

SEROLOGIC SURVEY OF CATTLE IN THE NORTHEASTERN AND NORTH CENTRAL UNITED STATES, VIRGINIA, ALASKA, AND HAWAII FOR ANTIBODIES TO CACHE VALLEY AND ANTIGENICALLY RELATED VIRUSES (BUNYAMWERA SEROGROUP VIRUS)

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Abstract. Bovine sera from northeastern states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia), north central states (Indiana, Illinois, Iowa, Kentucky, Michigan, Minnesota, North Dakota, Ohio, South Dakota, and Wisconsin), Virginia, Alaska, and Hawaii were examined for the presence of neutralizing antibodies to Cache Valley (CV), Lockern (LK), Main Drain (MD), Northway (NW), and Tensaw (TS) viruses. Microneutralization tests were performed using Vero cells. Ninety percent inhibition of the virus at a 1:10 serum dilution was considered positive for the presence of specific antibody. Sera having antibody to more than one virus were titrated from 1:10 to 1:640. The results indicated that 4–28% of the cattle per region had specific antibodies to CV virus. Neutralizing antibodies to NW, LK, and TS viruses were also detected, indicating possible exposure to these Bunyamwera serogroup viruses along with CV virus. Antibody titers measured against NW virus were very similar to those against CV virus. Antibodies to MD virus were present in low levels in bovine sera from Illinois, Maryland, and Ohio. Cattle from Alaska had only antibodies to NW virus. Antibodies to Bunyamwera serogroup viruses were not observed in sera from Hawaii.

INTRODUCTION

Cache Valley (CV) virus, a member of the Bunyamwera serogroup viruses (family Bunyaviridae; genus *Bunyavirus*) was first isolated in 1959 from mosquitoes in North America.¹ Cache Valley and other viruses of the Bunyamwera serogroup are prevalent in domesticated^{2–6} and wild animals^{4,7,8} and humans.⁴ The Bunyamwera serogroup viruses have been isolated primarily from mosquitoes, suggesting arthropod vectors are necessary for spread of virus.^{4,9–12}

An association between CV virus and Main Drain (MD) virus with congenital malformation of fetuses has been described in sheep.^{13–15} Recent studies suggest that the viruses of Bunyamwera serogroup may also be etiologic agents of congenital defects of the central nervous system in humans.^{15,16}

Main Drain virus, a member of the Bunyamwera serogroup viruses, has been isolated from the brain tissues of horses with encephalitis.⁶ Serologic and virologic studies suggest that viruses of the Bunyamwera serogroup may also affect the central nervous system of human patients.^{4,9,16–18} Bunyamwera serogroup viruses are known to cause undifferentiated illness, and rarely, central nervous system disease in humans in Africa, Brazil, and Argentina.^{19,20} Antibodies to CV virus,^{4,9,17,18} Northway (NW) virus,^{4,21–23} and Tensaw (TS) virus²⁴ were reported in humans in the United States and Canada. In California, evaluation of 702 individuals for antibodies to selected bunyavirus showed 6.4% had antibodies to California serogroup viruses and 0.3% to Bunyamwera serogroup viruses. No seroconversions were detected to selected viruses of California serogroup or Bunyamwera serogroup viruses in paired samples from 349 patients with acute central nervous system disease or undifferentiated febrile illness who were sampled from 1963 to 1988.²³ However, seroconversion to CV virus was observed in a febrile patient in Panama^{17,25} and in a patient from North Carolina with severe encephalitis and multiorgan failure.¹⁸

Bunyavirus contains three segments of negative sense

single-stranded RNA: L RNA, M RNA, and S RNA. The L RNA segments encodes for L protein, which is thought to be a component of virion-associated transcriptase or RNA polymerase, the M RNA encodes virion glycoproteins G1 and G2 and a non-structural protein NSm, and the S RNA encodes N protein and a non-structural protein NSs, which are encoded in overlapping reading frames.^{26–28} The G1 glycoprotein contributes many important biologic virus properties such as virulence, infectivity, attachment to cellular receptors, and hemagglutination.^{26,29–32} A comparison of relationships of Bunyamwera serogroup viruses by serum neutralization test showed NW virus, Tlacotalpan virus, and Maguari virus were more closely related to CV virus than TS and MD viruses.³³ Sequence analysis of the N protein of bunyaviruses S genome RNA segments showed that CV virus and NW virus were more closely related than CV virus and MD virus.³⁴

