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ARBOVIRAL DISEASE SURVEILLANCE AND CONTROL IN CALIFORNIA[1, 2]

Richard W. Emmons[3]

California's long-standing public health concern about arboviral encephalitis has helped spur development of an extensive surveillance and control program. This article provides an overview of current state actions directed at identification and control of arboviral disease.

Introduction

California has a long tradition of scientific interest and public health concern about arboviral encephalitis, malaria, and other mosquito-related health problems. Early studies by Reeves and Hammon (1962) in the San Joaquin Valley helped define the ecology and epidemiology of western encephalitis (WEE) and St. Louis encephalitis (SLE), the major mosquito-borne viral diseases in California. The large human epidemics of WEE and SLE in 1950, 1952, and 1954 (Table 1) further stimulated development of coordinated arbovirus surveillance and mosquito control programs (Longshore, 1960; Meyers et al., 1960; Loomis and Meyers, 1960; Longshore et al., 1960). The advance of Venezuelan equine encephalitis (VEE) into Texas during the summer of 1971, following its earlier progress northward through Central America and Mexico, added impetus to California's program. Although human cases have been rare over the past two decades, as compared with earlier epidemic years, the WEE and SLE viruses have persisted in their natural mosquito-bird cycles. Large epidemics could easily recur if control measures failed.

The surveillance program of the California Department of Health Services includes searching for human cases of WEE, SLE, and other arbovirus diseases; detection of equine cases of WEE; detection of arbovirus infections in mosquitoes and in various domestic or wildlife species; monitoring of larval and adult mosquito populations in endemic areas; and prediction of rainfall, snow-melt, and flood conditions that affect mosquito breeding, particularly in the Central Valley areas of California. Control and prevention activities include: management of agricultural water use; application of chemical, physical, and biological mosquito control methods; immunization of equine animals against WEE; and personal health measures. Research activities are an important part of the program.

The Health Services program is conducted largely by the Infectious Disease Section, the Veterinary Public Health Unit, the Viral and Rickettsial Disease Laboratory, and the Vector Control Section. This overall program is integrated with the programs of over 60 independent local vector abatement agencies, most of which have been established in encephalitis-endemic

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[3] Chief, Viral and Rickettsial Disease Laboratory, Department of Health Services, Berkeley, California.

Table 1. Recorded human cases of arthropod-borne encephalitis in California, 1950-1977.

Year	No. of cases			No. of deaths
	Total	WEE	SLE	
1950	157	88	69	2 (1 WEE, 1 SLE)
1951	55	22	33	–
1952	420	375	45	10 (9 WEE, 1 SLE)
1953	36	14	22	1 (SLE)
1954	121	22	99	2 (SLE)
1955	9	6	3	–
1956	21	14	7	–
1957	26	3	23	1 (SLE)
1958	53	37	16	–
1959	42	2	40	1 (SLE)
1960	13	1	12	–
1961	10	2	8	1 (WEE)
1962	21	5	16	1 (SLE)
1963	15	3	12	–
1964	12	10	2	–
1965	10	9	1	–
1966	17	9	8	–
1967	15	7	8	–
1968	15	11	4	–
1969	5	–	5	–
1970	2	–	2	–
1971	5[a]	3	2	–
1972	8[b]	3	5	–
1973	5	–	5	–
1974	–[c]	–	–[c]	–
1975	–[d]	–	–[d]	–
1976	3	–	3	–
1977	1	–	1	–

[a]One additional case of VEE was confirmed in a traveler to Mexico.

[b]Two additional cases of VEE were confirmed in travelers to Mexico.

[c]One case of SLE contracted in Texas is not included.

[d]One case of SLE contracted in Texas and one case contracted in Illinois are not included.

areas of the state, and with the programs of county health departments, the California State Department of Food and Agriculture, and various campuses of the University of California (see various review articles in California Mosquito Control Association, 1975). The surveillance findings of the Department of Health Services have been published annually since 1971 (Emmons et al., 1972 through 1977).

Human Arbovirus Disease Surveillance

A summary of the surveillance activities and findings of the past seven years is given in Table 2. Human arbovirus disease surveillance is carried out by the Infectious Disease Section and Viral and Rickettsial Disease Laboratory, with the cooperation of private physicians and county health departments. Acute-phase and convalescent-phase sera from something on the order of 500 to 1,000 suspected cases of encephalitis or meningitis are submitted annually and are tested for complement-fixing (CF) antibodies to WEE and SLE viruses, as well as for antibodies to mumps, herpes, poliomyelitis, leptospirosis, lymphocytic choriomeningitis, and other possible causes of central nervous system disease. During 1971-1973, routine tests for VEE virus were also done. Stool, cerebrospinal fluid, and throat-washing samples are tested for enteroviruses, herpes virus, and other viral agents that might cause similar disease. Brain samples from fatal cases of encephalitis are tested for virus by intracerebral (i.c.) inoculation into suckling mice, and by inoculation of human fetal diploid kidney cell cultures and primary rhesus or cynomolgus monkey kidney cell cultures. In addition to the state Viral and Rickettsial Disease Laboratory effort, several county public health laboratories also conduct arbovirus serologic tests.

