an Army soldier deployed as a cook to OEF from May 2010 to May 2011 illustrates how underreporting or false reporting can have lethal consequences: the cook adopted a stray dog from the local area in Afghanistan, and in January 2011, another stray dog got into a fight with the adopted dog. The soldier intervened to protect his pet and was bitten on the right hand by the stray dog. He mentioned this incident during a phone call with his family and told them he had sought medical care and received rabies vaccinations in the abdomen. He also told his mother that the dogs were tested for rabies and were found negative.

During follow-up investigations, no record of a bite report was found for this soldier, nor was there any record that he had received medical care. Additionally, no records existed for any animals submitted for testing from the location where this soldier was stationed during the time period of his service there. His claims to his mother also seemed unfounded, given that the intraabdominal vaccinations he said he received were not the current standard of practice for rabies PEP. For these reasons, the investigation concluded that the soldier actually had not reported the bite from the stray dog, he did not receive any medical care for the bite, and rabies testing had not occurred on either dog involved in the incident.[35]

A few months after the soldier's redeployment to Germany, he was routinely reassigned to Ft Drum, New York. During the plane flight to Ft Drum in August 2011, the soldier began experiencing pain in his right arm and neck, which he attributed to physical activity and the plane flight. Over the next few days, the pain worsened, and he developed nausea and vomiting and had presyncopal events. Physicians in New York recognized signs of hydrophobia, and

Figure 12-3. A US Army Public Health Command's rabies risk poster, part of an awareness campaign.
Photograph courtesy of US Army Public Health Command.

upon questioning, the soldier revealed his history of a feral dog bite 7 months earlier in Afghanistan. Physicians tested the soldier for rabies, and upon confirmation of positive results, initiated the Milwaukee protocol. Despite extensive medical treatment, the soldier died of complications associated with rabies infection on August 31, 2011, becoming the first US service member to die of rabies since the Vietnam War.[35]

In the months following the soldier's death, the US Army Public Health Command initiated a rabies awareness campaign in Afghanistan, including posters, interviews with media outlets such as *Stars and Stripes*, the development of a website as a point source for information, and updated medical threat briefings. These awareness efforts (such as Figure 12-3) may have contributed to the sharp increase in potential rabies exposure reporting in Afghanistan in the months following the soldier's death from rabies. The number of bite reports and the animal species involved in generating these bite reports are detailed in Figure 12-4 and Figure 12-5.

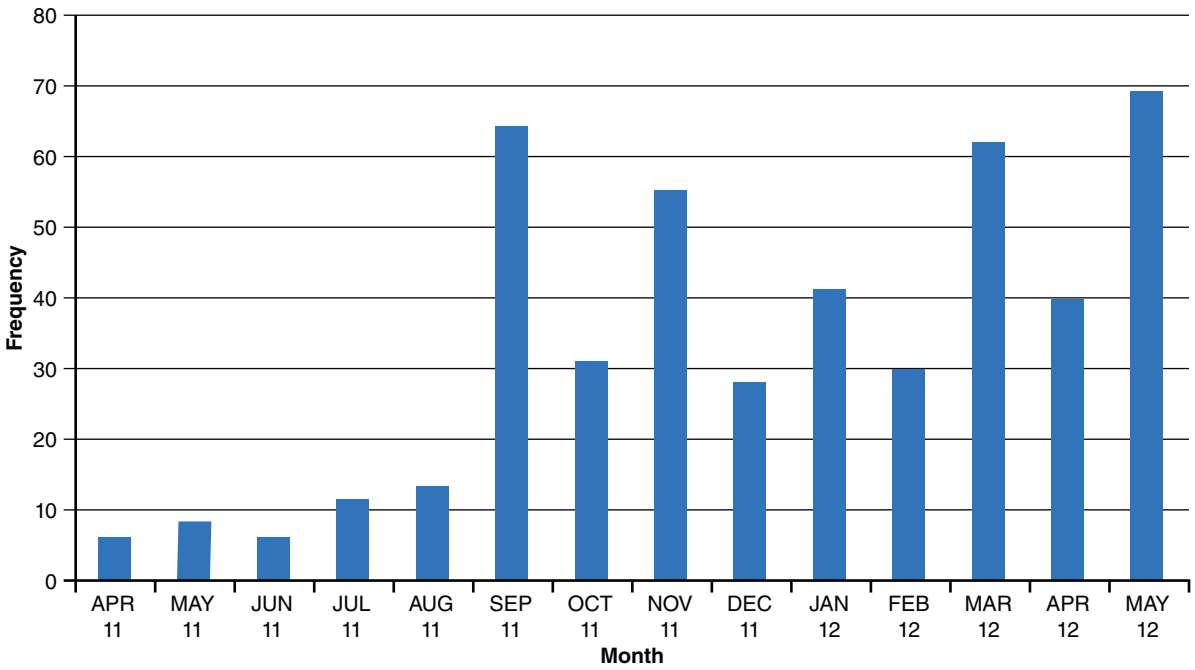

Figure 12-4. The number of bite reports in the Afghan theater of operations, April 2011–May 2012.

