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Rodents, Human Remains, and North American Hantaviruses: Risk Factors and Prevention Measures for Forensic Science Personnel—a Review

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ABSTRACT: In 1993, a previously unrecognized hantavirus was identified as the cause for a severe form of respiratory distress later termed Hantavirus Pulmonary Syndrome (HPS). In the past two years, several distinct hantaviruses, of which many are pathogenic, have been found in rodent populations in the US. Rodents shed the virus in their saliva, urine, and feces. Humans usually become infected after inhaling either aerosolized droplets of urine or particulates contaminated with rodent excreta. Rodents, including those identified as hantavirus reservoirs, will often infest and disturb human remains. Forensic science personnel should recognize the potential HPS risks associated with rodent contaminated remains and consider using High Efficiency Particulate Air-filter respirators, disinfectants, and insecticides to minimize risks.

KEYWORDS: forensic science, risk factors, biohazard hantaviruses, rodents, Sin Nombre virus, Hantavirus Pulmonary Syndrome

Postmortem alterations of human remains by vertebrates is frequently observed in both forensic and archaeological specimens (1–3). Rodent gnawing of bone and soft tissue is one of the most common forms of corpal modification (4,5), and it is not unusual to find rodents nesting in a skeleton or corpse (2,5). As a consequence, this type of postmortem disturbance is often regarded as innocuous and an inherent problem associated with corpal deterioration. However, recent epidemiologic research suggests exposures to rodents and their nests and excreta may place forensic specialists at risk to the newly defined respiratory disease, Hantavirus Pulmonary Syndrome (HPS). In 1993, the Centers for Disease Control and Prevention (CDC) identified a previously unrecognized hantavirus in North American rodents as the cause of HPS (6–8). The newly identified hantavirus, formerly named the Muerto Canyon virus, is now referred to as the Sin Nombre virus (SNV) (9).

Provided below is information on HPS, potential risk factors for forensic specialists, and suggested risk reduction guidelines based on CDC research and recommendations (9–17) and other proposed protocols (18,19). Although the guidelines provided herein should be implemented whenever possible, it may be necessary to modify them to meet specific needs of a case and the kinds of evidence to be collected.

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Hantavirus Pulmonary Syndrome

HPS was first identified when an outbreak occurred in the Four-Corners area of the American Southwest (Arizona, Colorado, New Mexico, and Utah) in late spring of 1993. To date, 124 cases in 24 states have been reported to the CDC (Table 1). There have been 61 deaths because of the disease, resulting in a mortality rate of 50%. The age range of cases is 11 to 69 years, and both sexes and all ethnic groups appear to be equally at risk.

Rodents shed hantaviruses in their saliva, urine, and feces, and patients probably become infected after inhalation of aerosolized rodent urine or fecal particulates (10,12,13). Infection through rodent bites or ingestion has been documented with some hantaviruses (20). A recent case-control study of HPS patients indicates that peridomestic cleaning, agricultural activities, and an abundance of rodents in buildings increases the risk of hantavirus exposures (17).

TABLE 1—*Reported cases of Hantavirus Pulmonary Syndrome, United States.**

State	Deaths/Cases
Arizona	6/20
California	7/13
Colorado	7/8
Florida	0/1
Idaho	4/7
Indiana	1/1
Kansas	3/5
Louisiana	1/1
Minnesota	0/1
Montana	2/3
New Mexico	14/27
New York	1/1
Nevada	2/7
North Carolina	0/1
North Dakota	2/3
Oregon	1/2
Rhode Island	1/1
South Dakota	1/5
Texas	2/4
Utah	3/8
Virginia	0/1
Washington	5/6
West Virginia	0/1
Wyoming	1/1
Totals	64/128

*CDC statistics as of 4 Feb. 1996.

The incubation period for HPS is 1 to 6 weeks, with a median of 12 to 16 days (12,13,21). Onset of illness (prodrome) is often abrupt and characterized by fever (greater than 100.5°F), chills, headache, muscle aches, malaise, nausea, vomiting and diarrhea, and progressing shortness of breath (sometimes with a dry cough) (13,21). Symptoms persist for 2 to 15 days (median is 4 days) before severe respiratory distress develops. Increased fluid in the lungs (noncardiogenic pulmonary edema) and respiratory distress are major clinical features of HPS (21). Detailed discussions on the pathology of HPS and differential diagnoses have recently been published (9,12,13,16,21,22). Patients with suspected HPS should be immediately evaluated by their physician. Travel, work, and rodent exposure histories may be helpful in determining the likely mechanism of transmission.