Cases of WEE and SLE detected by CF tests are further studied serologically by indirect fluorescent antibody, hemagglutination-inhibition (HI), and neutralization tests. Serum samples from some 100 to 200 cases of suspected encephalitis are saved annually for a cooperative study being conducted with the University of California (Berkeley) School of Public Health. These samples are tested for HI antibodies to a large group of other arboviruses whose presence is known or suspected in California, in order to detect possible new disease syndromes and disease agents.

Table 2. Results of arbovirus surveillance work performed by the California Department of Health Services.

	1971	1972	1973	1974	1975	1976	1977
I. Suspected human cases of encephalitis or meningitis tested serologically	*620*	*729*	*1,037*	*643*	*583*	*455*	*316*
SLE-positive	3	5	5	1[a]	2[a]	3	1
WEE-positive	3	3	0	0	0	0	0
VEE-positive	0	2[a]	0	0	0	0	0
II. Suspected equine cases of encephalitis tested serologically	*145*	*68*	*56*	*61*	*40*	*35*	*31*
WEE-positive	16	1	2	2	0	0	1
III. Number of mosquito pools tested	*1,784*	*6,336*	*4,838*	*1,690*	*1,002*	*1,273*	*836*
WEE-positive	16	42	97	4	0	0	19
SLE-positive	6	64	75	2	0	10	6
Other positive	43	74	109	38	0	12	19
Total positive	65	180	281	44	0	22	45

[a]Contracted out of state.

Clinical and epidemiologic reports on proven cases of WEE and SLE are submitted by the physician involved to the county and state vital statistics units, and summaries of those reports are forwarded to the Center for Disease Control and the World Health Organization.

Equine Disease Surveillance

Equine cases of encephalitis are reported by private veterinarians to the State Department of Food and Agriculture—and to county and State Health Department veterinarians, who provide consultation and diagnostic and investigative help. The first equine cases often occur several weeks before the first human cases, and may thus provide "early warning" of a threatening epidemic. Acute-phase and convalescent-phase serum samples are tested by the state Viral and Rickettsial Disease Laboratory for WEE complement-fixing antibody; in addition, these sera are tested by HI for various other arbovirus antibodies at the laboratory of the University of California (Berkeley) School of Public Health. Brain samples from fatal cases are tested for rabies by the fluorescent antibody test, and for WEE and other arboviruses by i.c. inoculation into suckling mice.

Mosquito Surveillance

Mosquito surveillance is conducted by local vector abatement agencies and by the state Vector Control Section, which also provides coordination and consultation services to the local agencies. Weekly reports are received on populations of larval and adult mosquitoes—especially *Culex tarsalis*, the primary vector of WEE and SLE. The reports, coming from 48 defined areas of the state where 361 standard light traps are currently in operation, provide a basis for estimating relative mosquito abundance and for predicting the potential threat of epidemic encephalitis.

The state Vector Control Section also makes special collections of mosquitoes, primarily *C. tarsalis*. These specimens are identified; pooled by species, date, and area; and tested at the state Viral and Rickettsial Disease Laboratory by i.c. inoculation into suckling mice. Fluorescent antibody staining of the brains of inocu-

lated mice—using specific fluorescein isothiocyanate-conjugated antisera prepared at the Viral and Rickettsial Disease Laboratory—provides a rapid, efficient, and accurate method for identifying isolated viruses. Under ideal circumstances virus can be isolated and identified within a week of the time the mosquitos are collected in the field, thus providing early warning of virus build-ups in endemic areas. As shown in Table 2, the number of viral isolates has varied widely from year to year: 1975 was unusual—in that no viruses could be isolated from over 1,000 mosquito pools tested, and no laboratory-confirmed human or equine cases were found that had acquired the infection in California.

Further Considerations and Activities

Though strains of California encephalitis virus (CEV) are isolated occasionally in the state, and although this virus is a common cause of childhood febrile illness and encephalitis in the central and eastern United States, it is not known to cause disease in California at present. Similarly, eastern encephalitis virus, a problem in the eastern and central United States, is not known to occur in California. Other mosquito-borne viruses encountered by the surveillance program—such as Turlock, Hart Park, and Bunyamwera-group viruses—are not yet known to play a significant role in human or equine disease but must be studied further in this regard.

