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Short Communication

Relationship of Human Behavior within Outbuildings to Potential Exposure to Sin Nombre Virus in Western Montana

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Abstract: Sin Nombre virus (SNV) causes hantavirus cardiopulmonary syndrome (HCPS) in humans. Transmission of SNV among the deer mouse (*Peromyscus maniculatus*) host predominates during spring and summer, and is greater in peridomestic than sylvan settings where, protected from UV light, SNV may survive longer. Incidence of HCPS reflects these times and settings and is associated with inhalation of mouse excreta. Little is known, however, about how human use of outbuildings contributes to potential exposure to SNV. Here, the frequency and seasonality of outbuilding use by humans was evaluated, via a survey of rural residents in western Montana, to quantify human behaviors and potential risk of exposure to SNV. Retrieving or return of tools and scooping feed/grain were the most frequently undertaken activities. Seasonal activities coinciding with seasons of highest HCPS incidence and times of potentially high viral shedding by deer mice, included retrieving or returning tools, calving or lambing, and, to a lesser extent, feeding livestock and sweeping or cleaning. Human behavior is a component of SNV transmission risk and this preliminary study provides a basis from which to further evaluate this route of exposure.

Keywords: deer mouse, hantavirus pulmonary syndrome, human behavior, *Peromyscus maniculatus*, Sin Nombre virus, seroconversion

To understand factors which drive human incidence of hantavirus cardiopulmonary syndrome (HCPS), it is critical to determine human behaviors which coincide with disease incidence. Sin Nombre virus (SNV, Bunyaviridae:*Hantavirus*) is the causal agent of HCPS (CDC, 1993; Hughes and Peters, 1993; Nichol et al., 1993), and its reservoir is the deer mouse (*Peromyscus maniculatus*) (Childs et al., 1994; Glass et al., 2002), which is one of the most common and widespread rodents in North America. Human exposure to SNV generally occurs during the spring and summer in rural peridomestic settings, particularly in outbuildings (such as barns, stables, storage buildings, detached garages, or sheds) (CDC, 2007, 2009), where SNV-contaminated mouse excrement may become aerosolized and inhaled (Armstrong et al., 1995). Accordingly, activities which aerosolize particulate matter, such as cleaning of rodent-infested buildings, have been identified as a risk factor for incidence of HCPS (Armstrong et al., 1995; Zeitz et al., 1995). While some human behaviors have been associated with incidence

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of HCPS, specific human activities, their frequency and seasonality in outbuildings, with respect to SNV exposure risk, remain poorly understood.

Spring–summer incidence of HCPS in Montana coincides with onset of the deer mouse breeding season (Douglass et al., 2001, 2005). This is also the time of year when seroconversions transpire in greatest numbers in peridomestic environments (Douglass et al., 2001; Kuenzi et al., 2001, 2005). In and around peridomestic settings, SNV prevalence is higher among deer mice, than in sylvan populations (Douglass et al., 2006; Hjelle and Glass, 2000; Kuenzi et al., 2001; Otteson et al., 1996), possibly owing to higher contact rates among deer mice (Douglass et al., 2006). SNV-contaminated deer mouse urine and feces likely accumulates in outbuildings, because rates of removal by wind and natural degradation of excreta are less in these environs. SNV may also persist in deer mouse excreta longer within peridomestic environments, due to reduced exposure to ultraviolet radiation (Douglass et al., 2006), which can kill many types of viruses (Shechmeister, 1991). Taken together, elevated rates of SNV transmission among deer mice, a greater proportion of deer mice infected, and human activities within outbuildings in spring–summer may account for SNV exposure (Armstrong et al., 1995; Childs et al., 1995; Zeitz et al., 1995, 1997).

This preliminary study sought to identify and document (1) human behaviors that are undertaken frequently, and (2) behaviors that are undertaken seasonally in outbuildings, as risk factors of SNV exposure in western Montana, which has the fourth highest rate of rural HCPS incidence nationally (Douglass et al., 2005). We undertook a novel survey of rural residents in western Montana to evaluate outbuilding use with respect to SNV exposure (Appendix section, $n = 55$ returned surveys; Chisolm, 1997). Volunteer participants were at least 18 years of age and had at least one outbuilding on their property that did not include their house. Rural residents were recruited from local organizations, such as Back Country Horsemen of Montana, and customers from a farm and tack store. Farming and ranching operations in western Montana include: small grain production, such as winter wheat, spring wheat, barley, and oats; alfalfa and other hay; livestock, such as cattle, sheep, lambs, and horses; and seedstock, such as breeding bulls and cows, semen, and embryos.