Hantaviruses belong to the family Bunyaviridae. This group of RNA viruses was first identified in 1976 as the cause for hemorrhagic fever with renal syndrome in Asia (23). Several antigenically distinct hantaviruses have been identified throughout the world, each with a primary rodent reservoir (20). The Hantaan (Eurasia), Seoul (throughout Asia and port cities worldwide), Belgrade/Dobrova (Europe), and Puumala (Europe) viruses are examples of nephropathic Old World hantaviruses (20,24). In addition to the SNV, at least five other distinct New World hantaviruses have been identified in rodent populations in the US. Three, the Bayou (Louisiana), Black Creek Canal (Florida), and New York-1 (New York) viruses, have been associated with HPS cases (25–30) whereas two others, El Morro Canyon (western US) and Prospect Hill viruses (eastern US), are not presently known to produce disease (24,30). Local strains of the Seoul virus are also present in commensal rat populations in US port cities (31). It is likely that additional hantaviruses will be identified in US rodent populations as research continues. The evidence accumulated thus far strongly suggests that the SNV and other North American hantavirus are not newly evolved (7,13,29).

The deer mouse (*Peromyscus maniculatus*) and other members of the *Peromyscus* genus, including the piñon mouse (*P. truei*), and brush mouse (*P. boylei*), are considered the primary rodent reservoirs for the SNV (24). The deer mouse is a highly adaptable animal that has a wide geographic range and biome distribution throughout North America. Other *Peromyscus* species, on the other hand, tend to be more limited in their distribution. This is also true of the rodent reservoirs of other hantaviruses in the US. The rodent hosts for hantaviruses can be chronically infected and shed the organisms for long periods of time. The known hantavirus-rodent relationships (diads) in the US summarized in Table 2 are based on current research (24,25,27–31).

Other rodent and small mammal species have also been found to have SNV antibodies including house mice (*Mus musculus*), woodrats (*Neotoma sp.*), rock squirrels (*Spermophilus variegatus*), chipmunks (*Eutamias sp.*), and desert cottontails (*Sylvilagus audubonï*) (24,30). Although this probably represents viral "spillover" into nonreservoir species, the ability of these animals to transmit the SNV or other hantaviruses to humans has not been fully determined. However, as several previously unrecognized hantaviruses have been detected since the initial 1993 Four Corners outbreak (25–30), many other rodent species may also be potential hantavirus sources. Consequently, reducing human contact with rodents, rodent excreta and nests, and contaminated particulates is the current regimen recommended for minimizing hantavirus associated risks (10,17,24).

TABLE 2—*Known hantavirus rodent reservoirs in the US.*

Scientific name	Common name	Hantavirus
Peromyscus maniculatus	Deer mouse	Sin Nombre virus
P. truei	Piñon mouse	Sin Nombre virus
P. boylei	Brush mouse	Sin Nombre virus
P. leucopus	White-footed mouse	New York-1 virus
Reithrodontomys megalotis	Harvest mouse	El Morro Canyon virus*
Sigmodon hispidus	Cotton rat	Black Creek Canal virus
Rattus rattus	Roof rat	Seoul virus
Rattus norvegicus	Norway rat	Seoul virus
Microtus pennsylvanicus	Meadow vole	Prospect Hill virus*
Oryzomys palustris	Rice rat	Bayou virus

*Not presently considered to be a pathogenic agent.

Risk Factors and Suggested Risk Reduction Guidelines

Forensic science personnel may be exposed to hantaviruses while recovering (excavation or exhumation) or examining human remains contaminated by rodents. The perceived level of risk derives from documentation of deer mice (32) and Norway rats (2), known hantavirus reservoirs, nesting in or modifying human cadavers. Woodrats (2) have also been observed infesting human remains. The greatest risk of exposure would be associated with the removal of rodent carcasses, nests, and feces as this could potentially lead to the inhalation of airborne contaminated particulates (10,13). Nests should be regarded as especially hazardous as they could be saturated with virus tainted urine. Recovering corpal remains or other kinds of evidence from rodent-infested structures contaminated with rodent excreta may also expose forensic personnel to hantaviruses (33). Another potential mode of infection is direct inoculation through rodents bites. Although infection through autopsy-related needle sticks, scalpel cuts, or other breaks in the skin is theoretically possible, this method of transmission has not been clearly evaluated (10,11).

