The Walter Reed Army Institute of Research
Tropical Medicine Course

Rabies

13 SEP 2010

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The opinions expressed in this talk are mine and should not be construed as official views of the US Navy nor the Department of Defense.
Rabies and the “Rabies-like” viruses may occasionally cause a rabies like illness in humans

Genera: *Lyssavirus*

Lyssavirus species (formerly serotypes or genotypes)

1 **Rabies virus (RABV)** several variants, including vampire bat
2 Lagos bat (LBV) 1956
3 Mokola (MOKV) 1968
4 Duvenhage (DUVV) 1970
5 European bat lyssavirus type 1 (EBLV-1) 1992
6 European bat lyssavirus type 2 (EBLV-2) 1995
7 Australian bat lyssaviruses (ABLV) 1996

Novel Lyssaviruses (in Russian and Central Asia)

8 Aravan 1991
9 Khujand Central 2001
10 Irkut 2002
11 West Caucasian bat virus (WCBV) 2002
Rhabdoviridae
Morphologic Characteristics

- bullet shaped
- single stranded RNA viruses
- 75 nm diameter and 150-180 nm long
Rhabdoviridae

Growth Characteristics

- Special affinity for brain and mucous secreting glandular tissues
  - rabies: highly selective for neuronal groups that cause the host to transmit to another host

- Can be propagated in CNS of inoculated mammals, cell culture systems and embryonated chicken and duck eggs

- Inactivated by sunlight, UV, air, heat, mercury, formalin and acid/base extremes

- Resistant to putrefaction in neural tissue
  - glycerol preserves infectivity in tissues
Rabies
Epidemiology

Schneider, M.C. Epidemiologic Situation of Human Rabies in Latin America in 2004
WHO Epidemiological Bulletin, Vol. 30 No. 1, March 2009
WHO-RABNET http://apps.who.int/globalatlas/default.asp

- Worldwide incidence ~50-60,000 human cases reported to WHO per year
- 95% of human cases are in Africa and Asia and ~½ in children <15
  - Indian subcontinent with >30,000 cases/year
  - 1596 autopsies in Columbia in the 80s: 1.7% with undx rabies
  - Since 1983 annual cases have decreased >90% in dogs (16000 to 1100) and humans (355 to 35) in the Americas
    - cases from bats have increased

- 10 million human post-exposure treatments annually
  - 5 million in China
  - 1 million in India
  - 40 thousand in North America
  - ? In South America
Rabies in Animals

- Tropics: >95% of rabies cases in domestic animals
  - dogs>>cats>cattle

- Temperate: >80% of rabies cases are in wildlife
  - raccoons>skunks>bats>foxes
  - cats>dogs but much lower than wildlife
  - 2008, 49 states, DC and Puerto Rico tested >121,000 animals
    - 6,841 cases of rabies in animals (Hawaii is the only state that is rabies free).
    - decrease by 3.1% from those reported in 2007
In 1968 Pedro Acha published the economic impact of paralytic bovine rabies in the Americas in that year. >500,000 deaths with an economic loss ~ US$50 million (40 years ago!)

- surveys 20 years later 7 nations with same level, 7 with decrease, 4 with an increase in bovine cases

Disproportionate increase in vampire bat populations caused by an ecologic imbalance due to human activities:

- Dramatic increase of livestock population, associated with the cattle industry, within vampire bat natural habitats
- Abundant and almost unlimited source of food for vampire bats
- 234 cases of human rabies associated with wildlife have occurred in Latin America 1990-2003 according to PAHO
- 175 caused by vampire bats

Acha 1968. Epidemiología de la rabia bovina paralítica transmitida por los quirópteros Bull WHO 64:411-430
Cost of Rabies Prevention

US Stats

- $300 million to $1 billion annually in the US:
  - vaccination of animals (mostly dogs)
  - animal control programs
  - postexposure prophylaxis (PEP)
  - maintenance of rabies labs

- ~40,000 PEPs/year in the US
  - one course of HRIG and vaccine ~$1000
  - cost per life saved is $10,000-100,000,000 depending on region
  - one rabid kitten in New Hampshire associated with 650 PEPs at a cost of >1.5 million