Interestingly, another study published in September 2011 documents only 643 animal bites in combat theaters from January 2001 through December 2010.[30] However, the study author collected this data from the Theater Medical Data Store and notes that many animal bites were likely not captured in this repository because of incomplete record capture in the data store system through 2007 due to service members' misperceptions regarding minor bite wounds or scratches from feral animals. Many service members did not consider such wounds to be a serious health threat that required reporting.

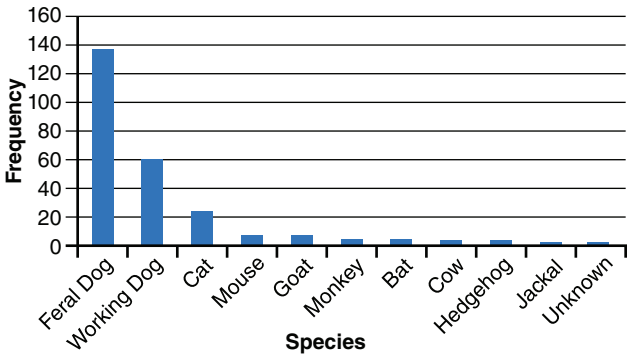

Figure 12-5. The number of bite reports by species in the Afghan theater of operations, January–May 2012.

For comparison purposes, the number of bite reports recorded over a 4-year period during OIF and the species of animals involved in these bite reports are shown in Figure 12-6 and Figure 12-7. Although it appears that the potential rabies exposures measured by animal bite report numbers are greater in OEF, it is possible that significant underreporting occurred in OIF, similar to the underreporting that occurred in OEF prior to the soldier's death. Interestingly, in both countries, feral dogs and cats are among the top three animals responsible for bite reports, which seems to indicate these ferals are more of a threat to US service members than other wild animal species.

Difficulties Posed by Certain Animal Populations

Animal populations in operational environments can generally be divided into three categories: (1) owned dogs (eg, military working dogs, mascots, and pets), which are readily accessible for disease and reproductive control; (2) community dogs (eg, force protection dogs), which are also reasonably accessible for disease and reproductive control but at greater cost because it is unlikely that the expense of vaccination and neutering will be covered by the community; and (3) stray or unowned animals that experience little human contact, which are often unable to be caught for disease or reproductive controls without considerable effort and resources. Each of these three categories