Records of water conditions and precipitation (rain and snow) have obvious significance for urban and rural life, especially for agriculture, industry, and flood control. Such records are also important for predicting possible epidemic outbreaks of arbovirus encephalitis, since inadvertently flooded Central Valley farmlands are a major source of mosquito breeding sites.

Other indices used in arbovirus surveillance include special serologic surveys of human populations, domestic chicken flocks, or wildlife populations—surveys conducted in order to study specific foci of arbovirus transmission in more detail.

The role of various bird species—as hosts for virus amplification and the primary source for mosquito infection—is undoubtedly important, but this is one link in the chain of virus maintenance that is not well-studied. At present, surveillance programs do not include accurate estimates of bird populations or their possible contribution to arbovirus epidemics.

Special arbovirus research programs being conducted by various University of California branches in selected foci (in particular those of the U.C., Berkeley, School of Public Health in the Sacramento and San Joaquin Valleys, and the U.C., Los Angeles, School of Public Health in the Imperial Valley) have elucidated arbovirus ecology and the biological characteristics of the important mosquito vectors in these areas. The information gained from these studies, which is shared with the Department of Health Services, has been making an important contribution to the planning of surveillance and control programs. The complex of factors that influence the probability of epidemics has been succinctly summarized by Reeves (1967). Annual review and planning sessions by the various concerned agencies also help to coordinate efforts for the coming year.

At present, the only tick-borne arbovirus disease of significance in California is Colorado tick fever. Only about one or two dozen cases are confirmed annually in the state, but many more undoubtedly occur without being detected or reported. Although rarely fatal, the malady occasionally appears as a hemorrhagic or encephalitic disease in children; and it often mimics a more serious rickettsial disease, Rocky Mountain spotted fever. Fluorescent antibody staining of peripheral blood smears provides a rapid diagnostic test for Colorado tick fever, and the virus is easily isolated from the blood by inoculation of suckling

mice. Control of this disease depends on personal prophylaxis rather than on environmental control measures.

Measures for controlling mosquito-borne virus diseases, mentioned briefly in the introduction, include public health education, water management, and mosquito reduction. Annual efforts are made—through news media and special bulletins to physicians and medical groups—to educate the public and the medical community about prevention of mosquito-transmitted diseases. Efforts are also made to avoid excessive irrigation of crops or flooding of land that would provide vector mosquitoes with breeding habitats. Use of larvivorous fish (*Gambusia*) in irrigated rice fields and other permanent or semi-permanent bodies of water is also helpful.

This latter biological control measure is supplemented by use of insecticides, primarily larvicides, formulated from approved, nonpersistent compounds that do the least possible damage to the ecosystem. Active research programs by the state Vector Control Section, the University of California, and the vector abatement agencies make vital contributions to countering problems of insecticide resistance, possible damage to the ecosystem by insecticides, and the changing distribution and biological and genetic characteristics of mosquito species. When an epidemic is anticipated, widespread air and ground dispersal of low-volume insecticides can be used to reach otherwise inaccessible terrain.

California has been fortunate in having a low level of arbovirus encephalitis—less than two dozen human cases annually—since 1959, and no fatalities since 1962. However, vigilance must be maintained, since epidemics could recur should mosquito control falter, and since the cost of prevention and control is only a small fraction of the potential cost to society in terms of disability and death caused by arboviral disease.

SUMMARY

California has a long tradition of public health concern about arthropod-borne viral encephalitis, a concern intensified by large human epidemics of western and St. Louis encephalitis (WEE and SLE) in the 1950's and the advance of Venezuelan equine encephalitis (VEE) into Texas in 1971. This article reviews the state's current efforts to identify and control these and other arboviral diseases.

With the cooperation of private physicians and county health departments, state agencies test numerous sera from suspected encephalitis and meningitis cases for WEE and SLE viruses, as well as for other causes of CNS disease. Also, samples of stools, throat-washings, and cerebrospinal fluid from such cases—as well as brain samples from fatal encephalitis cases—are tested for appropriate viral agents. Clinical and epidemiologic reports are drawn up on proven WEE and SLE cases, and summaries of these are forwarded to the U.S. Center for Disease Control and the World Health Organization.

Prompt detection and reporting of encephalitis cases in equine animals helps provide early warning of possible epidemics. Acute and convalescent equine sera are tested by complement fixation for WEE antibody and by hemagglutination-inhibition for various other arboviral antibodies. Brain samples from fatal equine cases are tested for WEE and other arboviruses by intracerebral inoculation into suckling mice.

