Exposure to rodents and lagomorphs has never been implicated as the cause of infection for a case of rabies in humans in the United States, nor are these animals considered natural reservoirs of the disease. However, the number and reliability of such reports are limited, and there is concern about rabies in rodents and lagomorphs. Reliable reports of human exposure to rabid rodents or lagomorphs outside of the United States are limited. Many suspect rodents and lagomorphs are tested each year for rabies, and a small but increasing number are found to be rabid. Although they represent a low risk for human exposure to rodents and lagomorphs may contribute to the rarity of rabies in humans. The purpose of the study reported here was to assess the epidemiology of rabies in rodents and lagomorphs and analyze spatial trends of rabies in groundhogs.

**Objective**—To assess the epidemiology of rabies in rodents and lagomorphs and provide information that will enable public health officials to make recommendations regarding postexposure prophylaxis for humans after contact with these animals.

**Design**—Cross-sectional epidemiological analysis.

**Sample**—Rodents and lagomorphs submitted to state laboratories for rabies diagnosis from 1995 through 2010.

**Procedures**—Positive samples were identified by use of direct fluorescent antibody testing, typed by sequencing of viral genes, and quantified via titration in mice or cell culture.

**Results**—737 rabid rodents and lagomorphs were reported from 1995 through 2010, which represented a 62.3% increase, compared with the number of rabid rodents and lagomorphs reported from 1979 through 1994. The most commonly reported rodents or lagomorphs were groundhogs (Marmota monax). All animals submitted to the CDC for additional viral characterization were positive for the raccoon rabies virus variant. Infectious virus or viral RNA was detected in salivary glands or oral cavity tissues in 11 of 13 rabid rodents.

**Conclusions and Clinical Relevance**—The increase in reported rabid rodents, compared with results of previous studies, appeared to be associated with spillover infections from the raccoon rabies epizootic during the first half of the study period. Analysis supported the assumption that raccoons remained rare in rodents and lagomorphs. However, transmission of rabies virus via exposure to a rabid rodent or lagomorph may be possible. Given the rarity of rabies in these species, diagnostic testing and consideration of postexposure prophylaxis for humans with potential exposures should be considered on a case-by-case basis. (J Am Vet Med Assoc 2014;245:333–337)
Materials and Methods


To characterize the spatial distribution of rabid groundhogs, commercially available software was used to create a map of reported rabid groundhogs by county from 2006 to 2010. The map represented the geographic range of groundhogs in the United States and the locations where most rabid rodents were reported.

Additional laboratory testing for rabies was performed on a convenience sample of rodents submitted to the CDC by state public health laboratories. These rodents were primarily groundhogs and beavers (Castor canadensis). The primary tissues that contribute to rabies virus transmission (ie, salivary glands, tongue, tonsils, and buccal mucosa) were examined to evaluate the potential for these species to transmit rabies virus via a bite. An RT-nPCR assay was performed on the nucleoprotein gene of rabies virus, as described elsewhere. All samples with positive results for the RT-nPCR assay were tested by use of intracranial inoculation of mice and propagated in mouse neuroblastoma cells for determination of infectivity and viral titers.

Results

A total of 737 rabid rodents and lagomorphs were reported from 1995 through 2010 (Table 1). This repre...
presented an increase of 62.3% from the 454 reports of rabid rodents and lagomorphs for the previous 16-year period (1979 through 1994). Rabid rodents and lagomorphs were reported in 27 states and the District of Columbia; the majority (700/737 [95.0%]) were reported in the Northeastern and mid-Atlantic region (Figure 1).

The 737 rabid rodents and lagomorphs reported during 1995 through 2010 represented only 1.0% of the total number of animals submitted for rabies testing. For 48 rabid rodents, denominator data of the rodents and lagomorphs submitted for rabies testing in a given year were not reported. The rodents and lagomorphs most commonly tested were squirrels (Sciurus spp; 21,977/70,682 [31.1%]) and groundhogs (3,188/70,682 [4.5%]). However, only 9 of 21,977 (0.04%) squirrels tested were rabid.

Species comprising the majority of the 737 rabid rodents and lagomorphs were groundhogs (663 [90.0%]), beavers (31 [4.2%]), European rabbits (Oryctolagus cuniculus; 25 [3.4%]), and squirrels (9 [1.2%]). All other species (chinchilla [Chinchilla laniger], chipmunk [Tamias striatus], guinea pig [Cavia porcellus], muskrat [Ondatra zibethicus], and brown rat [Rattus norvegicus]) with at least 1 reported rabies case during the 16-year study period each accounted for < 1% of the total number of cases reported (Table 1).

