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The epidemiology and control of lymphatic filariasis on Lihir Island, New Ireland Province

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SUMMARY

Clinical, parasitological and entomological surveys performed in 9 villages on Lihir Island, Papua New Guinea, before mass treatment with diethylcarbamazine (DEC), showed that lymphatic filariasis, caused by nocturnally periodic *Wuchereria bancrofti*, was endemic in 8 of them. Blood samples from 593 people revealed an overall microfilarial carrier rate of 24%. Amongst endemic villages, microfilarial carrier rates ranged from 5% to 43% and there was no significant difference in parasite prevalence between males and females. Obstructive filarial disease, defined as lymphoedema of the limbs or hydrocele, was observed in only 2% of 262 males examined. None of the 265 females examined had clinical symptoms. Entomological surveys yielded a total of 4095 mosquitoes including 3692 anophelines and 241 culicines but only *Anopheles farauti* was found to harbour infective larvae of *W. bancrofti*. Pretreatment infection and infective rates of *An. farauti* were 7% and 1% respectively and up to 12 infective larvae were found in a single specimen. The microfilarial carrier rate in a cohort of people who received two DEC treatments dropped from 59% to 32% but the difference was not statistically significant. However, density of microfilaraemia decreased significantly from 170 to 10 mf/ml. Biannual mass treatment with DEC significantly reduced vector infection rates and transmission intensity on Lihir.

Introduction

In Papua New Guinea lymphatic filariasis is caused only by *Wuchereria bancrofti* and the *Anopheles punctulatus* group of mosquitoes are the main vectors (1). The lymphatic-dwelling adult *W. bancrofti* causes damage to the lymphatic system which leads to lymphoedema, genital pathology (especially hydrocele) and elephantiasis. Globally, the disease is the second leading cause of permanent and long-term disability, with the deformation and mutilation of limbs and genitals resulting not only in physical disability but also in serious psychosocial consequences. In addition to the direct economic costs of managing the acute and chronic manifestations of lymphatic filariasis, there are the enormous indirect losses that follow from diminished productivity and incapacitation causing a severe drain on local and national economies (2).

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Large-scale construction work associated with the establishment of what was to become the largest gold mine in Papua New Guinea started on Lihir Island in 1995. Construction activities included the clearing of vegetation for erecting buildings, a 1200 m airstrip and a 75 km ring-road around the island. At least one village was relocated in the process. Invariably, in many areas where such large-scale environmental alterations have taken place there have been changes in disease patterns. This is especially true for mosquito-borne diseases such as lymphatic filariasis. Altering the environment could create more breeding grounds for mosquitoes and change the microclimate in such a way that their survival may be enhanced and ability to transmit disease increased.

Being fully aware of the health problems that may be associated with some mining activities, the Lihir Management Company requested the assistance of the New Ireland Health Department and the Papua New Guinea Institute of Medical Research to investigate the impact of the gold mine on the health of Lihirians and mine workers. This paper describes the prevalence of filariasis infection and disease before construction started and the impact of control measures initiated by the mining company.

Materials and Methods

Study site

Clinical and parasitological studies were performed among residents in nine villages on Lihir Island, which is located off the north coast of New Ireland (3°10'S, 152°40'E) about 70 km from Namatanai town. The island, which is volcanic in origin, has a land area of about 240 km^2 and is bounded by 70 km of coastline. It has a relatively dry savanna grassland in the north-east and a swampy vegetation with thick mangrove shores in the south-west. The average annual rainfall is about 4000 mm with no distinct dry and wet seasons. The inhabitants live in coastal villages, usually adjacent to a sandy beach or coral reef. In 1993, most of the islanders obtained their cash from coconut and cocoa plantations. However, most of the plantations, especially in the villages near the Ladolam Camp area, are now neglected as people prefer to work in the mines.

Clinical and parasitological methods

We made physical examinations for hydrocele or lymphoedema according to protocols described by the World Health Organization (WHO) (3). We assessed the rate of microfilaraemia from blood samples obtained between 2200 and 0200 hours. We used the thick blood film and modified Knott's technique (4) to determine infection status. All those examined, excluding pregnant women and children under 5 years, were treated with diethylcarbamazine (DEC) (6 mg/kg) in September 1993. Treatment was repeated in April 1994 but post-treatment infection rates were assessed in Wurtol village only.