Rabies Epizooses

RABIES RESERVOIRS

URBAN RABIES
- Dogs
- Raccoons
- Spotted skunk
- Cats
- Ferrets
- Raccoon dogs

WILD RABIES
- Coyotes
- Gray foxes
- Striped skunk
- Mongooses
- Vampire bat
- Big brown bat
- Silver hair bat
- Red bat
- Free tail bat

ENZOOTIC RABIES

ASSOCIATED WITH TERRESTRIAL CARNIVORES
- Beavers and woodchucks
- Pigs
- Humans and horses
- Cows
- Goats and sheep

ASSOCIATED WITH BATS

VECTORS

SUSCEPTIBLE SPECIES (Dead End Hosts)
Species Compartmentalization

- Eight separate epizootics in the US
  - Maryland:
    - 672 of 709 rabies cases in raccoons
    - 37/709 cases spread among 5 other species
  - Texas:
    - 404 of 412 rabies cases in skunks
    - only 3 in raccoons
- Monoclonal Ab analysis: 8 variant rabies strains (bat not included)
- Some degree of specificity of strains

1 Raccoon strain
4 Skunk strains
2 Fox strains
1 Mongoose strain
Numerous bat strains
Strain Specificity

- Sikes study of a fox rabies strain:
  - 100x larger inoculum to infect a skunk than a fox
    - i.e. foxes are more susceptible to the fox strains
  - foxes infected with a large inoculum when bitten more rapidly progress to rabies and die prior to salivary gland infection
  - low levels of viral shedding in small to moderate inoculum size
    - shedding is sufficient to infect other foxes
    - shedding is insufficient to infect skunks

Vampire bats

Three species but *Desmodus rotundus* is currently associated with rabies.

- Tropical and subtropical Americas and Caribbean.
- No higher than 2000m over sea level.
- Temperate temperatures never lower than 15°C and at least 45% of humidity.

Gross natural distribution of vampire bats.
Vampire Bat Associated Human Rabies
Mordido de mucierlago vampiro
Rabies Non-Threat Animals
Human Rabies in North America

- Never common, >100 cases/year in 1900
- Average of 55 human cases/year 1900-1950
- 37 US cases in the 1995-2006, most were believed acquired in the US:
  - 28/37 cases: domestic bat strain, no vampire bat strains
    - apparent
    - inapparent
  - 8/37 dog/coyote strain from outside the US
  - 1/37 raccoon strain

CDC’s National Center for Zoonotic, Vector-Borne, and Enteric Diseases
http://www.cdc.gov/rabies/epidemiology
Epidemiology

- Peak number of rabid animals in spring
- Human exposures most frequent during summer
- Exposures are highest in children, especially boys
- No racial, genetic, socioeconomic differences in susceptibility
Transmission

- Bites are most common route
- Small abrasions or cuts especially from infected animals teeth
  - abrasions/wounds licked by an infected animal
- Mucous membrane contact with virus
  - including nasal mucosa (bat strains)
- Corneal transplant from infected donors
- Laboratory exposure to aerosols or needle sticks
- Transplacental, milkborne and ingestion cases have all been documented in animals
Transmission

- Virus appears in saliva 1-3 days before clinical evidence of disease in most species and strains

- Some African dog strains appear to be attenuated and adapted with dogs living for years with clinically silent rabies
  - Ethiopian dogs alive >2 y with active virus

- Dog urine and blood has NOT been demonstrated to have virus

- Bats often have prolonged periods of infectivity
  - Develop rabies and die
  - Develop rabies but survive non-infectious
  - Asx infection but continued viral shedding

Siprija et al  *Does Contact with Urine and Blood from a Rabid Dog Represent a Rabies Risk?*  CID 2003; 37:1399–1400
Pathogenesis

Incubation Period

- In humans typically 1-3 months
  - 84% within 90 days but 1% > 1 year
  - May be as short as 4 days
  - Case documented 19.5 years post exposure
- Shorter period:
  - in bites to the face/neck
  - younger patients
  - multiple bites with high viral dose

- During incubation
  - clinically silent
  - no detectable antibody

Fishbein *NEJM* 329(22):1632-1638, 1993
Pathogenesis
Incubation Period

- After bite occurs:
  - virus localized in wound area
  - probable replication in local myocytes
  - latent period from days to years followed by spread along neurons to CNS
    - possibly shortened with stress, steroids, etc

- After CNS infection, rapid spread
  - salivary glands infected shortly after CNS
  - antibodies in serum and CSF 1-2 days prior to clinical rabies
Pathogenesis