Groundhogs were the most frequently reported rabid rodent or lagomorph (663/737 [90.0%]). This represented an increase of 75% for the number of reported rabid groundhogs, compared with the number reported for the period from 1979 through 1994. The annual rate for reported rabid groundhogs remained relatively constant from 1995 through 2002, with a mean of approximately 50 cases/y. In 2003, the number of reported rabid groundhogs decreased to 31 cases/y. The rate in subsequent years remained consistent with that for 2003, with a mean of 34 cases/y from 2004 through 2010.

Spatial distribution for reported cases of rabies involving groundhogs, by county, in the United States from 2006 through 2010 was analyzed (Figure 2). Total number of reported rabid groundhogs was analyzed to determine the seasonal distribution for the period from 2006 through 2010 (Figure 3). June and July were the months with the largest number of reported rabid groundhogs. The reported number of groundhogs submitted for rabies testing differed for the first and last 8-year periods of the study. The approximate mean for 1995 through 2002 was 903 submissions/y, and the approximate mean for 2003 through 2010 was 898 submissions/y; these values excluded data for which denominator information was not available. Reported rabid groundhogs were clustered primarily in counties where the raccoon rabies virus variant was enzootic.

Additional diagnostic testing for rabies was performed on 13 rabid groundhogs and beavers submitted to the CDC. Brain, salivary glands, tongue, tonsils, and buccal mucosa (ie, tissues primarily contributing to rabies virus transmission) were examined. Tests were not performed on all samples if the tissues had a previous negative test result or if tissue samples for each animal were not available. All animals were infected with the raccoon rabies virus variant. All RT-nPCR amplicons from the 13 brain samples yielded positive results; similarly, all 13...
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the early 2000s.9 The decrease in rabid groundhogs re-
tive results. Testing of buccal mucosa samples (n =
are involved in unprovoked bites may help reduce the
mals with a higher likelihood of being rabid. 
and morphs; however, other species, including
ferable infectious rabies virus (mean titer, 3.8 log10
MICLD50). All 13 tongue samples were tested by use
of RT-nPCR assay, but viral RNA was detected in only
5 tongue samples. Of these 5 samples, 1 had a rabies
virus titer of 0.7 log10 MICLD50. Nine tonsil samples
were tested by use of the RT-nPCR, and 5 had posi-
tive results. Results of testing of oral and salivary gland tissues from
groundhogs and beavers suggested a potential risk for
transmission of rabies virus from these animals.

Results of the analysis of national rabies surveil-
ance data supported previous assumptions that there
are no known rabies reservoirs in rodents or lago-
morphs in the United States. However, national ani-
mal rabies surveillance programs are primarily passive and
rely on potential exposures of humans or domestic-
tic animals and the capture and submission of suspect
animals for diagnostic testing. Analysis of rabid rodents
and exposures of humans could be enhanced by more
complete laboratory data (ie, records of all animals sub-
mitted for testing and antigenic or molecular typing of
rabies viruses) and routine data collection for human
encounters involving potential rabies virus exposures
from rodents, especially when PEP is administered.

It is important to consider the rabies risk for pet rab-
bids and rodents. Groundhogs account for most rabid ro-
dents and lagomorphs; however, other species, including
pet rabbits and rodents, have become infected with the
rabies virus after contact with an infected animal. Infected
pet animals may represent a high public health risk be-
cause of the amount of contact with humans. These pets
are at an increased risk of exposure when they are allowed
to roam outside or are housed in cages that are accessible
to wildlife. To prevent infection of pet rodents and lago-
morphs and therefore potential transmission to humans,
plants that are housed outside should be protected from con-
tact with wildlife. If contact with a rabid or suspect wild
animal occurs, the most conservative approach would be
to euthanize the pet immediately; alternatively, the pet
could be placed under strict quarantine for 6 months.
However, additional research is needed on the time frame
for onset of clinical signs and shedding of rabies in these
species, so euthanasia (with subsequent testing) or quar-
tine should be considered on an individual basis with
guidance from public health authorities.11

Testing of rodents or lagomorphs for rabies should be
considered on a case-by-case basis. As indicated by the pres-
cent study, rabies is seldom reported in these animals and ex-
posure rarely necessitates administration of PEP to humans.
However, potential transmission of rabies virus via a bite
or norbite exposure from rabid rodents or lagomorphs is
possible. Unprovoked bites by rodents or lagomorphs with
unusual behavior or that appear sick should be reported to
enable local health authorities to evaluate the circumstances
and assess the need for administration of PEP to humans.
When possible, these animals should be submitted for di-
gnostic testing to rule out the potential for exposure of hu-
mans and other animals to rabies virus.