Among forensic science personnel, pathologists, physical anthropologists, archaeologists, and other corpse or evidence recovery specialists are probably most at risk to hantavirus exposures. This is because they have more frequent contact with human remains and crime scenes where rodents have been or are active. Moreover, identified risk factors like agricultural or peridomestic cleaning activities (17) can be analogous to the exhumation or excavation of human remains as both can produce large amounts of air-borne particulates. If rodent activity is substantial around human interments, these particulates could potentially be contaminated with hantavirus.

However, risk of hantavirus infections still exist (although at a low level) if forensic specialists have nominal or incidental exposures to rodents, their excreta or nests, and potentially contaminated evidence (e.g., blood or tissue samples, clothing, etc.). Forensic personnel can evaluate their level of risk by considering both the frequency at which they are exposed to rodents and their excreta and nests and the specific tasks they perform. Forensic specialists who consider themselves at risk should take time to appropriate measures to prevent infection.

Presented below is a hantavirus risk reduction guideline for forensic science personnel based on current CDC and other recommendations (10–19). The guideline centers around two critical issues: (1) avoiding aerosol droplets or particulates of rodent excreta and direct inoculation from infected tissues, and (2) decontamination with a disinfecting product recommended by the CDC, i.e., Lysol®, a 10% solution containing chlorine bleach, or some other biphenyl compounds (10). Thus, the use of High Efficiency Particulate Air-filter (HEPA) respirators, latex gloves, and disinfectants are recommended as universal precautions against hantavirus exposures (10,11,13,14).

Using HEPA respirators may lower the risk of hantavirus transmission by contaminated air-borne particulates (10,14,15). Different respirator models (e.g., half mask, full mask, negative pressure, positive pressure, and disposable) are available and can be purchased from stores specializing in safety equipment. HEPA filtered respirators do not afford 100% protection against the hantavirus but are more adequate for filtering out particulates than surgical or dust masks and bandannas that are not recommended. To insure the best protection possible, the US Occupational Health and Safety Administration (OSHA) requires HEPA filtered respirators to be test fitted to ensure a proper fit without leaks or breaks in the seal (29-CFR-1910.134 OSHA Respiratory Protection Standard) (34). OSHA also requires pulmonary function tests for negative pressure respirators and instruction on their proper use and maintenance. Forensic personnel wishing to use HEPA filtered respirators should contact local OSHA authorities, university health offices, or respirator sales staff for information concerning the proper use of HEPA filter respirators and related government regulations. Specialists should also consider using protective eye wear to prevent particulates from entering the conjunctiva of the eye.

The following concepts should form the basis for forensic-related hantavirus risk reduction strategies:

(1) Plague, in all its manifestations (i.e., bubonic, septicemic, and pneumonic), has become endemic and enzootic in many parts of the US west of the 101st meridian (35). Infected fleas transmit *Yersina pestis,* the causative agent of plague, through their bite. Infected fleas are starving as a bacillary clot in the flea's prestomach *(proventriculus)* prevents the digestion of blood meals (35). As a consequence, they become frequent and voracious biters and will attempt to feed on any host within its reach, including humans.

Because hantaviruses share many of the same rodent reservoirs as plague, the CDC recommends adding flea control procedures to hantavirus risk reduction protocols (10,11,13,15). Forensic personnel working in plague endemic areas should apply insecticides to rodent carcasses and nests to kill surviving fleas. Use insecticides appropriately marked for flea control and follow instructions printed on the label. Forensic personnel may wish to spray nests after their removal from the corpse so as not to destroy chemically sensitive evidence. However, if case sites are located in areas where a plague epizootic is occurring, forensic personnel should probably consider applying insecticides before nest removal. Regardless, carcasses and nests should be removed with a long handled utensil and latex gloves should be pulled over the cuffs of gowns or overalls to avoid potential flea bites.

