

Public Veterinary Medicine: Public Health

Rabies in vaccinated dogs and cats in the United States, 1997–2001

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Objective—To identify cases of rabies involving vaccinated dogs and cats in the United States.

Design—Retrospective data review.

Sample Population—41 states that reported ≥ 1 rabid dog or cat between 1997 and 2001.

Procedures—States were contacted to request information on numbers of dogs and cats tested for rabies between 1997 and 2001. For animals with a history of rabies vaccination, respondents were asked to provide details of the vaccination history, age, history of exposure to rabid animals, time between exposure and onset of clinical signs, clinical signs, duration of clinical signs, and whether the animal had died or was euthanized.

Results—21 of the 41 (51%) states agreed to participate in the study. A total of 264 rabid dogs and 840 rabid cats were identified during the study period. Thirteen (4.9%) rabid dogs and 22 (2.6%) rabid cats had a history of rabies vaccination. Of these, 2 dogs and 3 cats were classified as currently vaccinated. Overall, 6 animals (1 dog and 5 cats) had a history of receiving 2 doses of rabies vaccine in their lifetime, including 2 cats that were classified as currently vaccinated.

Conclusions and Clinical Relevance—Results suggested that rabies is uncommon in vaccinated dogs and cats but can occur. Veterinarians should include rabies in the differential diagnosis for any dog or cat with clinical signs compatible with rabies regardless of vaccination history. Continued surveillance is imperative to document vaccination failure and identify trends related to vaccination failure. (*J Am Vet Med Assoc* 2009;235:691–695)

Rabies is one of the oldest zoonotic diseases and continues to be an important public health concern in the United States.¹ Globally, 35,000 to 50,000 human deaths can be attributed to bites from rabid dogs each year, although these deaths occur mainly in the developing regions of Southeast Asia, Africa, Latin America, and India.^{1,2} In the United States, the incidence of human rabies during the 1950s was 11 cases/y,³ but with the implementation of animal control and rabies vaccination programs and the development of effective postexposure prophylaxis for humans,² this figure has decreased to approximately 3 cases/y.³

The incidence of rabies in domestic animals in the United States has decreased substantially during the past 50 years, while the incidence in wildlife has increased.^{1,2} An epizootic of raccoon rabies along the eastern seaboard is mainly responsible for the increase in the number of rabies cases among wild animals in

the United States since 1990. In that year, 4,327 cases of rabies were reported in wildlife species.^{4,5} By contrast, 6,939 cases of rabies were reported in wildlife, including bats, skunks, raccoons, and foxes, during 2001.⁶ Of the 7,437 total cases of rabies in the United States and Puerto Rico during 2001, only 7% involved domestic species.⁶ The increase in the number of cases of wildlife rabies is of public health concern because of the subsequent increased risk that humans and domestic animals could come into contact with the virus.⁴ Considering the average cost of postexposure prophylaxis in humans, including the cost of biologics, doctor visits, and medical care, is approximately \$4,000,⁷ the financial burden associated with rabies is also a concern.⁸

Approximately 86% of humans that receive postexposure rabies prophylaxis do so because of exposure to rabid or potentially rabid dogs and cats.⁹ This percentage is high, considering that dogs and cats reportedly represented only 4.8% of all reported cases of rabies during 2001,⁶ but reflects the close relationship between people and dogs and cats. The last human death likely due to an indigenous canine rabies virus variant in the United States occurred in Texas in 1996,² although the exposure history for the case is unknown.

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Nevertheless, rabies in dogs and cats continues to be a concern.

To reduce the risk of rabies in domestic animals, vaccination of dogs and cats is essential, particularly in those areas where rabies is endemic in wildlife. The annual Compendium of Animal Rabies Prevention and Control provides updated recommendations to the veterinary and public health communities concerning vaccination procedures and rabies control programs in the United States.¹⁰ Although vaccination is an important tool in preventing rabies, the protection associated with vaccination is not 100%, and it is important to assess the proportion of rabies cases that occur in domestic animals considered to be current on their vaccinations according to the compendium guidelines. Such information could affect future guidelines for rabies prevention and control and help identify any trends in the occurrence of vaccine failure associated with a specific vaccine lot number or manufacturer or a particular rabies virus variant circulating in the United States. The purpose of the study reported here, therefore, was to identify cases of rabies involving vaccinated dogs and cats in the United States, determine the percentage of rabid dogs and cats with a history of vaccination, and identify factors (eg, vaccination history, clinical signs, and virus variant) potentially associated with rabies in vaccinated dogs and cats.