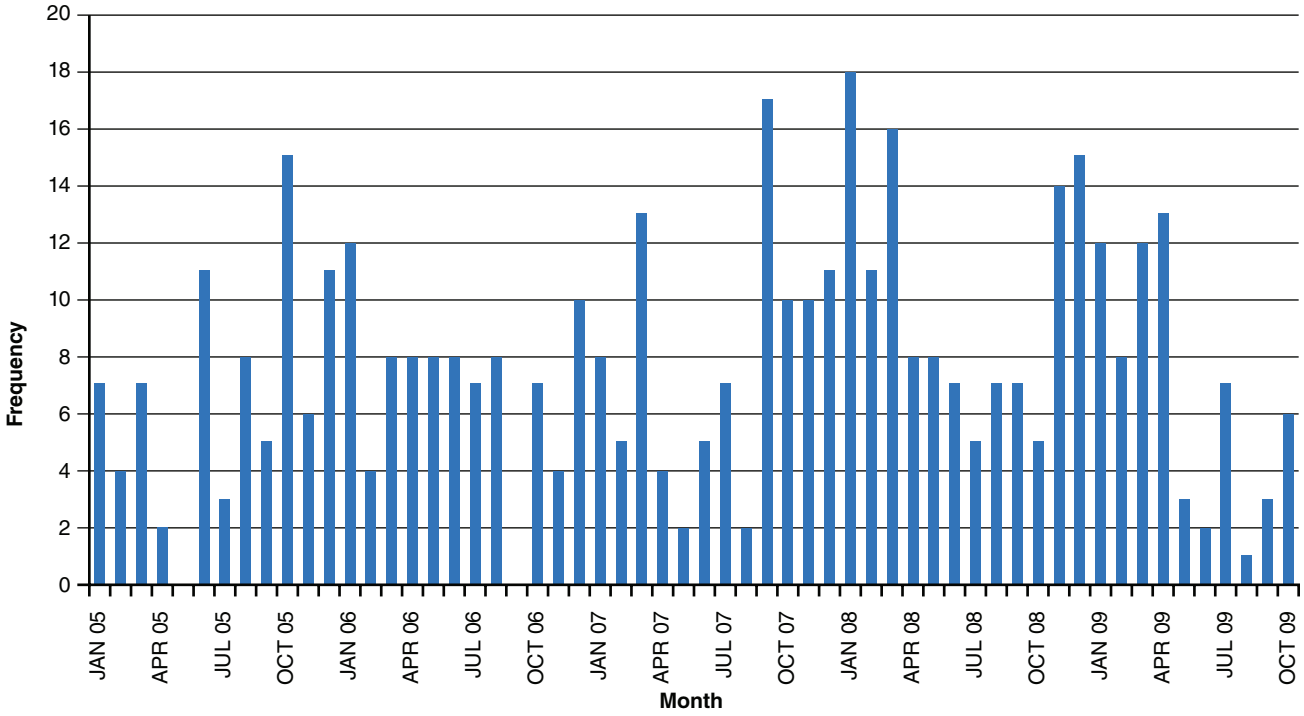

Figure 12-6. The number of bite reports in the Iraqi theater of operations, January 2005–October 2009.

of animals presents challenges to effective stray and rabies control programs, as outlined by the WHO.[36-39] Some of these challenges are presented below.

Problems with Enforcing General Order 1B for Local Pets and Mascots

A military-unique challenge to stray animal and rabies control is the long-standing tradition within the US military of adopting mascots and pets while on campaign or deployed. Perhaps one of the most famous military mascots was General Patton's bull terrier, Willie, who was with him during World War II from 1944 to Patton's death in 1945. But Willie was an exception to the tradition; he was purchased by Patton prior to deployment and was not a local stray.

During the Civil War, soldiers often brought their pets with them from home or, while deployed, adopted a mascot that traveled with the unit. In World War I, small dogs and cats were common pets of troops along the front lines. The soldiers described the animals as providing a normal experience within the highly abnormal experience of war.[40–42] A 1932 *Veterinary Bulletin* also describes an incident in which five sailors, disregarding regulations, smuggled a stray dog aboard a Navy vessel and subsequently died from rabies transmitted by the locally adopted dog.[5] The same report recognizes the attraction between soldiers and these stray dogs:

> The homeless dog always finds a friend in the average soldier. An army camp is a powerful canine attraction. The plentiful food supply beckons to dogs from remote corners, everywhere. With a little attention on the part of some soldier, the dog soon forgets its old master and adopts the new. . . . Post Orders may attempt to regulate the dog population, but the stray dog will not be regulated. He recognizes no restrictions. He may be exterminated, but, like the cat, his lives are multiple. He soon returns in a stranger's garb.[5(p107–108)]

The last decade of war reaffirmed the popularity of local adoption.[43] For example, after the onset of OIF, several nongovernmental organizations formed to assist service members with importing animals into the United States from Iraq and Afghanistan. These organizations reunited adopted pets with the soldiers who cared for them and shared happy reunion stories worldwide. In addition, news coverage of OEF and OIF showed service members repeatedly interacting in unofficial capacities with many different local animals, despite the directives of General Order 1B (GO-1B).

GO-1B was issued by the US Central Command on March 13, 2006. Its official title is "Prohibited Activities for US Department of Defense Personnel Present with the United States Central Command (USCENTCOM) Area of Responsibility."[41] The purpose of the order is

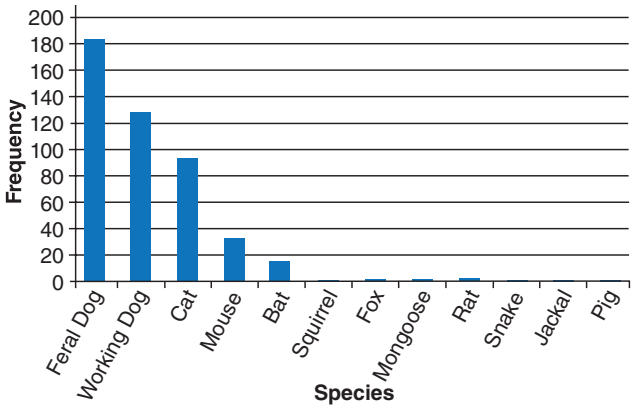

Figure 12-7. The number of bite reports by species in the Iraqi theater of operations, January 2005–October 2009.

to promote good order and discipline by providing guidance to all US military and civilian personnel working in diverse capacities.

The basis for the rule of good order resides in protecting soldiers from behaviors that may be considered normal or common within American culture but that could threaten the health of the force in the area of operations. Restricted activities in GO-1B include purchasing and possessing privately owned firearms; introduction, purchase, possession, sale, transfer, or consumption of alcoholic beverages, controlled substances, or pornographic items; entering mosques or proselytizing; gambling; and possession of war trophies or archeological artifacts.