Sampling and processing of mosquitoes

The all-night landing catch (1800 to 0600 hours) method was used to collect human-biting mosquitoes as described before (5). After morphological identification in the field, anopheline mosquitoes were randomly placed into two groups. One group was kept dry in silica gel while the other was preserved in 70% ethanol. In the laboratory, mosquitoes preserved in 70% ethanol were stained, using Mayer's acid haemalum according to the method of Nelson (6), and dissected for filarial larvae. Adult mosquitoes preserved dry were saved for malaria studies. All culicine species were preserved in 70% ethanol and dissected for filarial infection.

Calculation of monthly biting rate (MBR), monthly infective biting rate (MIBR) and monthly transmission potential (MTP)

Two indices of filarial transmission, MBR and MTP, were calculated based on the formula by Walsh et al. (7). MBR is the estimated number of female mosquitoes biting one person (1800 - 0600 hours) in one calendar month and MTP is the estimated number of infective third-stage larvae (L3) of *W. bancrofti* which the same person would be exposed to during the same one month. The product of MBR and the percentage of infective mosquitoes gives the MIBR.

Results

Clinical and parasitological findings

Clinical and parasitological examinations were carried out in 9 villages, not including Put Put where only entomological surveys were performed. Obstructive filarial disease in the form of lymphoedema or hydrocele was present in 2% of males (5/262). All 5 affected were more than 30 years old; 2 of them had both hydrocele and elephantiasis while 2 had hydrocele only. 1 had lymphoedema of the arm only. None of the 265 females examined had clinical symptoms.

The pretreatment cross-sectional survey of 593 people revealed an mf prevalence rate of 24% (Table 1). Microfilaraemic subjects were found in all villages surveyed, with the exception of Kunaie. Among endemic villages, microfilarial carrier rates ranged from 5% at Matakues to 43% at Wurtol. Blood samples from 294 people examined using both the Knott's and thick blood film techniques showed that microfilarial carrier rates determined by the two methods (28% and 17% respectively) were significantly different (χ^2=10.7, df=1, p<0.01). Microfilarial carrier rates (of 25%) were therefore underestimated for Talis and Sianus where only blood films were examined. A large proportion (37%) of microfilaraemic individuals, as determined by the Knott's test, were low-density carriers with less than 31 mf/ml of venous blood, and 13% had microfilarial densities of less than 11 mf/ml that would be difficult to detect using the thick film method.

Age-specific pretreatment microfilarial carrier rates and intensities of microfilaraemia for villages where blood samples were examined using the Knott's test are shown in Figure 1. The proportion of people with patent infection increased with age from 7.5% in children aged less than 5 years to 43% in adults aged 30-39 years; it then dropped slightly in the 40-49 year (36%) and over 50 year (23%) age groups. The difference in microfilarial carrier rates between males (27%) and females (21%) was not statistically significant. Among microfilaraemic individuals, the geometric mean intensity was 71 mf/ml (range 1-3500 mf/ml). The level of microfilaraemia peaked in the 5-9 year (106 mf/ml) and 20-29 year (146 mf/ml) age groups. Microfilaraemia was higher for females (87 mf/ml) than for males (59 mf/ml) but this difference was also not statistically significant.

TABLE 1

PRETREATMENT PREVALENCE (%) AND INTENSITY OF MICROFILARAEMIA IN NINE VILLAGES ON LIHIR ISLAND, NEW IRELAND PROVINCE

Village	No examined	% mf positive	Mf intensity (mf/ml)
Kunaie	36	0	0
Londolovit	69	5.8	4.2
Matakues	41	4.9	35.1
Talis*	105	24.8	*
Wurtol	120	43.3	162.4
Sianus*	83	25.3	*
Samo	50	38.0	80.1
Lamboar	47	19.1	13.6
Sali	42	26.2	14.2
Total	593	24.3	71.3

* Mf status was determined by the Knott's test except for villages marked with asterisks, where only blood films were examined