Materials and Methods

Annual rabies surveillance reports^{6,11–14} prepared by the CDC were reviewed to identify states that reported a rabid dog or cat between 1997 and 2001. For each state that was identified, the person responsible for rabies surveillance in the state health department was contacted by e-mail or telephone and invited to participate in the study. Questionnaires were subsequently sent to individuals who indicated a willingness to participate. The questionnaire listed the number of rabid dogs and cats reported to the CDC by the state for each year of the study (1997 through 2001) and asked respondents to provide the numbers of dogs and cats tested for rabies during each of those years.

For any dog or cat confirmed to have rabies on the basis of results of virus isolation or direct fluorescent antibody testing of brain tissue¹⁵ that also had a history of rabies vaccination, respondents were asked to provide details of the vaccination history (including age when vaccine doses were administered), age of the animal at the time of death, any history of exposure to a rabid animal, time between exposure and the onset of clinical signs, clinical signs exhibited by the animal, duration of clinical signs, whether the animal had been examined by a veterinarian, and whether the animal had died or was euthanatized. In addition, respondents were asked to indicate whether a particular virus variant had been identified and how many people had received postexposure prophylaxis as a result of exposure to the animal. Data that were collected did not include identifying information on any human subjects.

Dogs and cats for which information on history of vaccination was provided were classified as currently vaccinated if the first dose of rabies vaccine had been administered ≥ 28 days prior to exposure to a rabid ani-

mal and vaccination had been performed in compliance with guidelines from the National Association of State Public Health Veterinarians (ie, initial vaccination no earlier than 12 weeks of age, booster vaccination 1 year after initial vaccination, and additional regular booster vaccinations as directed by the vaccine manufacturer).¹⁰ Animals that had a history of vaccination but were not considered current on vaccination were classified as not currently vaccinated (eg, animals for which too much time had elapsed since the last booster vaccination) or as being within 28 days of the first vaccine dose administration at the time of rabies onset. Animals that had a history of vaccination but for which specific details were unavailable were classified as having unknown or unclassified vaccination status.

Data analysis—Information from returned questionnaires was entered into a spreadsheet^a and imported into a statistical software program^b for analysis. Descriptive statistics were calculated. Incidence of rabies among vaccinated dogs and cats was calculated on the basis of total number of rabid dogs and cats with a history of vaccination during the 5-year study period. The χ^2 test was used to determine whether species (dog vs cat) was significantly associated with having a history of vaccination (yes vs no). One-way Kruskal-Wallis analysis on ranks was used to determine whether the number of people requiring postexposure prophylaxis as a result of exposure to rabid dogs with a history of vaccination was significantly greater than the number of people requiring postexposure prophylaxis as a result of exposure to rabid cats with a history of vaccination. For all analyses, values of $P < 0.05$ were considered significant.

Results

Forty-one states reported ≥ 1 rabid dog or cat between 1997 and 2001. No rabid dogs or cats were reported during the study period by Colorado, Hawaii, Idaho, Illinois, Indiana, Mississippi, Nevada, Utah, or Washington. Of the 41 states with ≥ 1 rabid dog or cat, 21 (51%) agreed to participate in the study. New Mexico was unable to provide total numbers of dogs and cats tested for rabies during 1997 and 1998, and Pennsylvania was unable to provide total numbers of dogs and cats tested during any year of the study period.

Participating states indicated that 170,987 dogs and cats were submitted for rabies testing during the study period (Table 1; only partial data were available for New Mexico, and data were not available for Pennsylvania). A total of 264 rabid dogs and 840 rabid cats were identified during this period. Alaska (12/175 [6.86%]) and West Virginia (13/980 [1.33%]) had the highest percentages of rabid dogs among all dogs tested, and Virginia (124/5,211 [2.38%]) and Maine (18/1,152 [1.56%]) had the highest percentages of rabid cats among all cats tested. States with the most dogs and cats tested during the study period were Texas (18,741 dogs and 16,690 cats) and California (13,339 dogs and 11,481 cats).