A comprehensive study on the distribution of various Bunyamwera serogroup viruses in the United States was previously published.⁹ Prevalence data were based on the isolation of viruses from arthropods and/or the blood of vertebrates from specific regions. Infection with CV virus was observed in 22 states, mostly in the northeastern and north central regions (Colorado, New Mexico, Oregon, Texas, and Utah). Tensaw virus was present in the states around the Gulf Coast; MD virus in the southwestern region; and LK virus in northwest Texas, southern California, Colorado, and Utah. Northway virus was isolated only from samples from Alaska.

The present study was undertaken in an attempt to determine the distribution of Bunyamwera serogroup viruses (CV, Lockern [LK], MD, NW, and TS) in domestic cattle by evaluating neutralizing antibodies in bovine sera from the north central states, northeastern states, Virginia, Alaska, and Hawaii.

MATERIAL AND METHODS

Virus and mouse ascitic fluid (MAF). The CV, LK, MD, NW, and TS viruses were obtained from the American Type

Culture Collection (Rockville, MD). Mouse ascitic fluids containing antibodies to these viruses were produced in BALB/C mice.³⁵

Sera. Bovine sera samples used in this study were collected in 1991 from various slaughterhouses in northeastern states (Connecticut, Maine, Maryland, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia), north central states (Ohio, Indiana, Illinois, Iowa, Kentucky, Michigan, Wisconsin, Minnesota, South Dakota, and North Dakota), and Virginia, Alaska, and Hawaii. Fifty sera per state were tested, except for Connecticut, Delaware, Maine, Maryland, and Massachusetts, from which 25 sera were tested. Connecticut, Delaware, Massachusetts, Maryland, Maine, and Vermont are not large beef-producing states; therefore, the desired number of blood samples could not be obtained. After collecting the blood from cattle, the ear tag information was recorded on the tube labels. The ear tag information provides a number and the site of origin (state) of the animal. The study did not include cattle that originated in a state and were slaughtered in another. All sera were kept at -20°C until tested.

Serologic tests. Antibodies to viruses were identified by a microtiter virus neutralization test using 96-well microplates. Briefly, a 1:10 dilution of the test sera was prepared in tissue culture medium and was mixed with 100 50% tissue culture infective doses (TCID₅₀) of the virus. The serum-virus mixtures were incubated for one hour at 37°C to permit virus neutralization. Vero cells were added and the plates were incubated at 37°C for 96–120 hours. The cell monolayers were observed for a cytopathic effect at the end of the incubation period. The maximal serum dilution yielding 90% protection of cells was considered the titer of the serum. Protection of the cells at a 1:10 or greater serum dilution was considered a positive test result for the antibodies. All positive sera were further diluted from 1:10 to 1:640 and retested against viruses with which the sera cross-reacted. Controls included normal cattle sera, normal MAF, and MAF containing antibodies to Bunyamvera serogroup viruses used in the study.

RESULTS

The distribution of antibodies to CV, LK, MD, NW, and TS viruses in the northeastern and north central states, Alaska, and Hawaii are shown in Table 1. The distribution of seropositive bovine sera for CV virus varied from 6% in Alaska to 56% in Illinois; for NW virus from 4% in Maine and Vermont to 44% in Minnesota; for TS virus from 4% in Alaska, North Dakota, and Vermont to 36% in Maryland, and for LK virus from 4% in Alaska, Connecticut, and Vermont to 47% in Maryland. Two to six percent of the samples from Illinois, Maryland, New York, and Ohio were positive for MD virus. Antibodies to Bunyamvera serogroup viruses were not observed in sera from Hawaii.

Results of non cross-reacting sera are shown in Table 2. Non cross-reacting antibodies to Bunyamvera serogroup viruses were present at low levels in sera from many states. Other than Alaska, Delaware, Maryland, and Maine, CV virus appeared to be the most common virus of the Bunyamvera serogroup present in the northeastern and north central states.

