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VIRUSES IN *IXODES URIAE* (ACARI: IXODIDAE) FROM SEABIRD COLONIES AT RØST ISLANDS, LOFOTEN, NORWAY[1]

By P. Saikku,[2] A. J. Main,[3] I. Ulmanen[2] and M. Brummer-Korvenkontio[2]

Abstract. A total of 1929 *Ixodes uriae* collected from Røst Islands, Lofoten, Norway, in July 1974, was divided into 204 pools and inoculated into suckling mice and chick embryo cell cultures for virus isolation. Virus was detected in 6.6% of the laboratory-molted female ticks, 5.4% of the males and 1.8% of the nymphs. No isolates were obtained from 149 unengorged adult ticks. Of 50 viral strains recovered, 30 belonged to the Uukuniemi group, 13 to the Kemerovo group, and 1 was a strain of Tyuleniy of Group B. Of 6 untyped strains, 1 was orbiviruslike and 1 resembled a coronavirus in a negative-staining electron microscopy. The infection rates of *I. uriae* in Lofoten were similar to those reported in the Murmansk area in the northern USSR.

Ixodes (*Ceratixodes*) *uriae* White [=*I. putus* (Pick.-Cambr.)], whose mass occurrence in vast seabird colonies creates favorable conditions for circulation of arthropod-transmitted agents, has in recent years been actively studied for arboviruses (for reviews see L'vov et al. 1975, Yunker 1975, Main et al. 1976a). So far, arboviruses belonging to the serological groups B (L'vov et al. 1971, Clifford et al. 1971), Sakhalin (L'vov et al. 1972, Ritter & Feltz 1974, Doherty et al. 1975, Main et al. 1976a), Uukuniemi (L'vov et al. 1973a, Thomas et al. 1973, Traavik et al. 1974), and Kemerovo (L'vov et al. 1973b, Yunker et al. 1973, Main et al. 1973, 1976b, Main 1978, Ritter & Feltz 1974, Doherty et al. 1975) have been reported. In addition, 2 ungrouped viruses, Paramushir (L'vov et al. 1975) and Runde (Traavik et al. 1977), have been isolated from *I. uriae.*

To study the presence of arboviruses in *I. uriae* in Scandinavia, a survey was made at Røst Islands, Lofoten, Norway, where the presence of this tick species was reported earlier (Mehl 1968).

MATERIALS AND METHODS

Ticks were collected on 5–6 July 1974 at Røst Islands (68°30′N, 12°04′E), Lofoten, Norway. Detailed descriptions of the study area have been published elsewhere (Wagner 1958, Pomeroy 1966). The area is a breeding place for about 2 million pairs of birds, of which the Atlantic Puffin, *Fratercula arctica,* Black-legged Kittiwake, *Rissa tridactyla,* Common Murre, *Uria aalge,* and Razorbill, *Alca torda,* are the prevalent species. Unengorged female ticks were found in the active foraging state; unengorged males, engorged nymphs and larvae were collected from crevices in stones or from soil under the bird colonies. Ticks were transported on ice to the laboratory where they were kept alive up to 6 months at 6 ° or 15 °C until isolation attempts were made. Engorged specimens were allowed to molt. Ticks were triturated in pools averaging 5 adults or 20 nymphs and were inoculated into 0- to 3-day-old mice (Brummer-Korvenkontio et al. 1973). Negative pools were further tested in chick embryo cell cultures (Saikku 1974). Presumptive identification of isolates by negative-staining electron microscopy was done with cell culture supernatant or by touching the wet cut surface of the mouse brain with a grid that was then stained with uranyl acetate (pH 5.8) or sodium phosphotungstate (pH 7.0). Preliminary serological typing was done by complement fixation with crude, 2nd- or 3rd-passage suckling mouse brain extracts centrifuged at 10,000 *g* for 60 min as antigens. The following sera or immune ascitic fluids were used: Uukuniemi group isolate from Røst (NorAr V-697), Great Island (CanAr 41) of the Kemerovo Group, polyvalent Sakhalin group and group B.

Further serological identification of 3 Uukuniemi group and 3 Kemerovo group isolates by cross-complement fixation was done with sucrose-acetone extracted mouse brain antigens and immune mouse ascitic fluids supplied by the World Health

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[2]Department of Virology, University of Helsinki, Haartmaninkatu 3, 00290 Helsinki 29, Finland.

[3]Yale Arbovirus Research Unit, Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, Conn. 06510, USA.