States reporting rabid dogs and cats with a history of vaccination included Texas, California, Pennsylvania, South Carolina, Virginia, New York, and Missouri. Thirty-five of the 1,104 (3.2%) rabid dogs and cats had

Table 1—Numbers of dogs and cats tested for rabies by various states between 1997 and 2001.

State	Dogs		Cats	
	No. tested	No. (%) positive	No. tested	No. (%) positive
Alaska	175	12 (6.86)	51	0 (0)
Arizona	4,532	2 (0.04)	2,608	0 (0)
Arkansas	1,814	11 (0.61)	1,475	8 (0.54)
California	13,339	13 (0.10)	11,481	7 (0.06)
Connecticut	2,044	8 (0.39)	4,557	29 (0.64)
Kansas	2,923	9 (0.31)	3,461	41 (1.18)
Kentucky	2,245	9 (0.40)	1,984	10 (0.50)
Louisiana	1,853	2 (0.11)	1,702	2 (0.12)
Maine	367	3 (0.82)	1,152	18 (1.56)
Maryland	4,714	5 (0.11)	9,267	95 (1.03)
Missouri	3,397	5 (0.15)	3,685	9 (0.24)
New Mexico	938	2 (0.21)	483	2 (0.41)
New York	4,407	8 (0.18)	10,938	140 (1.28)
North Carolina	4,664	36 (0.77)	6,636	81 (1.22)
Ohio	4,972	1 (0.02)	5,210	4 (0.08)
Pennsylvania	NR	16 (NC)	NR	155 (NC)
South Carolina	3,336	14 (0.42)	4,053	30 (0.74)
Texas	18,741	74 (0.39)	16,690	61 (0.37)
Vermont	136	0 (0)	409	5 (1.22)
Virginia	3,092	21 (0.68)	5,211	124 (2.38)
West Virginia	980	13 (1.33)	1,265	19 (1.50)
Total	78,669	248 (0.32)*	92,318	685 (0.74)*

*Does not include rabid dogs and cats reported by Pennsylvania.
NR = Not reported. NC = Not calculable.

a history of vaccination, including 13 of the 264 (4.9%) rabid dogs and 22 of the 840 (2.6%) rabid cats. Rabid dogs were not significantly ($P = 0.06$) more likely to have a history of vaccination than were rabid cats.

Information on vaccination status at the time of death was available for 28 of the 35 (80%) rabid animals with a history of vaccination. Of the 13 rabid dogs with a history of vaccination, 2 were classified as currently vaccinated, 5 were classified as not currently vaccinated, and 4 were classified as being within 28 days of the first vaccine dose administration at the time of rabies onset. In the remaining 2 dogs, vaccination status was unknown or could not be classified. Of the 22 rabid cats with a history of vaccination, 3 were classified as currently vaccinated, 8 were classified as not currently vaccinated, and 6 were classified as being within 28 days of the first vaccine dose administration at the time of rabies onset. In the remaining 5 cats, vaccination status was unknown or could not be classified. Two of the 13 rabid dogs and 3 of the 22 rabid cats had received booster doses of rabies vaccine after exposure to a rabid animal.

Overall, 6 rabid animals (1 dog and 5 cats) had a history of receiving 2 doses of rabies vaccine in their lifetime, including 2 cats that were classified as currently vaccinated. The dog received its first vaccination in 1998 at 3 years of age and was given a booster dose in 2001 after suspected exposure to a skunk. This dog lived 8 days before dying of rabies and was not classified as currently vaccinated because it had not received the initial booster dose 1 year after first vaccination. One of the 2 cats that were classified as currently vaccinated had received its first vaccination at 1 year of age and received its initial booster dose exactly 1 year later. Rabies was diagnosed 10 months after the booster dose was given. The other cat had

been vaccinated at 3 months of age and received its initial booster dose at 15 months of age. This cat began to show clinical signs of rabies 3 days after the initial booster dose was given.

The 3 remaining cats that had a history of receiving 2 doses of rabies vaccine were classified as not currently vaccinated at the time of death. One cat had received its first vaccination at 1 year of age, received a second dose at an unknown age, and developed rabies at 8 years of age. The second cat received its first vaccination at an unknown age, received a booster dose after being exposed to a rabid raccoon, and died of rabies < 1 month after exposure. The third cat received its first vaccination at 3 months of age, received a booster dose after exposure to a rabid animal at 2.5 years of age, and developed clinical signs of rabies shortly after receiving the booster dose.