The survey was composed of questions identifying eight specific farming and ranching activities (included cleaning, shoveling feed/grains, entering an outbuilding for various reasons on foot, and driving heavy equipment into an outbuilding), that were initially determined by informal discussion with ranchers and ranch hands. The questionnaire asked for the frequency that the volunteers, not including family members or workers, entered outbuildings, for each activity listed during each of the four seasons. Two additional questions asked respondents to record any other activities performed in their outbuildings, as well as the frequency and timing of these activities. In addition, respondents were asked how many full work days they spent in outbuildings during each season. The survey also included an optional place for respondents to record reasons for entering outbuildings that were not identified on the survey.

Our survey demonstrated that the number of entrances into buildings differed between activities, but not season overall, and there was no interaction between season and activity (Table 1). The number of full days spent within outbuildings also did not vary between seasons (Table 2). The most common activities in outbuildings were entering to retrieve or return a tool, and to gather feed/grain; the least common activity was to conduct repairs to the building (Table 2). Within some activities, there were differences among seasons in the number of entrances into buildings (Table 2). Retrieving or returning tools was undertaken more frequently between summer and fall, and least frequently during winter (Table 2). Calving or lambing occurred predominantly during winter and spring, and less frequently during summer and fall (Table 2). Though not significant, entrance into buildings to feed livestock was more commonly undertaken in winter and spring, and sweeping within outbuildings was a more common practice from spring through to fall (Table 2). In addition, outbuildings were occasionally used for lawn care (sourcing of grass seed and fertilizer), storing of firewood, hobbies (such

Table 1. General Linear Model of the Effect of Season and Activity on the Number of Entrances into Outbuildings, Based on 2008 Survey of Western Montana Farmers and Ranchers[a]

GLM	*df*	*F*	*P*
Season	3	1.117	0.341
Activity	7	57.542	**< 0.001**
Season * activity	21	1.412	0.101
Error	1728		

GLM general linear model, *Season* spring, summer, fall, winter, *Activity* retrieving or returning a tool, calving or lambing, feeding livestock within buildings, gathering feed/grain, sweeping or cleaning, equipment maintenance, repairs to buildings, and parking or moving heavy equipment.
[a]Significant results shown in *bold*.

Table 2. General Linear Model of Seasonal Differences between Entrances, Days inside Outbuildings, and Activities within Outbuildings[a]

	Spring	Summer	Fall	Winter	$F_{3,\ 216}$	P
Entrance	187.73 (19.48)	169.75 (16.57)	154.76 (16.16)	175.78 (19.08)	0.090	0.966
Days	5.76 (1.93)	5.25 (1.74)	4.60 (1.55)	5.67 (1.83)	0.588	0.624
Tool	54.07 (6.26)	68.82 (7.83)	49.73 (5.16)	44.20 (5.99)	2.730	**0.045**
C/L	14.75 (4.87)	2.89 (1.84)	3.11 (1.85)	17.96 (6.60)	3.301	**0.021**
Feed	17.67 (5.35)	7.80 (3.74)	9.65 (4.00)	18.49 (5.17)	2.159	0.094
F/G	47.07 (7.67)	36.38 (7.05)	40.78 (7.15)	44.66 (7.30)	0.549	0.650
S/C	9.98 (1.55)	9.27 (1.60)	9.96 (2.24)	6.58 (1.15)	2.142	0.096
Equip	16.35 (2.86)	17.15 (2.96)	14.07 (2.70)	14.09 (3.87)	0.797	0.479
Repairs	6.55 (1.59)	7.25 (1.78)	6.60 (1.79)	6.33 (1.96)	0.701	0.552
P/M	21.29 (4.36)	20.18 (4.03)	20.85 (4.20)	23.47 (4.65)	0.109	0.955

Entrance number of entrances, *Days* full days, *Tool* retrieving or returning a tool, *C/L* calving or lambing, *Feed* feeding livestock within buildings, *F/G* gathering feed/grain, *S/C* sweeping or cleaning, *Equip* equipment maintenance, *Repairs* repairs to buildings, *P/M* parking or moving heavy equipment.
[a]Average (±1 SE) number of entrances and full days spent inside outbuildings (*upper portion* of table); average (±1 SE) number of entrances into outbuildings by activity (*lower portion* of table). Significant results shown in *bold*.

as social gatherings and car repair/restoration), and accessing freezers in outbuildings. However, these activities were infrequent activities among the survey demographic.