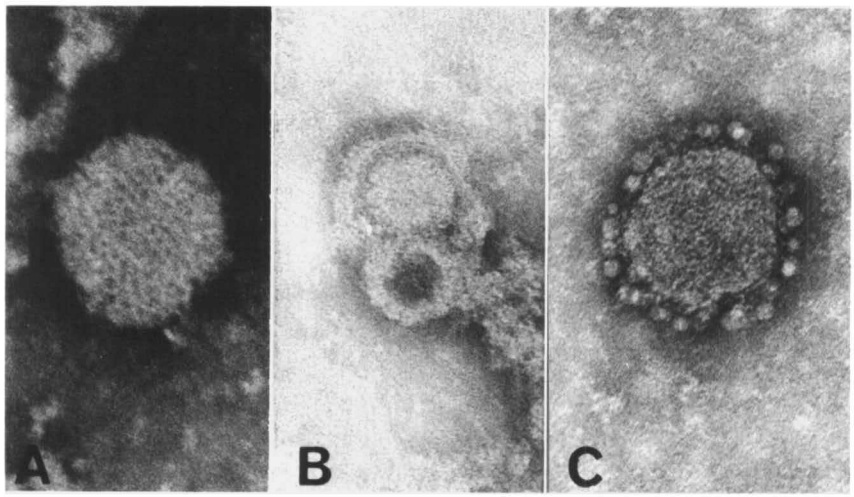

FIG. 1. Negative-staining electron micrographs of 1st-passage virus isolations from *Ixodes uriae* collected on Røst Islands, Lofoten, Norway. A, Uukuniemi group isolate (NorAr V-697) in suckling mouse brain; B, Kemerovo group isolate (NorAr V-950) in chick embryo cell culture supernatant; C, Coronaviruslike isolate (NorAr V-958) in chick embryo cell culture supernatant. Magnification 200,000×.

Organization Reference Centre at the Yale Arbovirus Research Unit. The group B isolate was tested both in cross-complement-fixation and hemagglutination-inhibition tests with 49 flaviviruses; it was compared further in suckling mouse neutralization tests with 2 group B isolates, Tyuleniy (L'vov et al. 1971) and Saumarez Reef (St. George et al. 1977).

RESULTS

A total of 50 strains was isolated, 48 in mice and 2 in chick embryo cell cultures. Virus was recovered from 2.6% of the ticks tested (TABLE 1). Unengorged, seemingly overwintered adults yielded no isolates. The infection rates in laboratory-molted males and females were similar, 5.4% and 6.6%, respectively, and 3-fold greater than the rate (1.8%) in molted nymphs. The ratio of Uukuniemi to Kemerovo group viruses was 2:1 in molted nymphs and males and 4:1 in molted females. There was no difference in infection rates in ticks held at 6 ° and 15 °C in the laboratory.

Viruslike particles were seen by negative-staining electron microscopy (FIG. 1) in 12 of 22 mouse brain dips or cell culture supernatants. Of these, 10 were in the 1st passage. Uukuniemi viruslike particles were seen in 4 of 7 mouse brain preparations and in 1 of 2 cell cultures; orbiviruslike particles were detected in 1 of 4 mouse brains and 4 of 6 cell cultures. Most of the strains yielded enough antigen in the 2nd mouse passage to be tentatively classified by complement fixation. Of serologically untyped isolates, 1 was orbiviruslike and 1 resembled a coronavirus. In no case was there a discrepancy between results of serology and electron microscopy.

TABLE 1. Virus isolations from *Ixodes uriae* collected at Røst Islands, Lofoten, Norway in July 1974.

STAGE	NO. TICKS	UUKUNIEMI GROUP	KEMEROVO GROUP	B GROUP	UNTYPED	ALL STRAINS
Unengorged ♂	114					0
Unengorged ♀	35					0
Molted ♂	278	10 (3.6)*	5 (1.8)			15 (5.4)
Molted ♀	197	8 (4.1)	2 (1.0)	1 (0.5)	2	13 (6.6)
Molted nymphs	1305	12 (0.9)	6 (0.5)		4**	22 (1.8)
Total	1929	30 (1.5)	13 (0.7)	1 (0.05)	6	50 (2.6)

* Number of pools positive; % of ticks infected in parentheses.
** Including coronavirus- and orbiviruslike isolates by electron microscopy.

TABLE 2. Comparison of 3 Uukuniemi group isolates from *Ixodes uriae* in Norway with other members of the serogroup, based on results of complement-fixation tests.