Of the 35 rabid animals with a history of vaccination, 12 (34%) reportedly were known to have been exposed to a rabid or potentially rabid animal. This included animals from Texas (2 dogs), Pennsylvania (8 cats), and New York (2 cats). Both of the dogs from Texas were reportedly known to have been exposed to rabid skunks. One of these dogs was infected with a Texas fox variant of the rabies virus; the other was infected with a skunk variant. One cat from Pennsylvania reportedly was known to have been exposed to a rabid raccoon, but virus identification was not performed. The other 7 cats from Pennsylvania and the 2 cats from New York reportedly were known to have been exposed to rabid animals, but the species of rabid animal was unknown. Thirteen of the 35 (37%) rabid animals (9 dogs and 4 cats) with a history of vaccination did not have any known exposure to rabid animals. For the remaining 10 (29%) animals (2 dogs and 8 cats), information on exposure to rabid animals was not available.

For the 2 dogs from Texas known to have been exposed to rabid skunks, the time from exposure to initial clinical signs was < 1 month. For the 10 cats known to have been exposed to rabid animals, the time from exposure to initial clinical signs was < 1 month in 4 cats, between 1 and 3 months in 2 cats, and unknown in the remaining 4 cats.

The virus variant was identified in 12 of the 35 (34%) rabid animals with a history of vaccination, including 10 dogs (6 from Texas, 1 from Missouri, and 3 from California) and 2 cats (both from Virginia). Three of the dogs from Texas were infected with the Texas fox rabies virus variant, and 3 were infected with skunk rabies virus variant. The dog from Missouri and all 3 dogs from California were infected with skunk rabies virus variant. Both cats were infected with raccoon rabies virus variant.

Information on clinical signs was available for 34 of the 35 (97%) rabid animals with a history of vaccination (information on clinical signs was not available for 1 cat), with 25 animals having > 1 clinical abnormality. Clinical signs in the 13 dogs included paralysis ($n = 6$), lethargy (5), and aggression (4). Six dogs had additional clinical signs, including restlessness, hypersalivation, anorexia, ataxia, limping, and visible wounds. One dog reportedly did not have any clinical signs. Clinical signs in the 21 cats included aggression

(n = 9), paralysis (6), and lethargy (2). Nine cats had additional clinical signs, including excitability, change in voice, loss of appetite, choking, difficulty swallowing, ataxia, tremors, and anorexia.

Duration of illness was reported for 22 of the 35 (63%) rabid animals with a history of vaccination (10 dogs and 12 cats). Duration of illness was 0 to 3 days in 7 dogs and 9 cats, 4 to 7 days in 2 dogs and 3 cats, and > 7 days in 1 dog. Eight of the 13 (62%) dogs and 13 of the 22 (55%) cats were euthanatized, which likely shortened the duration of illness in these animals. Five dogs and 7 cats died from rabies. Outcome was reported as unknown for 2 cats. Five of the dogs were < 5 years old at the time of death, 5 were between 1 and 5 years old, and 2 were > 5 years old. Age at the time of death was unknown for the remaining dog. Two of the cats were < 5 years old at the time of death, 8 were between 1 and 5 years old, and 4 were > 5 years old. Age at the time of death was unknown for the remaining 8 cats.

Postexposure prophylaxis was required for humans exposed to 12 of the 13 (92%) rabid dogs and 19 of the 22 (86%) rabid cats with a history of vaccination, with a total of 169 people receiving postexposure prophylaxis. Median number of persons requiring postexposure prophylaxis following exposure to dogs was 7 (range, 1 to 12), and median number of persons requiring postexposure prophylaxis following exposure to cats was 4 (range, 1 to 15). Number of people requiring postexposure prophylaxis following exposure to rabid dogs with a history of vaccination was not significantly ($P = 0.08$) different from number of people requiring postexposure prophylaxis following exposure to rabid cats with a history of vaccination.

