

Factors Affecting the Transmissibility of Bancroftian Filariasis by Mosquitoes

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Abstract

The transmissibility of bancroftian filariasis by a vector mosquito, in other words, the epidemiological danger of filariasis infection due to the mosquito to persons in a community is very important to understand the dynamic states of the disease. It may be expressed by the product of three factors, the effective microfilarial prevalence corrected considering the microfilarial density, the effective period of transmission, and the abundance of mosquitoes during the effective period. The epidemiological danger was estimated by using the data obtained in field experiments carried out from 1961 to 1967 at Nagate and Okubo Villages, Nagasaki Prefecture, Japan, under the changing conditions in microfilarial prevalence and density due to the control of vector mosquitoes or the treatment of positive persons by drugs.

Introduction

To learn the transmissibility of bancroftian filariasis by mosquitoes, in other words, the danger of filariasis infection to persons in a community is very important to understand the dynamic states of the disease. The epidemiological danger can be given by a product of the abundance of a vector mosquito with infective filaria larvae and the effective period for transmission of the disease in a community. However, it is usually

impossible to collect a sufficient number of mosquitoes with infective larvae for the comparison of occurrence rates of such mosquitoes between years and communities. It is especially so in Japan (Omori, 1962, 1963). For the purpose, an indirect procedure for obtaining the degree of the danger is developed, in which, instead of using the abundance of the most important vector mosquito with infective larvae, a product of the effective

microfilarial prevalence corrected considering the microfilarial density of persons and the abundance of the vector mosquito is used. Accordingly, the epidemiological danger in a community will be presented by the product of three factors, the effective micro-

filarial prevalence, the abundance of the vector mosquito and the effective period for transmission. The factors are discussed separately at first, and then collectively in relation to the danger.

Microfilarial density of a person and the infection rate of mosquitoes fed on him

Before considering the factors, the relation between the microfilarial density of a person and the infection rate in a batch of females of *Culex pipiens pallens* fed simultaneously on him will be discussed to give a conception for effective microfilarial prevalence of a community.

Wada(1963) gave the relation between the microfilarial count of a person and the experimental infection rate in a batch of females of *Culex pipiens* complex fed on him, by plotting the probit of the experimental infection rate against the logarithm of the microfilarial count. But, the occurrence of some difference in the susceptibility to larvae of *Wuchereria bancrofti* between *C. p. pallens* and *C. p. fatigans* has recently been found (Omori et al., 1965), and *C. p. molestus* may also differ in the susceptibility. Therefore, the relation is reexamined as under by using the data on only *C. p. pallens*.

The theoretical or expected infection rate in a batch of *pallens* females fed simultaneously on a microfilarial carrier is given by $1 - p(0)$, where $p(0)$ is the probability of non-infection or of the rate of the females which are not infected. Letting the mean uptake number of microfilariae for engorged females of the batch be m , then the theoretical infection rate, $1 - p(0)$, will be obtained as follows. If the numbers of microfilariae in female mosquitoes fed simultaneously on a carrier

follow Poisson distribution or random distribution, then $p(0)$ is e^{-m} and therefore $1 - p(0)$ is $1 - e^{-m}$. If the numbers of microfilariae in females follow negative binomial distribution or aggregated-type distribution, then $p(0)$ is $(1 - m/k)^{-k}$ and therefore $1 - p(0)$ is $1 - (1 - m/k)^{-k}$ where k is calculated as 1.103 after Bliss and Owen(1958).

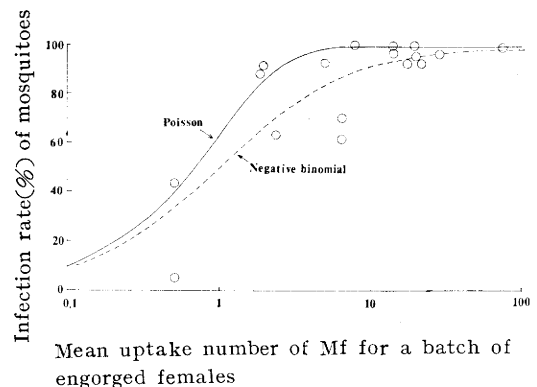


Fig. 1. Relation between the expected mean uptake number of microfilariae* for a batch of *Culex pipiens pallens* females fed simultaneously on a carrier and the observed infection rate of the batch (shown by circles), showing that the distribution of the observed infection rates coincides better with the distribution of the theoretical infection rates obtained under the assumption that the numbers of microfilariae in the females follow negative binomial (shown by a broken curve) than with the distribution under Poisson (shown by a solid curve). For further explanation, see text.

*The expected mean uptake number of microfilariae was calculated by multiplying the microfilarial count of the carrier by the ratio of the mean amount of blood in a batch of engorged females to the amount of the carrier's blood examined.

Fig. 1 gives the relation between the expected mean uptake number of microfilariae

(see*in Fig. 1) in a batch of *C. p. pallens* females fed simultaneously on a carrier and observed infection rate of the batch, together with the curves for the theoretical infection rates for Poisson and negative binomial distributions calculated as mentioned above. It is seen from Fig. 1 that the distribution of the observed infection rates coincides better with the curve for the negative binomial distribution than with that for Poisson distribution.