Discussion

In the present study, groundhogs accounted for
most of the cases of rabies in rodents and lagomorphs
and were primarily responsible for most of the increase
in reports of rabid rodents, compared with results of studies3,10 for a previous 16-year period (1979 through
1994). The increase in reported rabid groundhogs may
have been attributable to the ongoing expansion of
the raccoon rabies epizootic in the Northeast during
the early 2000s.9 The decrease in rabid groundhogs re-
ported in 2003 further coincided with the time when
the raccoon rabies epizootic reached its maximum geo-
graphic expansion in the United States.

Because of their size, groundhogs may be more
likely to survive the bite of a larger rabid animal (eg, raccoon or skunk) and therefore would have the poten-
tial to incubate the virus and become rabid.11 The size
and aggressive behavior of rabid groundhogs may also
make them more visible and likely to be captured and
submitted for diagnostic testing following a potential
exposure of humans or domestic animals.

Reports of rabies in other rodents or lagomorphs
continue to be uncommon. Squirrels were the ro-
dent most commonly submitted for rabies testing
(21,977/70,682 [31.1%]). However, only 9 (0.04%)
squirrels were found to be rabid during the study peri-
od. Increased risk assessments with a focus on submis-
sion of rodents with unusual behavior (eg, paralysis,
ataxia, atypical aggression, or abnormal vocalization),
involving in unprovoked bites may help reduce the
number of submissions and increase the focus on ani-
imals with a higher likelihood of being rabid.

Given the high rate of spillover infection, ground-
hogs would represent the most likely rodent species
within which there would be potential adaptation and
independent circulation of a unique rabies virus vari-
ant. However, on the basis of results of genetic typing,
spillover infection remained the most likely explana-
tion for the number of rabid groundhogs, possibly be-
cause of interactions between raccoons and groundhogs
at ground dens. All groundhogs tested were infected
with the raccoon rabies virus variant. Furthermore, ra-
bid groundhogs were clustered in counties where rac-
coon rabies is enzootic. On the basis of this evidence,
it is unlikely that there is independent transmission
of rabies virus from groundhog to groundhog. However,
more submissions and genetic analyses of rabies virus
isolates from rodents are needed to monitor potential
adaptation of viruses in these species.

Excretion of rabies virus in saliva may result in
transmission of infection via a bite. All mammals ap-
pear to be susceptible to rabies virus, but their ability
to act as reservoirs are variable among and within spe-
cies.12 The shedding period for rabies virus, compared
with the time of onset of clinical signs, is unknown in
rodents and lagomorphs. However, analysis of a conve-
nience sample of oral and salivary gland tissues from
groundhogs and beavers suggested a potential risk for
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a. ArcGIS Desktop, release 10, Environmental Systems Research
Institute, Redlands, Calif.
**References**


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From this month’s *AJVR*

**Comparison of air sac volume, lung volume, and lung densities determined by use of computed tomography in conscious and anesthetized Humboldt penguins (*Spheniscus humboldti*) positioned in ventral, dorsal, and right lateral recumbency**

Benjamin N. Nevitt et al

**Objective**—To determine the effects of recumbency on air sac volume, lung volume, and lung densities in CT images of healthy, conscious and anesthetized spontaneously breathing Humboldt penguins (*Spheniscus humboldti*).

**Animals**—25 adult (13 male and 12 female) Humboldt penguins.

**Procedures**—CT images of conscious penguins in ventral recumbency and anesthetized penguins in dorsal, ventral, and right lateral recumbency were obtained. Air sac volume, lung volume, and lung densities in CT images were calculated. A paired samples *t* test was used to determine whether right and left lung densities differed among recumbencies. Repeated-measures ANOVA (controlled for sex and order of recumbencies during CT) was used to determine whether air sac or lung volumes differed among recumbencies.

**Results**—Recumbency had a significant effect on air sac volume but not lung volume. Air sac volume was largest in conscious penguins in ventral recumbency (mean ± SD, 347.2 ± 103.1 cm³) and lowest in anesthetized penguins in dorsal recumbency (median, 202.0 cm³; 10th to 90th percentile, 129.2 to 280.3 cm³). Lung densities were highest in anesthetized penguins in dorsal recumbency (right lung median, 0.522 g/cm³; left lung median, 0.511 g/cm³) and lowest in anesthetized penguins in ventral recumbency (right lung median, 0.488 g/cm³; left lung median, 0.482 g/cm³).

**Conclusions and Clinical Relevance**—Results indicated that anesthetized Humboldt penguins had the lowest air sac volume and highest lung densities in dorsal recumbency. Therefore, this recumbency may not be recommended. Minimal changes in lung volume were detected among recumbencies or between conscious and anesthetized penguins. (*Am J Vet Res* 2014;75:739–745)

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