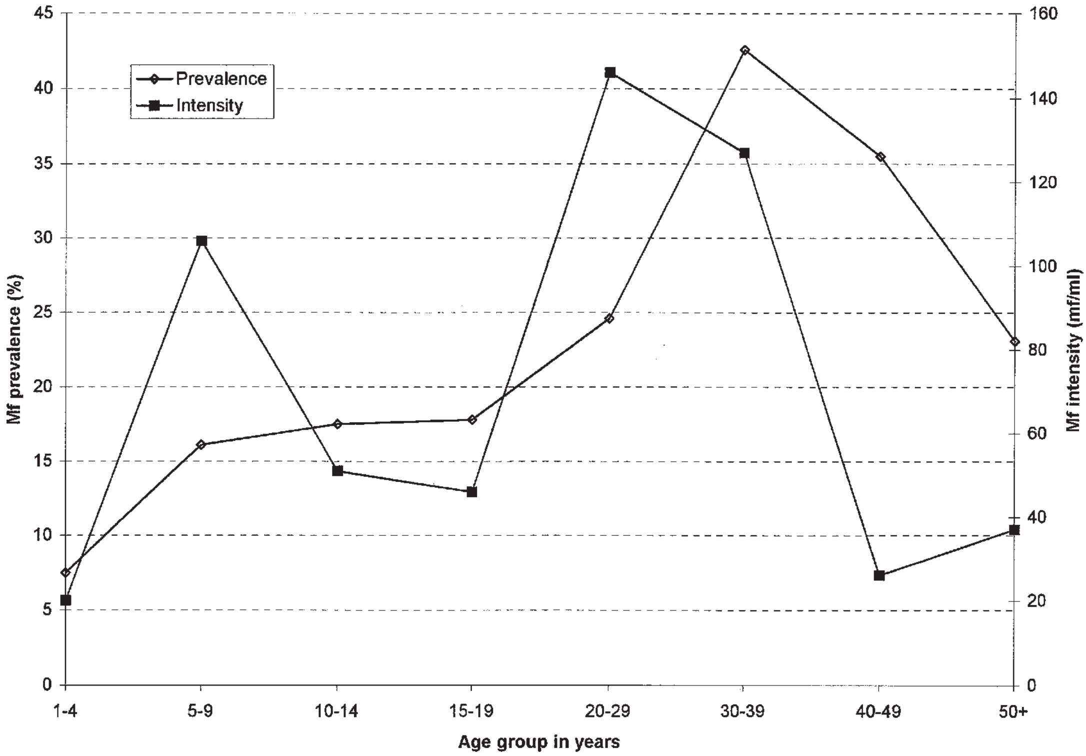

Figure 1. Age-specific pretreatment microfilarial carrier rates and intensities of microfilaraemia for villages where blood samples were examined using the Knott's test.

Effect of DEC treatment on microfilaraemia

Mass treatment with DEC was carried out at least once in all 8 villages where clinical examinations were performed. However, the effect of DEC treatment on prevalence and intensity of infection was determined only for Wurtol village where pre- and post-treatment blood samples were obtained. In the other villages people were bled only once.

Out of the 75 people who were bled and treated in Wurtol in September 1993, only 22 were available for bleeding in December 1994 after two DEC treatments. The mf prevalence for those treated twice reduced from 59% to 32% but the difference was not statistically significant. The geometric mean density of microfilaraemia decreased significantly from 170 to 10 mf/ml (Kruskal-Wallis H=9.38, df=1, $p<0.002$). All blood samples obtained from those treated twice had less than 27 mf/ml.

Mosquito vectors

Pretreatment mosquito collections in September 1993 revealed the average human-mosquito contact to be lower than 5 bites/person/night in 4 of the 9 villages surveyed. Mosquitoes were not collected at Lamboar. 2 person-nights of all-night biting catches produced no mosquitoes at Kunaie. For the subsequent 5 post-treatment entomological surveys, we selected 2 villages of low vector density (Londolovit and Put Put) and 2 of high vector density (Talis and Wurtol). The average human-biting rates in Londolovit and Put Put never exceeded 3 bites/person/night and none of the mosquitoes caught in these two villages were found to be infected with *W. bancrofti*.