		ANTIGEN			ASCITIC FLUID		
		NorV-707	NorV-820	NorV-868	NorV-707	NorV-820	NorV-868
NorV-707		—	512/256*	512/256	—	512/512	512/512
NorV-820		512/512	—	512/512	512/256	—	512/512
NorV-868		512/512	512/512	—	512/256	512/512	—
Scot FT/254		128/256	128/256	128/256	512/256	512/512	512/512
USSR LEIV 21c (Zaliv Terpeniya)	Ascitic fluid	256/512	256/512	256/512	512/256	512/512	512/512
USA 56300-38 (Oceanside)	Ascitic fluid	256/256	128/256	128/256	512/256	512/512	512/512
Fin S-23 (Uukuniemi)	Ascitic fluid	64/512	16/512	16/512	64/256	64/512	64/512
Fr Argas 27 (Grand Arbaud)	Ascitic fluid	16/≥1024	4/≥1024	8/≥1024	16/256	32/512	16/512
Pak T-462 (Manawa)	Ascitic fluid	<4/512	<4/512	<4/512	<4/256	<4/512	<4/512
EgAn 1825-61	Ascitic fluid	128/≥1024	128/≥1024	128/≥1024	64/256	64/512	64/512

* Heterologous serum titer/homologous serum titer.

Uukuniemi group viruses were readily reisolated. Their mean incubation time (about a week) did not markedly shorten in successive mouse passages. Most of the isolates reacted in early passages in complement-fixation tests with antibody prepared against the first Uukuniemi group virus isolated (NorAr V-697). This serum reacted with Zaliv Terpeniya and NorAr V-697 antigens to identical titers, but weakly, or not at all, with Uukuniemi (strains S 23, Jomala A 21, Potepli) and Grand Arbaud antigens. The relationships of 3 representative isolates of the Uukuniemi group are presented in TABLE 2.

Chick embryo cell cultures seemed to be more susceptible to Kemerovo group isolates than were mice because isolation of 2 strains and reisolation of 2 additional strains were successful in cell cultures only. Isolates were readily adapted to mice with a reduction in incubation time. In preliminary screening, all strains reacted with Great Island and

TABLE 3. Comparison of 3 Kemerovo group isolates from *Ixodes uriae* in Norway with other members of the serogroup, based on results of complement-fixation tests.

			ANTIGEN			ASCITIC FLUID		
VIRUS	STRAIN		NorV-808	NorV-873	NorV-962	NorV-808	NorV-873	NorV-962
—	NorV-808		—	256/1024*	256/1024	—	128/256	128/64
—	NorV-873		128/256	—	128/256	256/1024	—	128/64
—	NorV-962		128/64	128/64	—	256/1024	128/256	—
Tindholmur	DenAr 2		64/32	16/32	64/32	256/1024	128/256	64/64
Mykines	DenAr 12		64/256	32/256	8/256	512/1024	128/256	64/64
Cape Wrath	ScotAr 20		64/32	64/32	64/32	512/1024	128/256	128/64
Great Island	CanAr 41		64/128	128/128	128/128	512/1024	128/256	64/64
Bauline	CanAr 14	Ascitic fluid	64/128	128/128	64/128	256/1024	128/256	64/64
Yaquina Head	USA 15	Ascitic fluid	32/128	32/128	32/128	128/1024	128/256	64/64
Okhotskiy	USSR LEIV 287ka	Ascitic fluid	32/64	32/64	32/64	128/1024	64/256	32/64
Nugget	AusMI-14847	Ascitic fluid	128/256	64/256	64/256	256/1024	256/256	128/64
Kemerovo	R-10	Ascitic fluid	64/512	64/512	64/512	256/1024	128/256	64/64
Tribec	original	Ascitic fluid	32/128	32/128	32/128	128/1024	64/256	32/64
Lipovnik	Lip 91	Ascitic fluid	32/128	32/128	32/128	128/1024	32/256	32/64
Chenuda	EgAr 1152	Ascitic fluid	<4/128	<4/128	<4/128	16/1024	8/256	4/64
Baku	USSR LEIV 46A	Ascitic fluid	8/512	32/512	<4/512	64/1024	32/256	16/64
Mono Lake	CalAr 861	Ascitic fluid	8/256	<4/256	8/256	32/1024	32/256	16/64
Huacho	CalAr 883	Ascitic fluid	<4/128	<4/128	<4/128	128/1024	64/256	32/64
Wad Medani	EgAr 492	Ascitic fluid	<4/128	4/128	<4/128	4/1024	<4/256	<4/64

* Heterologous titer/homologous titer.