In addition, the state helps to monitor local mosquito populations—and also collects mosquitoes for the express purpose of finding out what arboviruses they may contain. Under ideal conditions, virus can be isolated from such mosquitoes and identified within a week of the time the mosquitoes were collected in the field—thus providing early warning of virus build-ups in endemic areas.

California has been fortunate in having a low level of arbovirus encephalitis since 1959, and no fatalities since 1962. However, vigilance must be maintained, since epidemics could recur should mosquito control falter, and since the cost of prevention and control is only a small fraction of the cost to society in terms of the potential disability and death that could be caused by arboviral disease.

REFERENCES

(*1*) California Mosquito Control Association. *Proceedings and Papers of the Forty-third Annual Conference of the California Mosquito Control Association, Inc., January 26-29, 1975.* California Mosquito Association Press, Visalia, California, 1975, 176 pp.

(*2*) Emmons, R. W., R. F. Peters, and G. L. Humphrey. Surveillance for Venezuelan Equine Encephalitis Virus and Other Arthropod-borne Viruses by the California State Department of Public Health, 1971. In: *Proceedings and Papers of the Fortieth Annual Conference of the California Mosquito Control Association, Inc., January 31-February 2, 1972.* California Mosquito Control Association Press, Visalia, California, 1972, pp. 9-16.

(*3*) Emmons, R. W., G. Grodhaus, and D. Cappucci. Surveillance for Arthropod-borne Viruses and Disease by the California State Department of Public Health. In: *Proceedings and Papers of the Forty-first Annual Conference of the California Mosquito Control Association, Inc., January 28-31, 1973.* California Mosquito Control Association Press, Visalia, California, 1973, pp. 13-25.

(*4*) Emmons, R. W., G. Grodhaus, and E. V. Bayer. Surveillance for Arthropod-borne Viruses and Disease by the California State Department of Health, 1973. In: *Proceedings and Papers of the Forty-second Annual Conference of the California Mosquito Control Association, Inc., and the Thirtieth Annual Meeting of the American Mosquito Association, Inc., February 24-27, 1974.* California Mosquito Control Association Press, Visalia, California, 1974, pp. 193-203.

(*5*) Emmons, R. W., G. Grodhaus, and E. V. Bayer. Surveillance for Arthropod-borne Viruses and Disease by the California State Department of Health, 1974. In: *Proceedings and Papers of the Forty-third Annual Conference of the California Mosquito Control Association, Inc., January 26-29, 1975.* California Mosquito Control Association Press, Visalia, California, 1975, pp. 59-65.

(*6*) Emmons, R. W., G. Grodhaus, and E. V. Bayer. Surveillance for Arthropod-borne Viruses and Disease by the California State Department of Health, 1975. In: *Proceedings and Papers of the Forty-fourth Annual Conference of the California Mosquito Control Association, Inc., January 25-28, 1976.* California Mosquito Control Association Press, Visalia, California, 1976, pp. 21-25.

(*7*) Emmons, R. W., G. Grodhaus, and E. V. Bayer. Surveillance for Arthropod-borne Viruses and Disease by the California State Department of Health, 1976. In: *Proceedings and Papers of the Forty-fifth Annual Conference of the California Mosquito and Vector Control Association, Inc., February 13-16, 1977.* California Mosquito Control Association Press, Visalia, California, 1977, p. 23-27.

(*8*) Longshore, W. A., Jr. California encephalitis surveillance program: Introduction. *Am J Hyg* 71(3):363-367, 1960.

(*9*) Longshore, W. A., Jr., E. H. Lennette, R. F. Peters, E. C. Loomis, and E. G. Meyers. California encephalitis surveillance program: Relationship of human morbidity and virus isolation from mosquitoes. *Am J Hyg* 71(3):389-400, 1960.

(*10*) Loomis, E. C., and E. G. Meyers. California encephalitis surveillance program: Mosquito population measurement and ecologic considerations. *Am J Hyg* 71(3):378-388, 1960.

(*11*) Meyers, E. G., E. C. Loomis, F. Y. Fujimoto, M. I. Ota, and E. H. Lennette. California encephalitis surveillance program: Mosquito-virus relationships. *Am J Hyg* 71(3):368-377, 1960.

(*12*) Reeves, W. C. Factors that influence the probability of epidemics of western equine, St. Louis, and California encephalitis in California. *California Vector Views* 14(2):13-18, 1967.

(*13*) Reeves, W. C., and W. McD. Hammon. *Epidemiology of the Arthropod-borne Viral Encephalitis in Kern County, California, 1943-1952.* University of California Publications in Public Health, Vol. 4, University of California Press, Berkeley, California, 1962, 257 pp.