Prodromal Period

• Generally lasts 2-10 days

• Numerous non-specific sx before gradual progression to acute neurologic period:
  • pain and paresthesia at bite site in ~1/2
  • intense pruritus at bite site in >40%
  • malaise, fatigue, HA, anorexia and fever
  • apprehension, anxiety, insomnia, depression
Marked excoriation that occurred in the prodromal period before development of furious rabies
Pathogenesis

Acute Neurologic Period

• Onset with development of objective signs of CNS involvement
  • typical duration 2-7 days

• Two clinical states:
  • Furious (classical or agitated rabies) ~80%
  • Paralytic or “dumb” rabies ~20%
Furious Rabies

Characteristics

- hydrophobia is pathognomonic
  - violent, spastic contractions of the diaphragm and accessory muscles triggered by attempts to swallow

- fever 100-104°

- muscle spasms, seizures, hallucinations

- alternate between sx and long asx periods during which patient is alert and appropriate

- death due to cardiac or pulmonary arrest

- progressive neuro deterioration over 2-7 days to coma
Paralytic Rabies

Characteristics

- 20% of cases:
  - especially with bat strains
  - post exposure to nerve tissue vaccine
  - post corneal transplant from patients who died of undiagnosed paralytic rabies

- diagnostic dilemma

- “la rage tranquille” with no agitated stage or hydrophobia
Coma Stage

- Usually occurs 4-10 days after onset of sx and gradually develops from acute neurologic stage.
- Hydrophobia disappears and swallowing becomes possible.
- Patient may appear to be improving.
- Anxiety and excitement replaced by apathy, stupor, and coma.
Diagnosis of Rabies

- No technique for dx prior to CNS infection

- Virus does not stimulate Ab production while immunologically protected at bite site

- Ab production begins after CNS infection:
  - rabies serum neutralizing Ab not detected until 6th day of illness
  - CSF Ab neg as long as 7 days after detection of serum Ab
  - if no post exposure prophylaxis, 50% Ab by day 8 and 100% by day 15 of clinical dz
  - steroids or interferon may delay Ab development
Rabies

Laboratory Diagnosis

- Direct fluorescent antibody (dFA) staining of full thickness punch bx from the neck above the hairline is most rapid, reliable and readily available.

- Rapid Fluorescent Focus Inhibition Test (RFFIT) – WHO gold standard
  - in vitro cell cx that measures neutralizing Ab
  - highly sensitive and specific
  - rare reports of an unimmunized human with Ab
  - follow titers, only clinical rabies >50 IU

- PCR is rapidly becoming available in many state labs for dx. Can be performed on saliva, CSF or biopsy material.
Diagnostic Specimens

Four sample sites required by CDC to R/O Rabies

1. **Saliva:** Collect with a dropper and place in small sterile container. Tracheal aspirates & sputa not suitable
   - RT/PCR
   - isolation of infectious virus in cell culture.

2. **Neck biopsy:** section of skin 5-6 mm in diameter from posterior region of the neck at the hairline.
   - minimum of 10 hair follicles
   - sufficient depth to include cutaneous nerves at base of the follicle
   - specimen on a piece of sterile gauze moistened with sterile water
   - RT/PCR and IF staining for viral Ag in frozen sections of the biopsy.

3 & 4. **Serum and CSF:** ≥0.5 ml of serum and CSF; NOT whole blood
   - If no vaccine or RIG given, presence of serum rabies Ab makes dx and CSF tests unnecessary
   - Ab to rabies virus in CSF, regardless of immunization hx, suggests rabies infection.
   - tests for Ab include indirect IF and virus neutralization.

CDC Rabies Lab Request Form: www.cdc.gov/rabies/docs/standard_dfa_protocol_rabies.pdf
Diagnostic Specimens
Do not use preservatives!