Discussion

Results of the present study suggested that rabies is uncommon in vaccinated dogs and cats but can occur. Among the 1,104 laboratory-confirmed cases of rabies reported by the 21 states participating in the present study, 35 (3.2%) involved dogs and cats with a history of rabies vaccination, including 2 dogs and 3 cats in which vaccinations were considered current. In a similar, unpublished retrospective study of data for 1992 through 1996, we found that 40 of 485 (8.2%) rabid dogs and 17 of 1,152 (1.5%) rabid cats had a history of vaccination. Differences between results of the present study and results of this unpublished study most likely relate to a decrease in the canine variant of rabies in the southern United States resulting from active oral vaccination programs and an increase in cat rabies secondary to the raccoon variant epizootic in the northeast.^{16,17}

In a previous prospective study¹⁸ of data for 1988, 14% of rabid dogs and 5% of rabid cats had a history of vaccination. It is likely that the prospective approach in this study was the reason for the higher percentages of rabid dogs and cats with a history of vaccination, compared with percentages in the present study, which was retrospective in nature. Collectively, these findings strengthen the observation that rabies can occur in vaccinated animals, albeit uncommonly.

Because domestic animals can serve as a bridge between wildlife rabies reservoirs and humans, vaccination of pets is one of the most effective public health tools available to safeguard human health. Currently, at least 18 rabies vaccines are licensed for use in domestic dogs or cats.¹⁰ Proof of potency, safety, purity, and efficacy is required for vaccine licensure. Currently, the USDA requires that at least 86% of vaccinated dogs or cats be protected against a lethal rabies virus challenge before the vaccine can be licensed for use.¹⁹

For rabies vaccines, vaccination failure can be defined as any instance when an animal that has been vaccinated in accordance with protocols recommended in the Compendium of Animal Rabies Prevention and Control¹⁰ develops rabies following exposure to the virus. A variety of factors can lead to vaccination failure. As an example, use of a vaccine that has not been properly stored or that is past its expiration date can lead to vaccination failure. Host factors that result in a failure to mount an appropriate immune response, such as immunocompromise secondary to disease or corticosteroid treatment, can also lead to vaccination failure. All of these factors should be examined in cases of suspected vaccination failure.

Vaccination failure can also occur as a result of exposure to a particularly virulent virus variant. Vaccine trials typically involve determining efficacy against a single virus variant, when in actuality, each variant exhibits a different degree of virulence. Thus, it is unknown how effective vaccines would be against other variants, unless multiple trials are performed. In the present study, there was no apparent overrepresentation of particular virus variants in those animals with vaccination failure, but additional studies and continued surveillance are needed to determine whether a problem exists.

An important limitation of the present study was the variability in data collected by each state, which affected our ability to make comparisons among states. States differed with regard to their surveillance systems and methods for investigating potentially rabid animals; criteria for submission of potentially rabid animals for testing, which could have reduced the number of rabid animals identified; population size, which affected the number of owned pets and chances for human and domestic animal interactions with wildlife; and the presence of various rabies virus strains. For example, Alaska tested as few as 175 animals during the 5-year study period, whereas Texas tested 18,741 animals. One reason for the difference in number of animals tested among states could be that the criteria for submission of animals for rabies testing may vary from state to state. Regions that are affected by > 1 predominant rabies virus variant, such as Texas and Arizona,¹² were more likely to have more extensive surveillance programs, which would increase the number of animals tested each year. Another reason for the difference in number of animals tested could be the difference in population size among participating states.

Rabies virus variants identified in dogs and cats in the present study were typical of the geographic region from which the animals came. This indicates that spillover from one terrestrial reservoir to another did not

occur frequently during the study period and suggests that rabies control programs implemented by the states to control enzootic rabies in their specific region were successful.

Typically, rabid cats are reported to have aggressive behavior, whereas rabid dogs are more likely to have lethargy and paralysis,¹⁸ and findings in the present study were similar. This suggests that regardless of vaccination status, signs of rabies will be similar for a particular species.

In attempting to collect data for the present study, we were struck by the degree of difficulty some states had in acquiring information on rabid animals. In particular, only 51% (21/41) of the states that were contacted had the information available and were willing to participate. This was a major weakness of the study, as it affected the quality of the data and could have affected the conclusion that vaccination failure is a rare event. Many states experienced difficulties in completing the study questionnaire because these data are not kept or routinely monitored. This is problematic in that it is difficult to identify problems or trends in vaccination failure when data are not kept on a regular basis. In addition, it is recommended in the Compendium of Animal Rabies Prevention and Control that rabies in vaccinated animals be reported promptly to state public health officials, the vaccine manufacturer, and the USDA.¹⁰ The compendium also recommends that the virus variant be identified by a reference laboratory in every case of rabies in a vaccinated animal as part of a thorough epidemiologic investigation. In the present study, in contrast, the virus variant was known for only 10 of 13 dogs and 2 of 22 cats with history of rabies vaccination. Despite these limitations, the present study was effective in documenting the existence of rabies in vaccinated animals. It is our hope that similar studies will encourage states to develop an improved system to effectively record and report this information to public health authorities. For instance, as each state identifies a rabid animal, a questionnaire similar to the one used in the study could be administered to collect relevant information regarding exposure and vaccination status.