To date, the seasonal use of outbuildings by humans, with respect to SNV exposure risk, has received little empirical attention; data from this preliminary study provides a basis from which to further evaluate potential routes of human exposure to SNV. Activities (either frequent or seasonal activities) that are particularly relevant to SNV exposure in this investigation are those which likely aerosolize large amounts of particulate matter within buildings which may contain SNV-contaminated deer mouse excreta. While the most frequent activities in outbuildings were to retrieve or return a tool and gather feed/grain, we hypothesize that only entrance to scoop feed/grain is probably related to SNV exposure. This is because scooping of feed/grain is likely to generate a sufficient volume of particulate matter that is inhaled, and deer mice are likely attracted to grain sources, presumably resulting in concentration of excreta. Similarly, activities which exhibited seasonality of entrance (entry for retrieving or returning tools, calving or lambing) coinciding with either spring or summer (the high-risk HCPS seasons) appear unlikely to be significant sources of particulate aerosolization. Previous studies have identified sweeping to be particularly important in dust aerosolization and human exposure to SNV (Armstrong et al., 1995). In this study, sweeping and cleaning did not differ significantly among seasons, but there was an increased spring–fall trend, relative to winter.

Human behavior is a component of risk of exposure to SNV (Armstrong et al., 1995; Zeitz et al., 1995), and this study provides insight into how frequently rural residents in Montana enter their outbuildings during each season. Precautions, such as covering the mouth and nose with a respirator, while undertaking activities between spring and fall which aerosolize significant amounts of dust, may greatly reduce the risk of exposure to SNV within outbuildings where deer mice are present. It is also important to acknowledge that the risk of human exposure to SNV is connected to changes in population and infection among peridomestic deer mice. For example, a predominance of adult deer mice occurs in peridomestic settings during early spring in Montana (Kuenzi et al., 2001), and Childs et al. (1994) and Glass et al. (2002) found that peaks in SNV prevalence among deer mice followed peaks in the aging population. Thus, infection prevalence was age-dependent. Subsequently, risk of human infection is likely higher where deer mice populations show a predominance of adult mice in peridomestic settings.

This study takes a unique survey approach to zoonotic disease investigation. Extending from this preliminary study, investigations aimed at assessing exposure risk of humans to SNV could evaluate the amount of time each individual activity is undertaken in the outbuildings. Future studies could also evaluate how the propensity of particulate matter to become aerosolized changes between seasons, and the concentration and aerodynamic diameter of particulate matter generated with each task. Identifica-

tion of the diameter of aerosolized particle matter may indicate the region in the respiratory tract where the dust would reach. It is possible there may be differences in the use of outbuildings by humans and mice among geographic areas. For example, the use of outbuildings in the Four Corners region may differ from Montana. Accordingly, studies which consider geographic variation in outbuilding use by humans and deer mice would be valuable.

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Appendix

Survey Sent to Western Montana Farmers and Ranchers

Information gathered will be used to determine if there is a seasonality of activities and tasks done in outbuildings. Outbuildings include: barns, stables, detached garages, chicken coops, storages for harvested feed/grain, calving/lambing sheds, gardening/tool sheds, tractor/heavy equipment/combine sheds. Researchers have already discovered that the hantavirus can survive longer in outbuildings, where it is protected from UV light. This information will help to establish which activities are most performed during the window when hantavirus patients became infected. Please fill in the blanks for each season with your best estimate. Only count the number of times that you, not including any other worker or family member, enter an outbuilding during each season.

Each season is approximately 90 days, or 13 weeks.

Season Dates: [Spring: Mar 21–Jun 20], [Summer: Jun 21–Sep 20], [Fall: Sep 21–Dec 20], [Winter: Dec 21–Mar 20]

1. How many times do you usually scoop grain/feed into a container for the purpose of feeding animals in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

2. How many times do you usually sweep or do any other cleaning task inside an outbuilding in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

3. How many times do you usually enter an outbuilding for calving or lambing in the:

a. Spring _____
b. Summer_____
c. Fall _____
d. Winter _____

4. How many times do you usually park or drive out any type of heavy equipment in an outbuilding in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

5. How many times do you usually enter an outbuilding to get a tool/item or to store a tool/item in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

6. How many times do you usually do any type of equipment maintenance in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

7. How many times do you usually feed livestock that are housed inside the outbuilding in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

8. How many times do you usually make repairs to the inside of the outbuilding in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

9. Other activity or task you do that requires you to enter an outbuilding? Please describe:

_____

_____

How many times does this task require you to enter an outbuilding in the:

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

10. How many full (all day) workdays do you usually spend inside an outbuilding during the: (90 days/season)

a. Spring _____
b. Summer _____
c. Fall _____
d. Winter _____

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