TABLE 4. Comparison of NorV-724 and other group B viruses by complement-fixation and hemagglutination-inhibition tests.

VIRUS	NORV-724 ANTIGEN		NORV-724 ANTIBODY	
	CF	HI	CF	HI
Tyuleniy	64/64*	320/160	128/128	160/2560
Saumarez Reef	32/128	160/320	128/128	320/2560
Kadam	8/64	80/80	16/512	80/2560
Kyasanur Forest disease	32/512	320/160	8/512	80/2560
Karshi	32/512	160/1280	16/128	80/2560
Langat	0/256	160/640	16/512	80/2560
Louping ill	64/≥1024	160/640	8/512	80/2560
Omsk hemorrhagic fever	16/256	80/160	0/512	40/2560
Powassan	32/512	20/160	16/512	80/2560
Tick-borne encephalitis—Far East	64/1024	80/320	0/512	80/2560
Tick-borne encephalitis—Central European	16/1024	160/160	0/512	80/2560
Alfuy			16/512	160/2560
Banzi	0/64	20/40	32/512	160/2560
Bussaquara			8/512	320/2560
Dengue 1	16/512	160/1280	0/512	40/2560
Dengue 2	0/32	0/20	16/512	160/2560
Dengue 3	256/≥1024	640/1280	0/512	80/2560
Dengue 4	0/128	20/2560	32/512	160/2560
Edge Hill	0/64	20/—	32/512	—/2560
Ilheus	0/128	40/—	32/512	—/2560
Japanese B encephalitis	32/512	160/2560	0/512	640/2560
Kokobera	0/16	40/20	16/512	160/2560
Kunjin	8/128	80/160	32/512	320/2560
Murray Valley encephalitis	0/128	40/320	64/512	1280/2560
Ntaya	0/64	20/640	16/512	640/2560
St. Louis encephalitis	256/≥1024	640/640	32/512	160/2560
Spondweni	8/256	80/160	16/512	80/2560
Stratford			16/512	
Tembusu			32/512	80/2560
Uganda S	0/32	20/20	16/512	0/2560
Usutu	128/≥1024	320/320	64/512	160/2560
Wesselsbron	0/64	20/40	32/512	320/2560
West Nile	128/≥1024	320/—	16/512	—/2560
Yellow fever	0/128	40/40	32/512	80/2560
Zika	0/256	40/640	32/512	160/2560
Apoi	0/128	20/10	16/512	40/2560
Cowbone Ridge		20/20	8/512	80/2560
Dakar bat	0/64	20/20	8/512	40/2560
Entebbe bat	0/8	10/20	0/512	0/2560
Jutiapa	8/≥1024	40/160	0/512	40/2560
Israel turkey meningitis		20/160	32/512	160/2560
Modoc	0/16	20/40	0/512	20/2560
Montana *Myotis* leukoencephalitis	32/1024	40/—	0/512	—/2560
Negishi		40/—	8/512	40/2560
Phnom Penh bat	32/256	160/320	0/128	80/2560
Saboya			8/512	160/2560
U.S. (Burns) bat	64/512	160/80	0/512	40/2560
Yokose	32/256	320/2560	0/128	2560/2560
Sokuluk			0/512	
Group B ascitic fluid	16/64–128	320/40–320		

* Heterologous serum titer/homologous serum titer. Initial dilution: Sera—CF 1:8, HI 1:10; Antigen—CF 1:4.

Okhotskiy ascitic fluids. Results of cross-complement-fixation tests with 3 isolates and Kemerovo group agents are presented in TABLE 3.

One strain (NorAr V-724), from a pool of 3 molted female ticks, was found to be similar to or identical with Tyuleniy virus by hemagglutination-inhibition, complement-fixation and neutralization tests (TABLE 4, 5). Of the untyped isolates, 1 strain (NorAr V-958) morphologically resembled a coronavirus by electron microscopy (FIG. 1). It was isolated from a pool of 20 nymphs collected as larvae and held in the laboratory for 6 months. This

TABLE 5. Comparison of NorV-724 with Tyuleniy and Saumarez Reef viruses by neutralization tests in suckling mice.