GO-1B also prohibits adopting pets or mascots or caring for any type of domestic or feral (stray) animals. The reasoning behind this prohibition is that service members who illegally adopt these animals while deployed put others at increased risk of rabies transmission, especially in areas where rabies is enzootic. These personnel also create risk when they use nongovernmental agencies to ship strays stateside.

For example, in 2008, 24 dogs and two cats were brought into the United States from Iraq. Because these animals lacked proper vaccination certificates, they were quarantined for 30 days. During that period, one of the dogs developed neurologic symptoms and tested positive for rabies. (This dog had been a pet of a US service member in Iraq for 7 months and was kept in an indoor-outdoor run.) By the time the rabies diagnosis was confirmed, the other animals in the shipment group had been sent to destinations in 16 states.[44] Despite controlling the infected dog's movement, the animal still potentially exposed numerous caretakers, the soldier who adopted it, and the other 25 animals in the shipment, who in turn had the potential to spread disease to 16 other areas in the United States.

In the media coverage of this Iraqi incident, soldiers reported that their leaders were aware of nongovernmental efforts to ship animals back to the United States, but these leaders allegedly "turned a blind eye."[45] Similar GO-1B irregularities were revealed during the OEF investigation conducted after the soldier's death from rabies. Over 8,500 soldiers, sailors, airmen, and Marines were interviewed during this inquiry.[46] Multiple accounts emerged of US service members in Afghanistan keeping pets as well as having commanders who condoned pets or had some of their own, demonstrating inconsistent or poor enforcement of GO-1B.[35]

However, as stated in the article "Protecting Service Members in War–Non-Battle Morbidity and Command Responsibility," the ability to protect US service members from disease and nonbattle injury such as rabies has as much to do with consistent command awareness and good discipline as it does with medical care. Regulations must be followed in order to maintain stray populations and for the safety and good discipline of service members, despite the myriad attractions of canine and feline companionship during war. Violations of GO-1B also may result in legal action in accordance with the Uniform Code of Military Justice for US service members and administrative and criminal prosecution for civilian personnel.[5]

Problems Posed by the Force Protection Dog Program

One reason GO-1B was difficult to consistently enforce may have been the unintended problems associated with the short-lived military-sponsored Force Protection Dog program for certain bases. When functioning, the Force Protection Dog program allowed units on smaller operating bases in Iraq to officially maintain one or two stray dogs to act as alert systems for unknown personnel approaching the base. Unofficially, it also allowed these units to maintain a "pet" or "mascot" that was authorized Army veterinary care, including rabies vaccinations. Units maintaining these dogs were responsible for contacting Army veterinary detachments in Iraq to register the dogs and ensure they were vaccinated for rabies. Ideally, service members in units with a Force Protection Dog program would be able to interact safely with vaccinated animals, which would not pose a potential rabies threat.

Despite the projected benefits, the program proved difficult to properly maintain. Authorized force protection dog numbers, locations, and their associated points of contact were constantly fluctuating because units redeployed, vaccinated dogs died and disappeared, and new dogs were authorized. Under these fluid circumstances, maintaining accurate records and getting every dog vaccinated was nearly an impossible

challenge. In some cases, units owned a dog that was not vaccinated for rabies, increasing the risk of rabies exposure to troops and civilians.

Another unintended effect of the Force Protection Dog Program was the development of strong human-animal bonds between some service members and their unit's dogs. These bonds were beneficial when the unit was deployed, but many US service members experienced difficulty leaving the dogs behind when the unit redeployed to their home station (eg, adverse secondary mental health effects that were not immediately apparent).

Although shipping these animals to the United States was unauthorized, as noted earlier in this chapter, several US service members worked with nongovernmental organizations to export their beloved dogs to the United States. Problems with these adoptions (eg, the 2008 example cited above), coupled with the aforementioned maintenance issues, forced the Force Protection Dog Program to begin phasing out in 2009 and cease completely in 2010.

Stray Animal Control Efforts in Afghanistan and Iraq

According to the WHO, stray animal population densities on US operational bases increase from reproduction and animal migrations until "carrying capacity" is reached. The carrying capacity of a given environment is a function of available food and area for establishing territories and is defined as the upper limit of the dog and cat population density that can be supported by the habitat based on the availability of resources (eg, food, water, and shelter) and human acceptance.[36] Carrying capacity expands when military forces begin to set up base camps in contingency environments because the large population influx and base camp build-up increases the local animals' access to vital resources. When these stray animals have easier access to such resources, their generally low reproductive rates increase, further expanding population density.[38]

Primary efforts for stray animal and rabies control in OIF focused on trapping and euthanizing stray dogs, cats, and wildlife. In Iraq, the goals of the feral animal control policy were to reduce human-animal contact, the zoonotic disease reservoir populations, and the likelihood of human injury by an animal.[47] In Afghanistan, the goal of the feral animal control policy was to, "reduce feral animal populations on areas of US military bases where their presence may negatively affect human life, property, or military missions."[48(p2)] Both policies also reiterated the enforcement of GO-1B and restricted compassionate feeding of stray animals and animal access to trash and burn pits.