- **Brain biopsy.** The rarity of rabies and the lack of an effective treatment make the collection of a brain biopsy unwarranted;
  - samples negative for HSV encephalitis should be tested for rabies
  - biopsy in a sterile sealed container
  - RT/PCR and IF staining for viral Ag in touch impressions
  - Suspension of brain tissue inoculated intracerebrally into mice or cell cx confirms dx

- **Postmortem diagnosis** by IF staining of viral Ag in touch impressions of brain tissue.
  - Portions of medulla, cerebellum, and hippocampus- freeze and ship on dry ice
  - Preservation of tissues by fixation in formalin is not recommended for rabies dx

- patients dying after a prolonged course may not have measurable virus or Ag due to intense Ab response

Pathology

- Perivascular cuff of lymphs and PMNs in gray matter with varying degrees of neuronal degeneration

- 70-80% with pathognomonic Negri bodies
  - cytoplasmic inclusions, round or oblong, 2-10 μm
  - most common in the hippocampus and cerebellar Purkinje cells
  - one or more may be seen in a single cell
  - consist of viral nucleocapsid proteins
  - can be seen with light microscopy but DFA improves ID

Fig. 35 Rabies. Histological section of brain showing a Negri body. (H&E stain.) These eosinophilic cytoplasmic inclusions, which often contain basophilic spots, are found in 70–80% of cases, most commonly in the hippocampus. They may be demonstrated by conventional histological techniques or by immunofluorescent staining.
Rabies Mortality

- Untreated patients usually die of respiratory arrest
- In ICUs duration from onset to death averages 25 days
  - patient may survive in a coma for months
  - respiratory complications are the most common cause of death
  - usual complications of ICU/ventilated patients
Rabies Post Exposure Care

- Wound Care is most important!!
  - generous irrigation with saline followed by debridement and vigorous cleaning with soap solution to depth of wound
  - reduces risk of rabies by 90%
  - povidine solution increases efficacy
  - vaccine failures associated with poor wound care
Rabies Post Exposure Care

Immunizations

- Pasteur’s dried extract of serially infected mice and rabbit spinal cords in 1885
  - early success no subsequent human trials performed prior to widespread use

- Semple phenol inactivated vaccine - 1919

- Live attenuated (Fleury strain) grown in eggs in 1949

- Suckling mouse brain with ↓ neuro complications (1 in 8000)

Rabies vaccination post vampire bat bite
Madre de Dios, Peru 2007
Rabies Post Exposure Care

Immunizations

- Duck embryo vaccine developed in 1958
  - safe but low potency requiring 23 injections
  - 10-20% develop antibodies
  - 1/3 develop skin reactions
  - significant number of vaccine failures
**Vaccines**

- Many inferior vaccines available outside the US.
  - Often less immunogenic, poorly purified
  - Increased association with neurologic and other side effects
  - Failure associated with protocol breach (1 in 80,000 in developed nations)

- Two β-propiolactone **inactivated** vaccines, each ~ 100% efficacious:
  - **HDCV**- Human Diploid Cell Vaccine, from infected human cell line
  - **PCEC** - Purified Chick Embryo Cell, grown in chicken fibroblast cultures
    - if hypersensitivity to other vaccines ie frequent boosters
    - chicken allergy does not preclude use

- **HRIG** - Human Rabies Immune Globulin - from vaccinated veterinary students, provides 3-6 weeks of passive immunity

Vaccine

- **Pre-exposure:**
  - 1.0 cc IM or 0.1 cc ID in the deltoid
  - 3 Doses: days 0, 7 and 21 or 28, complete > 30 days before exposure risk
  - frequent risk give booster q 2 years
  - continuous, high risk check Ab q 6 m.

- **Postexposure:**
  - CLEAN the wound and give tetanus booster
  - if *pre-immunized*: 2 doses 1.0 cc deltoid IM on days 0 and 3
  - if *unimmunized*: 4 doses (ACIP changed 24 JUN 09)
    - 20 IU/kg HRIG, half around the site and half in the buttock
    - 1.0 cc vaccine deltoid IM on days 0,3,7 and 14 (day 21-28 dropped)

- **Side Effects:**
  - Injection site swelling and pain, itching, HA, myalgias and fever may occur.
  - Immune complex reactions occur 2-21 days late in 6% HDCV and 1% PCEC booster patients

Rupprecht et al. Use of a Reduced (4-Dose) Vaccine Schedule for Postexposure Prophylaxis to Prevent Human Rabies Recommendations of the Advisory Committee on Immunization Practices. MMWR 2010:55 RR2
Travelers and Rabies

• Vaccine not indicated for travelers unless staying in rural areas for >4 weeks or with no access to medical attention
  • 6.8% of street dogs in Thailand are rabid
  • a dog lick was experienced by 8.9% and a dog bite by 1.3% of travelers visiting for avg of 17 days

• pre-exposure vaccine for military unit not necessary if ready access to vaccine in the event of exposure

Sailors befriend a Laotian dog
Bats in the Attic – Bats in the Bedroom!
Bats in the Bedroom

What do you do?