Mean amount of blood taken by *pallens* females in the present data was 5.65mm³. Therefore, the expected mean uptake number of microfilariae in a batch of females fed on a carrier is obtainable proportionally from the number of microfilariae in 60mm³ blood of the carrier. Thus, in Table 1, a necessary mean uptake number of microfilariae in a batch of *pallens* females fed on a carrier to be expected to get a certain infection rate

Table 1. The relation among the expected infection rate in a batch of *Culex pipiens pallens* females fed on a carrier, the expected mean uptake number of microfilariae in the batch of females which engorged 5.65mm³ blood of the carrier and the microfilarial count in 60mm³ blood of the carrier on whom the mosquitoes are simultaneously fed. For further explanation, see text.

Expected infection rate (%) of fed females	Expected mean uptake No. of Mf in the fed females	No. of Mf in 60mm ³ blood of a carrier
10	0.11	1.17
20	0.24	2.55
30	0.41	4.36
40	0.66	7.01
50	0.97	10.30
60	1.44	15.29
70	2.18	23.15
80	3.38	35.89
90	7.99	84.72
99	71.70	761.42

in the batch of females is calculated by using the curve for the negative binomial distribution, and the microfilarial count in 60mm³ blood of the carrier to be expected to get a certain mean uptake number of microfilariae in the batch of females which have engorged 5.65 mm³ blood on an average is proportionally calculated. The expected infection rate of mosquitoes fed on a certain carrier can be considered as the ability of the carrier to infect mosquitoes. Here it will be called an "infection index" of the carrier. From the figures shown in Table 1, the relation is given between the number of microfilariae in 60mm³ blood of a carrier and the infection index in Table 2. For example, if the microfilarial count in 60mm³ blood of a carrier is from 3 to 4, the range of expected infection rates in *C. p. pallens* females fed on the carrier takes the value from 0.20 to 0.30; then the mean expected infection rate of mosquitoes or the infection index of the carrier is given by 0.25.

Table 2. Relation between the number of microfilariae in 60mm³ blood of a carrier and the infection index of the carrier expressed by the expected infection rate of *Culex pipiens pallens* when fed on the carrier.

No. of Mf per 60mm ³ blood of a carrier	Range of expected infection rates(%) of mosqs. when fed on the carrier	Infection index or mean expected infection rate of mosqs.
1	—10	0.05
2	10—20	0.15
3—4	20—30	0.25
5—7	30—40	0.35
8—10	40—50	0.45
11—15	50—60	0.55
16—23	60—70	0.65
24—35	70—80	0.75
36—84	80—90	0.85
85—761	90—99	0.95
762—	99—	1.00

Effective microfilarial prevalence in a community

The epidemiological danger of the filariasis infection to persons in a community is closely

related to microfilarial prevalence and density in the persons. When the prevalence is higher

in a village, then the infection rate of vector mosquitoes will be generally higher, and accordingly the epidemiological danger of filariasis infection will be larger. However, the infection rate of mosquitoes fed on a carrier depends greatly on the microfilarial density of the carrier, as shown in the preceding section.

Effective period for transmission

The second factor to affect the epidemiological danger is the effective period for bancroftian filariasis transmission. The speed of the development of filarial worms in mosquitoes is greatly influenced by temperature, and no development is likely to occur below about 15°C (Omori, 1958b). The possible transmission period in a year was determined in our Department to be about three months from late June to mid-September

If the infection indices for all persons in a village are totalled and then divided by the total number of villagers, the effective microfilarial prevalence corrected considering the microfilarial density is obtained. The effective microfilarial prevalence thus obtained is thought to be directly proportional to the natural infection rate of the vector mosquito.

in South Japan. On the other hand the residual spraying of imagicide suppresses perfectly the emergence of mosquitoes with infective filariae for about two months (Omori et al., 1967). Therefore, in a village where a residual spraying was applied, the effective period of transmission is given by the period which is obtained by subtracting the suppressed period in transmission from the possible transmission period of the three months.

Abundance of the vector mosquito

The third factor is the abundance of the vector mosquito during the effective period

Table 3. Yearly changes in epidemiological danger for the filariasis infection of persons in Nagate and Okubo Villages, given by the product of effective microfilarial prevalence (%), effective period of transmission (months), and mean number of *Culex pipiens pallens* per house during the effective period.

Village	Year	Effective microfilarial prevalence(%) (1)*	Effective months of transmission (2)**	Mean No. of <i>C. p. allens</i> per house (3)	Epidemiological danger of filariasis infection (1) x (2) x (3)
Nagate	1961	9.2	3.0	11.1	306.4
	1962	7.7	1.4	1.5	16.2
	1963	7.4	1.2	1.0	8.9
	1964	5.5	1.1	0.2	1.2
	1965	3.9	1.0	0	0
	1966	3.5	1.3	0.1	0.5
	1967	1.9	1.0	0	0
Okubo	1964	16.1	1.6	6.7	172.6
	1965	16.1***	1.5	3.8	91.8
	1966	10.7	1.6	1.6	27.4
	1967	11.5	1.6	2.8	51.5

*Effective microfilarial prevalence is given by dividing the total of indices for all villagers by the total number of villagers. As for infection index, see Table 2.