If insecticide application is deemed inappropriate for whatever reason, fleas can be killed by placing rodent carcasses and nests in a tightly sealed container with cotton or gauze saturated with chloroform until fleas die (14). This should be done outdoors or in a well-ventilated room where inhalation of the chloroform fumes can be avoided (14). An older method, involving the immersion of rodents or nests in a jar containing water and detergent and shaking it until the fleas come off (36), can be amended by adding 10% standard Lysol or bleach to the water to meet CDC decontamination recommendations (10).

(2) Rodent carcasses, nests, or feces should be sprayed with 10% standard Lysol, a 10% bleach/water solution, or any product containing biphenyl compounds approved for viricidal use prior to their removal (10). Allow 10 to 15 min for disinfection to work. This not only disinfects the remains but keeps potentially contaminated particulates from becoming air-borne. Although disinfection of rodent remains prior to their removal is ideal, some specialists may wish to wait until needed evidence, sensitive to contamination, is collected.

(3) Carcasses, nests, or feces can be removed with a long handled utensil or with rags or paper towels doused with disinfectant (10). Double bag contaminants in plastic bags and seal tightly. Disinfect implements used to remove contaminants. Do not vacuum or sweep droppings that spill out on laboratory or morgue facilities as this will cause contaminants to become air-borne (10).

(4) Discard containers with contaminates (fleas, carcasses, etc.,) in the trash. Rodent remains removed directly from body cavities should be considered medical waste as they were in direct contact with potentially infected tissue (11).

(5) The CDC advises universal precautions and using respiratory protection for aerosol-generating procedures when performing autopsies (11,13,16). Depending on the procedure, handling potentially infected tissues may require the use of a biological safety cabinet and respiratory protection use at Biosafety Level 2 or 3 practices (11). It should be noted that some infection control precautions are in the process of being amended or updated (36).

This five-step-risk-reduction guideline is offered as a suggested methodology and it is left to the discretion of forensic specialists to adopt or amend these recommendations. Forensic anthropologists active in the exhumation or excavation of human burials will find additional risk reduction methods in hantavirus-related guidelines recently prepared for archaeologists (18,19).

Although decontamination with disinfectants is an essential part of any hantavirus prevention protocol, application of disinfectants to human remains, especially bone, could potentially contaminate or destroy forensic evidence. For example, Lysol may contaminate C^{14} and carbon isotope bone samples as its active ingredient, Alkyl, contains 50% C^{14}, 40% C^{12} and 10% C^{16}. Other biphenyl compounds may also contaminate carbon samples as they contain $C^{12}H^{10}$. These products should therefore be used accordingly and at the discretion of analysts working with osteological specimens (19).

Because rodents and other vertebrates can inflict substantial postmortem damage on human corpal and skeletal remains, some forensic specialists have begun studying the taphonomic processes associated with animal behavior (38). However, because cases of HPS have occurred among laboratory researchers studying hantaviruses (39), studying rodent alterations on human remains, either in the field or laboratory, could potentially expose forensic personnel to hantavirus infection. Forensic personnel interested in studying rodent-related taphonomic processes in human remains should consult CDC hantavirus guidelines for small mammal research (11,14,15).

Finally, rodent infestations in morgue or forensic laboratory facilities can be prevented by covering or filling small openings (at least quarter inch in diameter) providing outside entry with steel wool or cement or by placing metal flashing around the building's base (13). Additional ideas for control and exclusion

programs are contained in several standard CDC publications (40–42). In plague endemic areas, however, it is recommended that indoor rodent elimination programs be preceded by indoor insecticide application to control potentially infected fleas (13).

Conclusions

Forensic specialists are usually well acquainted with the proper use of prophylactic procedures. Many of these procedures, which are designed to lessen the chance for accidental contamination or infection of forensic personnel, are already in place. The point of this review is to alert forensic specialists to additional dangers imposed by hantaviruses and suggest guidelines for risk reduction. It is hoped that this information will generate discussion among forensic scientists on the possible health hazards they may face as a result of rodent activity on human remains. For additional information on HPS, forensic personnel should contact their local and state health departments.

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