	Ascitic fluids						
	(NorV-724)		Tyuleniy (USSR LEIV 6c)		Saumarez Reef (Aus CSIRO 4)		Normal
Virus	LLD_{50}*	LNI*	LLD_{50}	LNI	LLD_{50}	LNI	LLD_{50}
NorV-724	2.4	4.6	3.4	3.6	5.4	1.6	7.0
USSR LEIV 6c	3.1	4.7	3.1	4.7			7.8
Aus CSIRO 4	6.0	2.2			4.4	3.8	8.2

* LLD_{50} = $\log_{10}$ of the LD_{50} by intracerebral inoculation of suckling mice, LNI = $\log_{10}$ of the neutralization index.

strain was reisolated and caused a cytopathic effect in both chick embryo and baby hamster kidney (BHK/WI-2) cells (Vaheri et al. 1967).

DISCUSSION

Studies on the ecology of *I. uriae* at Lofoten are lacking, although they have been published from the Murmansk area of the USSR (Flint & Kostyrko 1967, Karpovich 1970), which is at the same latitude but with a much cooler winter temperature due to the diminished effect of the Gulf Stream. At Murmansk, the Thick-billed Murre, *Uria lomvia,* replaces the Common Murre as a primary host for this tick.

Engorged female *I. uriae* were not collected in early July, suggesting that they had not completed their engorgement. Males, which do not feed, and engorged larvae and nymphs were found tightly packed in crevices in the rocks. Virus was not isolated from unengorged adult ticks that apparently had overwintered. This is compatable with the hypothesis that an arbovirus in a hibernating vector can go into an "invertebrate" cycle in which the virus is difficult to detect in vertebrates or in vertebrate cells at higher temperatures (Schlesinger 1975). Evidence of this phenomenon has been presented in studies on transovarial transmission of Japanese encephalitis virus in mosquitoes (Rosen et al. 1978). The easily detected isolates from engorged and molted ticks in our studies may be due to recently acquired virus of the "vertebrate" type, to alterations in tick physiology during feeding and molting, or to exposure during engorgement to the body temperature of the bird. The isolates, although not proven arboviruses, were recovered from molted ticks and thus were maintained and passed transstadially in *I. uriae.*

The spectrum of viruses isolated from this species in different parts of the world varies considerably (L'vov et al. 1975, Yunker 1975, Main 1976). The high infection rates of viruses in *I. uriae* may have led to some mixed isolates, but overall ratios of Uukuniemi and Kemerovo group viruses and Tyuleniy virus were similar to those reported in the Murmansk region but differed from those observed in the Far East (L'vov et al. 1975). Viruses of the Kemerovo and Sakhalin groups, but not the Uukuniemi group, were isolated from *I. uriae* in eastern Canada and the Faeroe Islands (Main et al. 1976a, b), despite similar host species and connecting bird migratory pathways between the Faeroe Islands and Lofoten. A comparison can be made only by matching the status of ticks and isolation methods. Chick embryo cell cultures were more sensitive to Kemerovo group viruses than were mice.

Electron microscopy was a simple and rapid method for preliminary classification of these viruses and worthy of wider application in arbovirus studies.

The isolation of a coronaviruslike agent, transmitted transstadially and maintained for 6 months in *I. uriae,* is interesting. Runde virus, morphologically a coronaviruslike agent, was reported from *I. uriae* in southern Norway (Traavik & Mehl 1975, Traavik et al. 1977). This is an unusual structural group among the arboviruses. These isolates must await biologic verification of an arbovirus cycle and biochemical characterization of nucleic acid and polypeptide composition before final classification is attempted.

Complement-fixation tests on the Uukuniemi and Kemerovo group viruses produce complexes that often reflect the origin of the isolates (Main 1976). For example, within the Kemerovo serogroup there are 4 such groupings: the Chenuda complex associated with argasid vectors, the Wad Medani complex from ixodid ticks of the subfamilies Amblyomminae and Rhipicephalinae, the Kemerovo complex from the *Ixodes ricinus* com-

plex, and the Cape Wrath complex from *I. uriae* (Main et al. 1976b). The Uukuniemi and Kemerovo group viruses isolated in our studies fall into the complexes associated with *I. uriae*. Neutralization tests reveal a variety of serotypes of Kemerovo group viruses circulating in the same bird colony (Main et al. 1973, Main 1978); therefore, cross-neutralization tests must be completed before final classification of the isolates is made.

The complex pattern of viruses recovered from the ecosystem involving *I. uriae* and seabirds, with a limited number of variables, presents a suitable model for the study of virus evolution.

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