  - 22 (39%) cases a bite was reported
  - 9 (16%) cases apparent contact but no bite detected
  - 6 (11%) cases bats in the home but no known contact
    - 2 (4%) in their bedroom
  - 19 (34%) no hx any bat exposure
- Median incubation period 7 weeks
- If bat is available, send it for rabies testing
- Consider PEP if bat is unavailable and persons were unaware that a bite or direct contact occurred
  - but only 2 cases in 20 years
- Number needed to treat and cost benefit analysis ???

De Serres et al. Bat Rabies in the US and Canada CID 2008:46
Recovery from Rabies

- Most uniformly fatal infection in humans
- only five well documented cases of survival in proven rabies
  - three received post exposure prophylaxis prior to development of clinical rabies
  - three made full recovery after intensive tx
  - one survived with significant neurologic sequelae
  - one treated with “coma therapy” and survived with minimal neurologic sequelae


A rabies survivor

- Induced coma with ketamine, midazolam, phenobarb and cooling
- Antiviral therapy with amantadine and ribavirin
- Multiple subsequent trials with coma induction have failed
- Patient now with no apparent sequelae

Rabies Treatment

- No effective therapy for clinical rabies
- High doses of immune globulin after disease onset are ineffective
- Vaccine post onset of dz may induce increased CNS pathology
- Steroids blunt immune response and hasten time to death in animal models
- Interferon trials in animals were promising but had no benefit in humans
- Ribavirin ineffective in animal trials
Therapy

- Supportive therapy
  - Patient isolated to minimize exposure of staff to virus in secretions and urine
  - virus has NOT been isolated from blood
  - masks, gloves and gowns recommended for staff and visitors
  - pre or post exposure prophylaxis is not required for staff or family unless clearly contaminated

- Patient should be made comfortable:
  - barbiturates, phenothiazines and benzodiazepines used symptomatically
  - Use of “coma Therapy” as in the Wisconsin survivor is worth trying
  - morphine is CONTRAINdicATED, even small doses markedly increase agitation
History of rabies associated with vampire bats

Carini 1911, wrote the first scientific report on rabies in cattle (his study started in 1908)
He observed protein inclusions in infected brains of cows and reproduced the disease in rabbits

Haupt 1916, reproduced the disease in rabbits and Guinea pigs by inoculation of medulla of a rabid Artibeus lituratus

Pawan 1931, isolated RABV from different species of bats including vampire bats (Desmodus rotundus)

• 1990-2003, according to PAHO, 234 cases of human rabies associated with wildlife have occurred in Latin America
  • 175 caused by vampire bats
Three species but *Desmodus rotundus* is currently associated with rabies.

- Tropical and subtropical Americas and Caribbean.
- No higher than 2000m over sea level.
- Temperate temperatures never lower than 15°C and at least 45% humidity.
Bat Behavior and Rabies Transmission

- Bats of numerous species will roost together with vampire bats in natural or man made shelters
  
  Vampire bat colonies (of 10-300) will roost with other bats but each species has its own territory

- Bats groom with their feet and tongues and *Desmodus* sp are very fastidious
  
  - Over 6 hours observation 34 minutes cleaning and 260 mouth-body contacts
  - Frequent cleaning (licking) of bats surrounding them

Bat strains of rabies have been shown to be transmitted via aerosols so bats in the same space may be infected without any actual contact
Desmodus lands on the ground and crawls onto its prey.
Vampire bats require a blood meal at least every few days and will often revisit the same animal and same wound site repeatedly.

If unsuccessful in obtaining a meal other bats may regurgitate blood in a mouth to mouth transfer.
Casos de Rabia Humana Urbana y Silvestre Perú 1970 – 2007

Fuente: OGE-DGSP-MINSA.
Urban and Sylvatic Rabies in Southeastern Peru

- **Urban rabies:**
  - Area of enzootic canine rabies, likely due to close proximity to Bolivia
    - 1995-2006: 1,522 canine cases & 12 human cases
  - 2006: 8 canine, 1 bovine and 1 human rabies case
  - 2007: 8 canine rabies cases