Antibody titers to Bunyamvera serogroup viruses used in

TABLE 1

Presence of antibodies to Bunyamvera viruses in sera of cattle in the United States

States [†]	Percent sera with antibodies to*				
	CVV	NWV	TSV	LKV	MDV
Alaska	6	10	4	4	-
Connecticut	16	8	-	4	-
Delaware	28	12	8	12	-
Hawaii	-	-	-	-	-
Illinois	56	34	10	24	2
Indiana	50	24	8	16	-
Iowa	42	28	10	20	-
Kentucky	36	12	12	10	-
Massachusetts	48	36	16	24	-
Maryland	52	28	36	47	6
Maine	4	4	-	-	-
Michigan	34	26	16	16	-
Minnesota	48	44	12	22	-
New York	30	6	6	12	2
North Dakota	52	32	4	34	-
Ohio	44	18	6	14	4
Pennsylvania	34	26	6	18	-
South Dakota	54	40	10	16	-
Vermont	12	4	4	4	-
Virginia	16	6	12	22	-
Wisconsin	32	28	14	14	-
West Virginia	50	22	16	6	-

* CVV = Cache Valley virus; NWV = Northway virus; TSV = Tensaw virus; LKV = Lokern virus; MDV = Main Drain virus; - = less than 1:10.

[†] Sera n = 50 all states except Connecticut, Delaware, Maine, Maryland, Massachusetts, and Vermont (n = 25 each).

the study for representative cattle sera are shown in Table 3. The titers of the sera ranged from 1:10 to 1:320. Some sera had four-fold or higher titers to one virus compared with other cross-reacting viruses. However, there were sera that

TABLE 2

Presence of non-cross-reacting antibodies to Bunyamvera viruses in sera of cattle in the United States

States [†]	Percent sera with antibodies to*				
	CVV	NWV	TSV	LKV	MDV
Alaska	-	4	-	-	-
Connecticut	6	-	-	-	-
Delaware	-	-	-	-	-
Hawaii	-	-	-	-	-
Illinois	22	4	-	4	2
Indiana	20	2	-	2	-
Iowa	8	-	-	2	-
Kentucky	18	-	2	-	-
Massachusetts	4	-	-	4	-
Maryland	-	4	-	-	4
Maine	-	-	-	-	-
Michigan	10	-	2	2	-
Minnesota	6	2	-	-	-
New York	14	-	-	2	2
North Dakota	12	-	-	6	-
Ohio	20	-	-	2	-
Pennsylvania	4	-	-	-	-
South Dakota	10	-	-	-	-
Vermont	8	-	-	-	-
Virginia	8	-	2	10	-
Wisconsin	10	6	-	-	-
West Virginia	28	6	2	-	-

* CVV = Cache Valley virus; NWV = Northway virus; TSV = Tensaw virus; LKV = Lokern virus; MDV = Main Drain virus; - = less than 1:10.

[†] Sera n = 50 all states except Connecticut, Delaware, Maine, Maryland, Massachusetts, and Vermont (n = 25 each).

TABLE 3

Antibody titers of cattle serum samples to various Bunyamwera viruses representing typical results obtained in this study*

Serum numbers	CVV	NWV	TSV	LKV	MDV
1	160	—	—	—	—
2	—	10	—	—	—
3	—	—	10	—	—
4	—	—	—	20	—
5	—	—	—	—	20
6	40	40	—	—	—
7	20	—	—	—	10
8	20	320	—	—	—
9	20	160	20	—	—
10	10	10	40	—	—
11	10	160	—	20	—
12	10	10	—	10	—
13	10	10	—	40	—
14	160	40	20	40	—
15	40	160	20	20	—
16	160	160	80	80	—
17	80	320	80	80	40

* CVV = Cache Valley virus; NWV = Northway virus; TSV = Tensaw virus; LKV = Lokern virus; MDV = Main Drain virus; — = less than 1:10.

had similar titers to several cross-reacting viruses. Few sera showed high monospecific antibody titer (1:40 or greater) to CV virus.

DISCUSSION

The present work represents a serologic survey for antibodies to the five major Bunyamwera serogroup viruses (CV, NW, LK, TS, and MD). There is evidence of widespread activity of CV, NW, LK, and TS viruses in the northeastern and north central states and Virginia.

Serologic surveys and various case reports indicated the presence of CV virus infection in human and animals in the United States.^{2-9,18-20,36,37} Results obtained in the present study confirmed the presence of CV virus in northeastern and north central states. Antibody to CV virus was also found in sera of cattle from West Virginia, Pennsylvania, Massachusetts, Maine, and Vermont.