Global Lessons Learned About Stray Animal Control Measures

The military's experiences in Iraq and Afghanistan showed that euthanasia as a primary, standalone effort for animal control is counterproductive and may even contribute to the spread of rabies in the area. When dogs are removed from operating base populations, other dogs quickly fill the void. Operating bases are particularly attractive because they provide stray animals with access to food and water that cannot be found in their normal environment. Standalone euthanasia programs also likely intensify interdog aggression because of the breakdown of pack dynamics, thus increasing bites between dogs and the potential for rabies transmission.[38]

Worldwide experts in animal control and rabies prevention also have demonstrated that trap and euthanize policies are ineffective when used alone. The WHO has concluded that standalone euthanasia programs are ineffective: "There is no evidence that removal of dogs alone has ever had a significant impact on dog population densities or the spread of rabies… attempts to control dog populations through culling…have generally been unsuccessful."[38(p53)] A World Organization for Animal Health conference on eliminating rabies in Eurasia similarly concluded that culling dogs as a primary means of rabies control has no impact on rabies transmission. As a result of these findings and recommendations, most countries have discontinued using euthanasia as a standalone method in favor of a more effective, comprehensive approach.[49]

Stray animal euthanasia programs can also have less quantifiable but deleterious mental health effects on those who perform these duties. During the deployment of the 64th Medical Detachment, Veterinary Service, to OIF from December 2008 through December 2009, veterinary personnel were euthanizing up to 20 animals every day at each operating veterinary clinic, resulting in hundreds of euthanasias across Iraq each month as shown in Figure 12-8 (Unpublished data, Lieutenant Colonel Nicole Chevalier, chapter author, Operation Iraqi Freedom, 2008–2009).

Veterinarians and animal care specialists who deployed with the expectation that they would be improving animal health and saving the lives of combat-injured working dogs may have been mentally unprepared for the unexpected daily challenge of euthanizing stray dogs, cats, and various wildlife species. On more than one occasion, reports emerged of veterinary personnel suffering from nightmares related to euthanasia duties, refusing to euthanize, and departing the facility in tears. At least one soldier

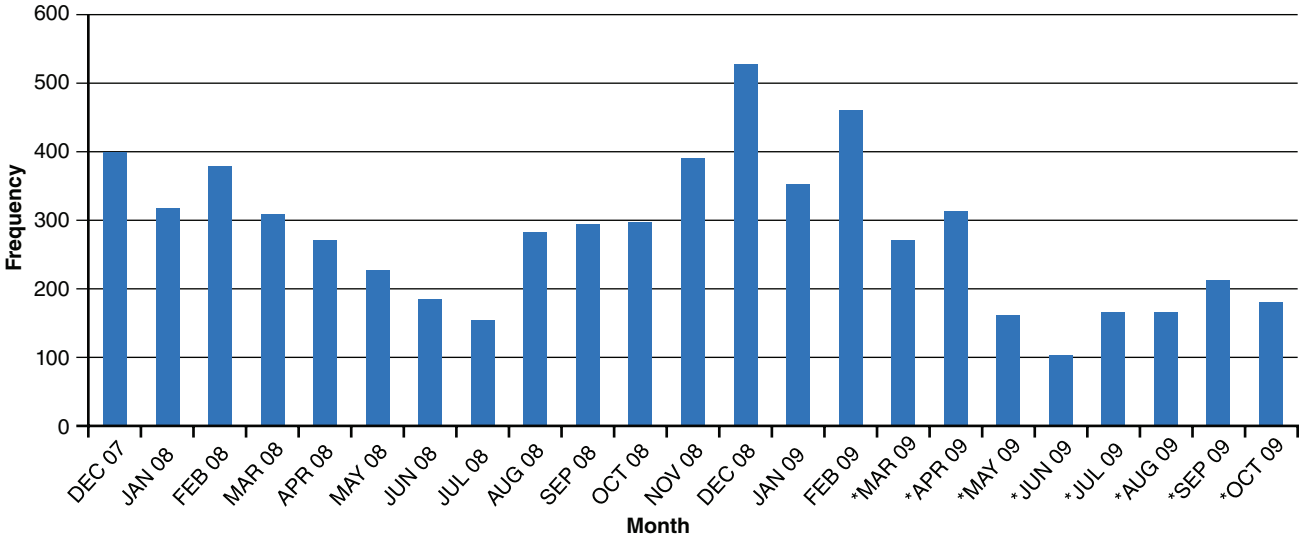

Figure 12-8. The number of animal euthanasias performed by the US Army Veterinary Services in Iraq, December 2007–October 2009.
*No euthanasias were performed in the International Zone (Baghdad) due to clinic renovation and closure.