a. Excel, Microsoft Corp, Redmond, Wash.

b. SAS, version 8, SAS Institute Inc, Cary, NC.

References

1. Wilkinson L. History. In: Jackson AC, Wunner WH, ed. *Rabies*. San Diego: Elsevier Science, 2002;1.
2. Noah DL, Drenzek CL, Smith JS, et al. Epidemiology of human rabies in the United States, 1980 to 1996. *Ann Intern Med* 1998;128:922–930.
3. CDC. Human rabies—Iowa, 2002. *MMWR Morb Mortal Wkly Rep* 2003;52:47–48.
4. Chang HG, Eidson M, Noonan-Toly C, et al. Public health impact of reemergence of rabies, New York. *Emerg Infect Dis* 2002;8:909–913.
5. Uhaa IJ, Mandel EJ, Whiteway R, et al. Rabies surveillance in the United States during 1990. *J Am Vet Med Assoc* 1992;200:920–929.
6. Krebs JW, Noll HR, Rupprecht CE, et al. Rabies surveillance in the United States during 2001 (Erratum published in *J Am Vet Med Assoc* 2003;222:460). *J Am Vet Med Assoc* 2002;221:1690–1701.
7. Dhankhar P, Vaidya SA, Fishbien DB, et al. Cost effectiveness of rabies post exposure prophylaxis in the United States. *Vaccine* 2008;26:4251–4255.
8. Meltzer MI, Rupprecht CE. A review of the economics of the prevention and control of rabies. Part 1. Global impact and rabies in humans. *Pharmacoeconomics* 1998;14:365–383.
9. Moran GJ. Dogs, cats, raccoons, and bats: where is the real risk for rabies? (edit) *Ann Emerg Med* 2002;39:541–543.
10. National Association of State Public Health Veterinarians Committee. Compendium of animal rabies prevention and control, 2008. *J Am Vet Med Assoc* 2008;232:1478–1486.
11. Krebs JW, Smith JS, Rupprecht CE, et al. Rabies surveillance in the United States during 1997 (Erratum published in *J Am Vet Med Assoc* 1999;214:1025). *J Am Vet Med Assoc* 1998;213:1713–1728.
12. Krebs JW, Smith JS, Rupprecht CE, et al. Rabies surveillance in the United States during 1998 (Erratum published in *J Am Vet Med Assoc* 2000;216:1223). *J Am Vet Med Assoc* 1999;215:1786–1798.
13. Krebs JW, Rupprecht CE, Childs JE, et al. Rabies surveillance in the United States during 1999 (Erratum published in *J Am Vet Med Assoc* 2001;218:1097). *J Am Vet Med Assoc* 2000;217:1799–1811.
14. Krebs JW, Mondul AM, Rupprecht CE, et al. Rabies surveillance in the United States during 2000. *J Am Vet Med Assoc* 2001;219:1687–1699.
15. CDC. Case definitions for infectious conditions under public health surveillance. *MMWR Morb Mortal Wkly Rep* 1997;46(RR10):1–55.
16. Robbins AH, Borden MD, Windmiller BS, et al. Prevention of the spread of rabies to wildlife by oral vaccination of raccoons in Massachusetts. *J Am Vet Med Assoc* 1998;213:1407–1412.
17. Rupprecht CE, Hanlon CA, Slate D. Oral vaccination of wildlife against rabies: opportunities and challenges in prevention and control. *Dev Biol* 2004;119:173–184.
18. Eng TR, Fishbein DB. Epidemiologic factors, clinical findings, and vaccination status of rabies in cats and dogs in the United States in 1988. National Study Group on Rabies. *J Am Vet Med Assoc* 1990;197:201–209.
19. 9 CFR 113.147.