Northway virus was originally isolated from arthropods and from blood of sentinel rabbits from Alaska, and it was previously believed that it does not occur in any other part of the United States.⁹ The virus was subsequently detected in mosquitoes from California and Oregon and viral antibody was detected in humans and deer from California.^{12,23,36} It appears that CV, LK, TS, and MD viruses are not present in Alaska. The conclusion is based on the fact that no sera were found to have the monospecific antibody to CV, LK, MD, or TS viruses. However, monospecific antibody to NW virus was observed in many sera from Alaska. Three sera in this study that originated in Alaska showed cross-reactivity with NW, CV, TS, and LK viruses; however, these sera had four-fold higher titers to NW virus than to CV, TS, and LK viruses. Similar results were previously demonstrated during Bunyamwera serogroup virus infection surveys in Alaska.^{9,21,22}

A previous study noted the presence of TS virus in states around the Gulf coast and LK virus in western Texas, Colorado, Utah, and southern California.^{9,24} Although antibodies to TS virus and LK virus were observed in sera from many states, test results for non-cross-reacting antibodies in this

study indicated the presence of monospecific antibodies to TS virus in four of 19 states and to LK virus in all northeastern and north central states except Connecticut, Kentucky, Maryland, Maine, Minnesota, Vermont, and Alaska and Hawaii, indicating the presence of these viruses in many more states than thought earlier.

Low antibody titers to MD virus were observed in cattle sera from Illinois, Maryland, and New York. The incidence of MD virus infection appears to be low since only six of 950 sera tested had antibodies to MD virus. Of 377 sera titrated, two cross-reacted with CV virus, and one serum had a titer to all five Bunyaviruses used in this study. Cross-reactivity of MD virus with CV antiserum was previously reported.³³ This is the first report demonstrating that antibody to NW virus also showed cross-reactivity with MD virus. Sera that had antibodies to TS or LK viruses did not neutralize MD virus, indicating MD virus is antigenically different from TS and LK viruses. These results support previous findings.⁹

Many sera used in the study had antibodies to more than one Bunyamwera viruses. Sera with antibodies to CV virus cross-reacted with NW virus to a greater extent than with LK virus, TS virus, and MD virus. This indicated that CV virus and NW virus are antigenically more closely related than other Bunyamwera viruses used in the study. Similar results were previously observed.^{33,34}

In this study, cattle sera exhibited several patterns of reactivity. Sixty percent of the sera were negative for all five viruses of the Bunyamwera serogroup. The remaining 40% of the sera showed several types of reactions. Some sera had low (1:10-1:20) or high (1:40-1:160) monospecific antibody titers. Only CV virus showed a high monospecific antibody titer. There were sera that reacted with more than one viral antigen. In the latter case, any one virus showing a four-fold or higher antibody titer was considered the infecting agent. It is possible that an animal was infected with several Bunyamwera serogroup viruses. Subsequent infection(s) with one or more Bunyamwera serogroup viruses may cause an anamnestic reaction to infecting virus(es). This could cause a large increase in the antibody titer to the infecting virus(es). In the case of infection with one virus, the homologous titer could be expected to increase over those of other cross-reacting viruses. The titer of the infecting virus could conceivably increase four-fold or higher compared with the other cross-reacting Bunyamwera serogroup viruses. Conversely, if vectors carrying different Bunyamwera serogroup viruses infected an animal, an increase in antibody titer to all infecting viruses would occur. This is supported by the fact that there were many sera in this study that had similar antibody titer to two or more Bunyamwera viruses. It is also possible that animals were infected by other antigenically related Bunyamwera serogroup viruses not included in the study.³³ However, nonspecific cross-reactivity cannot be ruled out.

In the present study, antibodies to LK virus and NW virus were much more prevalent than previously observed.⁹ Monospecific antibodies to LK and NW viruses were present nine and seven states, respectively, in the cattle sera. Sera of cattle from Hawaii did not have antibodies to all five Bunyamwera serogroup viruses used in this study. However, it cannot be definitively stated that Hawaii is free of Bunyamwera serogroup viruses because no arthropods and other animals were evaluated for presence of the Bunyamwera viruses. Also, there may be animals infected with Bunyamwera serogroup

viruses that were not included in the neutralization test panel.³³

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