deployed to Iraq visited the combat stress control detachment because of the stress of daily euthanasia duties. Discussions between detachment personnel and unit leadership indicated that this soldier may have been suffering from acute stress disorder, a potential precursor to posttraumatic stress disorder (Lieutenant Colonel Nicole Chevalier, chapter author, oral communications [staff meeting with Combat Stress Control Detachment and personal conversation with Lieutenant Colonel David Galloway, Commander, 64th Medical Detachment, Veterinary Service, Balad, Iraq] 2009). During discussions with other veterinary detachment leaders, additional anecdotal reports emerged of veterinary personnel in units in Afghanistan experiencing similar difficulties as those in Iraq (Lieutenant Colonel Nicole Chevalier, chapter author, oral communications [personal conversations with veterinary detachment commanders and medical brigade staff], International Veterinary Symposium, Garmisch, Germany, May 2010).

To mitigate such problems, the veterinary detachment leadership deployed in Iraq took steps to decrease the burden of euthanasia on their personnel, including performing a comprehensive feral animal control policy review and recommending changes to the policy; discontinuing trapping and euthanizing of Iraqi wildlife species because data analysis indicated they did not pose a threat to soldiers; decreasing euthanasia duties to 3 days each week; training non-veterinary teams on various installations to perform humane euthanasia of trapped feral dogs and animals that posed a threat to soldiers; and encouraging subordinate leaders to support soldier visits to combat stress control detachments and chaplains.

INTERNATIONALLY SUPPORTED RABIES CONTROL PROGRAMS

Successful internationally recognized and scientifically supported rabies control programs are comprehensive and multifaceted. Components of an effective program include rabies surveillance, mass parenteral vaccination, supplementary oral vaccination, and stray animal population management.[38] Although research indicates that a stray animal and rabies control program will likely be ineffective on US base camps without the inclusion of all of these components, implementing the necessary comprehensive program is logistically difficult, if not impossible, in a contingency environment.

Rabies Surveillance

Surveillance is the foundation of any successful rabies control program. The goal of surveillance programs is to provide information on human and animal rabies incidence using laboratory disease diagnosis, effectiveness of control efforts, estimates of the stray and wildlife population numbers, and locations to distribute oral rabies baits in the areas of concern.[38] This information is already tracked in operational environments to some degree using the animal bite reporting system previously described in this chapter.

However, underreporting is of great concern, especially given that very few of the animals involved in these bite reports are captured and tested. Therefore, it is probable that current surveillance efforts by US military veterinarians and preventive medicine personnel vastly underestimate the rabies burden in contingency environments.

Mass Parenteral Vaccination

"Herd immunity" is the concept that a majority of an animal population needs to be vaccinated in order to disrupt the spread of disease in a population. To confer "herd immunity" for rabies in a given population, at least 70% of the animals within the population must be vaccinated.[38,50] The high level of herd immunity required for rabies control in stray animal populations is associated with the high birth and death rates in stray dog populations. The death rate results in a loss of vaccine-immune adults, while the birth rate contributes to the numbers of the susceptible fraction of the population; the overall result is an increased susceptibility to disease. Unfortunately, the difficulty associated with trapping and parenterally vaccinating at least 70% of the strays on large base camps would be substantial. Compounding this difficulty is the fact that every vaccinated animal would require a rabies booster vaccine after 1 year to ensure lasting immunity.[22]

Oral Vaccination

Oral rabies bait vaccines, mentioned earlier in this chapter, are recombinant vaccines. Typically, a biomarker is also included as part of the vaccination. Biomarkers allow researchers to assess whether or not a particular animal ingested a bait vaccine and analyze how many animals that ingested bait seroconverted, facilitating surveillance of bait-efficacy in the targeted area.[31,49]

Numerous oral bait vaccines currently meet the WHO's requirements for efficacy, defined by the ability of the vaccine to protect a dog against a local canine rabies virus administered at a dose that would kill 80% of unvaccinated dogs.[37] Oral bait vaccine programs were successful in numerous field studies worldwide, including the Philippines, Tunisia, India, and Turkey.[38,51–53] These studies also indicate that the vaccine protected from infection even when there was not a sufficient rabies-neutralizing antibody titer of 0.5 IU/mL, the titer recommended for animals by the World Organization for Animal Health to be considered vaccine immune to rabies.[54]

Given these successes, countries with long-term governmental commitments to rabies control and the associated infrastructure should incorporate oral rabies bait programs into their enzootic rabies control programs. However, according to the WHO, oral baiting is meant to be a supplement to established parenteral vaccination programs, not an initial control program. Oral baiting can be particularly effective in areas where a large percentage of the animal population is inaccessible or free-ranging and where the targeted population is wildlife.[49]