- **Sylvatic Rabies:**
  - Historically, only limited evidence of rabies transmission from bats to humans in Puno unlike northern Peru and Ecuador
Sylvatic Rabies in Madre de Dios, Peru

Human rabies:
- 42 cases recorded since 1987
- Last previous case was reported in 2002, in Las Piedras District, Madre de Dios
- Initial outbreak occurred in Huepetuhe District, Madre de Dios in 2006-07

Bovine Rabies:
- SENASA reported 12 cases in 2006
- Clearly many more cattle are dying
  - MoH does not have the resources for a widespread animal and human rabies vaccine program
  - After some herd deaths, farmers are told their animals died of anthrax
Two and four lane highway thru the Peruvian and Brazilian Rainforest
Human Rabies Outbreak in Peru

- Occasional bat associated cases in areas bordering Colombia and Ecuador for many years
- Southern Peru mainly with canine rabies along Bolivian border

Reports of human rabies cases transmitted by vampire bats, DISA Madre de Dios & Puno, Week 51 – 2006 to Week 10 – 2007
Episodes of bites by vampire bats,
San Gabán, Puno, June 2006 to January 2007

n = 254
Unexpected consequences of environmental change
Logging, Mining, Livestock

Río Huapetuhe 29/01/2007
Ecological change...
...and habitat loss
Mordido de mucierlago vampiro
What caused a dramatic increase in human rabies in southern Peru?

- Disproportionate increase in vampire bat populations caused by an ecologic imbalance:
  - Destruction of bat nesting areas by road teams and gold miners causing movement of bats to new areas
  - Dramatic increase of livestock population to feed road workers and new ranches with easier access via the road to markets
  - Abundant and almost unlimited source of food for vampire bats
Limitations

- Bat bite surveillance remains passive
- Lack of communication between the human and animal public health sectors
  - suspected epizootic of bovine rabies on November 2006 was not reported to the MoH
- Due to lack of economic support, surveillance for sylvatic rabies is not routine
Evaluation Efforts

- Ecological survey (multisectorial)
  - Experienced CDC-NMRC\textsuperscript{D} outbreak team led by Joel Montgomery
  - Bat collection in Vuelta Grande and Lechemayo
  - Ten species (n=185), including *Desmodus rotundus*, were captured near case households and near areas of previous bovine outbreaks
  - Provided training to Peruvian nationals
    - Safe bat collection
    - Augmented laboratory capacity in regional lab
  - No actively infected bats found
  - Hematophagous, fruit and insect eating bats all had equivalent rates of rabies Ab, 10%

Interior de una vivienda, Vuelta Grande, 13/01/07
Investigation summary

• 2 foci of vampire bat to human rabies infections have been identified in Southern Peru:
  1. Vuelta Grande, District of Huepetuhe, Province of Manu, DIRESA Madre De Dios – 6 cases
  2. Multiple villages of Lechemayo – 19 cases
• Risk factors identified:
  • Living in rural areas without protection from exposure to vampire bat bites (i.e., nonexistent or permeable household walls and roofs)
  • No hx of vaccination prior to receiving a vampire bat bite
  • Being a goldminer
  • No use or infrequent use of bednets
Investigation summary

**Proposed hypotheses:**

- Construction of the Inter-Oceanic Road
  - Initiated May 2006
- Deforestation and habitat perturbation associated with road construction and mining activities
- Increase in human & animal populations (cows, goats, horses, etc.)
- Other non-vampire species may be involved in transmission to humans
How to diminish the threat

- Campaign to provide post bite rabies prophylaxis to population in highest risk area
  - Use of HDCV or PCEC vaccine and not older, less potent vaccines
- Increased use of rabies vaccine in livestock
- Decrease vampire bat numbers in areas with rabies cases
  - Capture of vampire bats and coat with vaseline impregnated with warfarin
  - Administer low dose warfarin to cattle that have been fed on by bats
  - Surround wounds on cattle with warfarin

Brazil has already increased vaccine use but Bolivia has not addressed the problem
Rabies Information

- CDC Website:
  - http://www.cdc.gov/ncidod/dvrd/rabies

- CDC Rabies Lab:
  - (404) 639-1050

- Maryland Department of Health and Mental Hygiene, Center for Veterinary Public Health
  - (877) 463-3464

- Virginia Dept of Health, Office of Epidemiology
  - http://www.vdh.state.va.us/epi/rabies.htm
  - (804) 786-6261
Thanks for your attention

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