**Effective months of transmission are given by subtracting the suppressed period in transmission of two months by residual spraying from the possible transmission period of three months from late June to mid-September.

***Blood examination for microfilariae was not made in 1965, therefore the value in 1964 is substituted for.

of filariasis transmission. It can be given by the mean number of *C. p. pallens* per house by 20 minute catch.

Epidemiological danger for filariasis infection in a community

The epidemiological danger for bancroftian filariasis in a community may be presented by the product of the three factors mentioned above; i.e., the effective microfilarial prevalence, the effective transmission period, and the abundance of vector mosquitoes. In Table 3, the yearly changes are given of the epidemiological danger thus obtained in Nagate and Okubo Villages.

At Nagate Village, where microfilarial prevalence was 14.0% in 1961, mosquito control works by residual spraying and larvicide application have been continued since 1962 under non-treatment of persons with drugs (Wada, 1966). The effective microfilarial prevalence gradually decreased from 9.2% in 1961 to 1.9% in 1967. The effective period of transmission in month was 3.0 in 1961, and from 1.0 to 1.4 in and after 1962, owing to the residual spraying applied yearly in June. The mean number of mosquitoes was as large as 11.1 in 1961, but was very small thereafter. The epidemiological danger of filariasis infection was as high as 306.4 in 1961, while very markedly decreased to 16.2 in 1962, 8.9 in 1963, and 1.2 in 1964, and about zero thereafter. This marked reduction is apparently due partly to the gradual decrease in the effective microfilarial prevalence and mostly to the very notable decrease

in the number of mosquitoes.

At Okubo Village, where microfilarial prevalence was 26.4% in 1964, the residual spraying has been conducted in early August every year, and the treatment for microfilarial carriers was made in 1964. The effective microfilarial prevalence which was 16.1 in 1964 decreased slowly thereafter. The effective period of transmission was nearly the same during the four years. The mean number of mosquitoes was 6.7 in 1964, and the number decreased considerably thereafter owing to the elimination of some breeding places of mosquitoes by the villagers. The epidemiological danger was 172.6 in 1964, and it decreased rather slowly in and after 1965 due partly to the decrease in the effective microfilarial prevalence and partly to the decrease in the number of mosquitoes.

The epidemiological danger mentioned above is concerned with the situation in South Japan where only bancroftian filariasis exists and a main vector is *C. p. pallens*. But, it seems that the same procedure can be applied in the cases of other filariasis and other vectors. When two or more vector mosquitoes are responsible for the transmission of filariasis, the epidemiological danger for each vector species must be added to get the whole danger of the transmission in the area.

Summary

The transmissibility of bancroftian filariasis by the vector mosquito, or the epidemiological danger of filariasis infection to persons, may be presented by the product of three

factors, the effective microfilarial prevalence, the effective period of transmission, and the abundance of mosquitoes.

The effective microfilarial prevalence is

given as follows: The experimental infection rates of mosquitoes, *Culex pipiens pallens*, obtained by feeding experiments on carriers of various microfilarial counts well coincide with the theoretical infection rates calculated under the assumption that the number of microfilariae picked up by a mosquito follows negative binomial distribution. The theoretical or expected infection rate in a batch of females fed on a carrier can be considered as the ability of the carrier to infect the mosquito, or an infection index of the carrier. If the total of indices for all villagers is divided by the total number of villagers, then the quotient is the effective microfilarial prevalence corrected considering the microfilarial density.

The effective period of transmission is given by the period obtained by subtracting the suppressed period of two months in transmission by a residual spraying of insecticide from the possible transmission period of three

months from late June to mid-September.

The abundance of mosquitoes is given by the mean number of *C. p. pallens* per house during the effective period of transmission.

At Nagate Village, the epidemiological danger was very high in 1961, and very markedly decreased thereafter. This marked reduction is apparently due partly to the gradual decrease in the effective microfilarial prevalence and mostly to the very notable decrease in the number of mosquitoes owing to the yearly mosquito control work by residual sprayings and larvicide applications.

At Okubo Village, the epidemiological danger was considerably high in 1964, and decreased slowly in and after 1965 by the decrease in the effective microfilarial prevalence and the decrease in the number of mosquitoes owing to yearly residual sprayings and the drug administration for microfilarial carriers in 1964.

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蚊によるバンクロフト糸状虫症伝搬の危険性に影響 する要因について

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摘 要

ある部落におけるバンクロフト糸状虫症の蚊による伝搬性、即ち人間に対するフィラリア症感染の疫学的危険性は本病の動的様相を理解する上で極めて重要である。これは次の3つの要因の積として表わし得る：(1)仔虫数によって修正した有効仔虫保有率、(2)有効伝搬期間、(3)有効伝搬期間中の蚊の多少。これら3つの要因について、伝搬蚊の駆除あるいは患者に対する投薬によって仔虫保有率が変化しつつある長手及び大久保部落で得られた値を用い、疫学的危険性を吟味した。