Not all groups agree with the WHO's recommendations for the best use of oral bait vaccinations. Some recommend that oral bait vaccines be employed as a primary vaccination effort when a majority of the canine population is inaccessible for vaccination or when parenteral vaccination is not as viable as the use of an oral bait vaccine program (eg, for stray animal populations in a contingency environment).[49,51]

Population Management

Successfully decreasing a population's rabies carrying capacity includes implementing strategies for movement restriction, habitat control, and reproduction control. On base camps, movement restriction is accomplished by repairing breaks in fences where animals can enter. Habitat control includes eliminating stray animal access to food sources such as burn pits and trash collection sites and eliminating compassionate feeding of animals. Reproduction control involves methods to prevent animals from breeding. This comprehensive approach to population management reduces animal turnover, decreases the animal populations susceptible to rabies, and limits male dog behavior (eg, fighting and roaming) that contributes to human-animal interactions and rabies spread.[38] When coupled with a vaccination program, this comprehensive approach also results in a stable population of animals on base camps that are essentially immune to rabies infections.

Trap, neuter, and release programs are a major component of population and reproductive control in the United States and other nondeployment areas. Currently, surgery is the most common form of reproductive sterilization used by these programs, but chemical sterilization may become increasingly available as research continues. The US Department of Agriculture is studying an injectable antigonadotropin releasing hormone vaccine called Gonacon (US Department of Agriculture/Animal Plant Health Inspection Service/Wildlife Services/National Wildlife Research Center, Ft Collins, Colorado), which has shown significant promise in sterilizing vaccinated dogs without impacting rabies vaccine effectiveness.[54-56] Free-roaming animals can be identified as sterilized and vaccinated by using an ear notch or tag, collar, tattoo, or some other distinguishing marker.

In addition to Gonacon, several other chemical sterilants have been developed, and one has been approved by the US Food and Drug Administration for use in dogs and cats: Zeuterin (Ark Sciences, Irvington, New York) was released for sale in the United States in February 2014. This male sterilant uses zinc gluconate, which binds with arginine in the animal's body, resulting in testicular sclerosis and permanent sterility.[57] Products approved for use in other countries include Infertile (Brazil) and Suprelorin (Australia, New Zealand, and several European Union countries).[58,59]

Historically, surgical sterilization of stray dogs and cats in operational environments has been logistically infeasible because of the large number of animals trapped compared to the small number of veterinarians assigned to these theaters. In a contingency environment, chemical sterilization could prove to be an efficient reproduction control option. Currently, Gonacon is only approved for use on deer and other cervids, Zeuterin can only be used on cats and dogs, and both of these products are only approved for use in the United States. Until more chemical sterilants are approved to be utilized by DoD authorities, the trap, neuter, and release programs commonly implemented by stateside personnel will continue to be beyond the scope of deployed DoD forces.

Euthanasia

Euthanasia programs have their place in comprehensive rabies control programs. All animals that are neurologically ill (including aggression) or overtly ill or lame at the time of capture should be euthanized humanely in accordance with American Veterinary Medical Association guidelines and disposed of properly.[60] Indiscriminate trap and euthanize efforts should be avoided as part of a comprehensive rabies control program because animals vaccinated parenterally or through oral rabies baiting would likely be euthanized, inhibiting the goal of achieving herd immunity. However—if combined with stringent movement restriction (ie, no way for animals to enter the operating base) and habitat control efforts—trap, euthanize, and dispose programs could be successful.

Human Preexposure Vaccination

Another option for protecting US service members from rabies in operational environments is to confer rabies protection on the individual versus attempting to control rabies in the animal population. Ideally, if this option were implemented in its entirety, each deploying US service member and civilian contractor would receive the three preexposure rabies vaccination series, but this option is currently fiscally untenable. In 2011, the Defense Logistics Agency procured vaccine for $121.23 per one-dose vial (Written communication, email from Defense Logistics Agency, December 2011), making the cost of the preexposure vaccination series $363.69 per person. Vaccination of one million personnel would cost $363,700,000, which does not include the cost of titers and booster vaccinations throughout a person's career. It also would not relieve personnel potentially exposed to rabies from the requirement to receive rabies PEP. Finally, preexposure vaccination of all US personnel does not offer any benefit to the local population such as would occur with broad-spectrum animal population vaccination. Therefore, only personnel considered "at-risk" currently receive the initial three preexposure vaccinations and any necessary boosters throughout their service (eg, veterinary personnel and contractors involved in trapping animals).

Human Postexposure Prophylaxis

Despite the accuracy of modern laboratory tests for infection, PEP is often a precautionary part of any successful rabies control and prevention program, given the complex nature of the disease and certain environmental constraints. As noted earlier, providing preexposure vaccination for all troops, DoD civilians, privately owned pets, and feral animals is currently not possible. Rabies is prevalent in contingency opera-

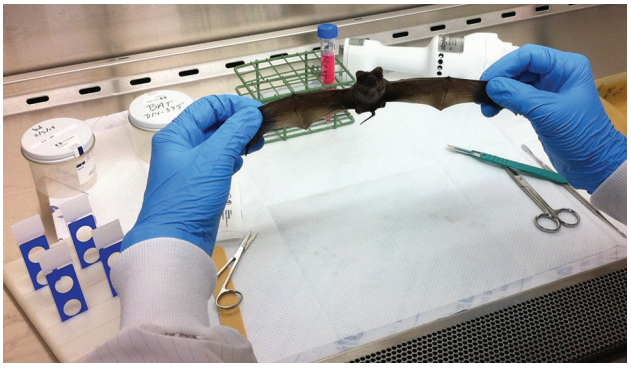

Figure 12-9. A Department of Defense Food Analysis and Diagnostic Laboratory (DoD FADL) veterinary technician performing rabies testing under a hood on a submitted bat. The bat featured above is not the bat received from the Joint Base San Antonio-Lackland incident described in this chapter's text, but it is the same species (ie, a Mexican free-tail bat), and the same diagnostic procedures were used on both free-tail bat submissions.
Photograph courtesy of Deputy Director, Major Karl J. Hochstein, DoD FADL, Joint Base San Antonio-Ft Sam Houston, Texas.

tions, can be contracted via several different routes (eg, scratches, bites, and inhalation), has variable but often rapid incubation periods in multiple animal species, and is almost always fatal after symptoms appear. Therefore, once exposure is suspected, the military quickly uses PEP to safeguard troops, whether they are deployed or stationed stateside.

A case in point is the recent capture of a Mexican free-tail bat at Joint Base San Antonio-Lackland. Although the captured bat tested negative for rabies at the DoD Food Analysis and Diagnostic Laboratory located at Joint Base San Antonio-Ft Sam Houston (Figure 12-9), more than 200 trainees who were living in the dormitory where the bat was caught were given PEP before test results were completed. A joint base spokesman noted that these "vaccinations were given as a precaution" and that even though it was "unlikely" that any trainees had "physical contact" with the captured bat or any other bats, the "primary concern [was] for the health and welfare of the trainees."[61(p1)]

RABIES CONTROL IN FUTURE CONTINGENCY OPERATIONS

In early 2013, the directorate of combat and doctrine development at the Army Medical Department Center and School convened a triservice integrated process action team (IPAT) to examine feral animal risk mitigation in future contingency operations. The IPAT used lessons learned; focus groups; surveys; joint operating concepts and doctrine; frameworks for rabies and stray animal control from the WHO and World Organization for Animal Health; research from a review of military policy, doctrine, and scientific literature; and professional military judgment to conduct a capabilities-based assessment. Their analysis identified the capabilities required to mitigate traumatic injury and zoonotic disease risks posed by feral dogs and cats in future conflicts, current capability shortfalls, and potential solutions for identified shortfalls.

The IPAT assumed that US service members will always choose to interact with animals, despite the risks involved or theater orders (eg, GO-1B). Therefore, the IPAT developed the following "solutions" to help mitigate the chances of spreading or contracting rabies in various military environments, given these inevitable interactions: increasing awareness among US service members as to what constitutes a potential rabies exposure and the importance of prompt reporting and treatment; standardizing reporting and treatment procedures for US service members potentially exposed to rabies; increasing awareness among leaders of feral animal threats; publishing technical guidance to standardize feral animal control measures for dogs and cats in contingency environments; clarifying various responsibilities for feral animal control and feral animal risk mitigation procedures in policy and doctrine; instituting triservice measures to collate and analyze bite reports (ie, DD Form 2341) to estimate traumatic injury and rabies risk to US service members in various environments; and publishing policy to ensure that all appropriately categorized "at risk" personnel receive preexposure rabies vaccination prior to deployment.

The documents outlining these proposed solutions have initially been approved by the Headquarters, Department of the Army, and are currently being reviewed by DoD staff. The proposed timeline for implementing the final approved solutions began in the fall 2014 and continued through fiscal year 2015.

SUMMARY

Because the risk of exposure to *Lyssavirus* is high in areas where the United States will deploy its military in the future, rabies continues to be a legitimate disease threat to force health protection. Compounding this risk is the likelihood of stray animals on and around military base camps in contingency environments and the reality that US service members will likely choose to interact with animals, despite this risk and command regulations against doing so. Controlling rabies is a complicated problem for which the ultimate prevention and control program has yet to be found, especially in operational environments. However, efforts are underway to implement improved measures to mitigate rabies risk to deployed US forces.

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