The 6 surveys yielded a total of 4095 mosquitoes, including 3692 anophelines and 241 culicines. Culicine species included *Armigeres papuensis* (174 mosquitoes), *Cx. annulirostris* (18 mosquitoes) and *Cx.*

TABLE 2

Summary of dissection results for combined catches of *Anopheles farauti* at Talis and Wurtol villages, Lihir Island, Papua New Guinea

	Pretreatment		3 months after treatment		Months (M) after second treatment			
	N	(%)	N	(%)	M4 (%)	M6 (%)	M7 (%)	M9 (%)
Number of mosquitoes caught	291		660		205	320	722	170
Number dissected	258		271		123	155	440	95
Number with L1, L2 or L3 (%)	18	(7.0)	14	(5.2)	5 (4.1)	5 (3.2)	16 (3.6)	5 (5.3)
Number with L3 (%)	3	(1.2)	3	(1.1)	0	2 (1.3)	1 (0.2)	1 (1.1)
Geometric mean larvae per infected mosquito	3.6		2.8		2.4	2.0	2.6	4.3
Total number of L3	15		17		0	8	1	2
Maximum number of larvae per infected mosquito	18		11		41	5	25	13
Maximum number L3 per infective female	12		11		0	5	1	2
Number of person nights	4		8		12	8	8	8
Bites/person/night	72.8		82.5		17.1	40.0	90.3	21.3

TABLE 3

PRE- AND POST-TREATMENT MONTHLY BITING RATE (MBR), MONTHLY INFECTIVE BITING RATE (MIBR) AND MONTHLY TRANSMISSION POTENTIAL (MTP) OF *ANOPHELES FARAUTI* IN THE VILLAGES OF TALIS AND WURTOL, LIHIR ISLAND, PAPUA NEW GUINEA

	Pre-treatment	3 months after first treatment	Months (M) after second treatment				Total
			M4	M6	M7	M9	
MBR	2183	2558	530	1240	2702	657	9870
MIBR	26	28	0	16	5	7	82
MTP	127	160	0	64	6	13	370

quinquefasciatus (49 mosquitoes). All culicine mosquitoes were dissected but none was found infected with *W. bancrofti*.

A large proportion (96%) of the *Anopheles* mosquitoes caught were identified as *An. farauti*, followed by *An. punctulatus* (3.6%) and *An. koliensis* (0.4%). A total of 1906 *An. farauti* were dissected giving infection and infective rates of 3.9% and 0.6% respectively. Out of 80 *An. punctulatus* dissected, only 3 were infected with developing larvae (L1 or L2) and none with infective larvae (L3). None of the 10 specimens of *An. koliensis* dissected were infected with larvae of *W. bancrofti*. Table 2 gives a summary of dissection results for combined catches of *An. farauti* from Talis and Wurtol.

Impact of mass treatment on transmission

The effect of mass treatment with DEC on vector infection rates and transmission intensity was investigated at Talis and Wurtol only. According to the 1990 national census, the combined population of the two villages was 328. A total of 206 people above the age of five years, excluding pregnant women, received DEC (6 mg/kg) in September 1993 after mosquitoes were collected. During the second treatment visit in April 1994, the number of people who received the drug decreased to 157.

Three months after the first mass treatment with DEC the infection rate of *An. farauti*, the only species with infective larvae, was 5% compared to a pretreatment rate of 7% but the difference was not statistically significant. However, the combined infection rate for the 4 surveys after the second treatment (3.8%) was significantly lower than the pretreatment infection rate (χ^2=4.5, df=1, p=0.034). The total infective rate for the surveys after the second treatment (0.5%) was much lower than the pretreatment infective rate (1.2%) but the difference was not statistically significant. The mean number of total larvae (L1-L3) per infected mosquito did not change much during the different surveys (Table 2) but the mean number of infective larvae per infective mosquito for the 2 surveys before the second treatment (5.3) was almost double that for the 4 surveys after the second treatment (2.8).

The entomological indices of transmission, MBR, MIBR and MTP, calculated for the six different surveys are given in Table 3. Generally, MBRs were lower after the second treatment than before, but the highest MBR (2702 bites/person/month) was recorded 7 months after the second treatment. The MIBR for each of the 4 post-second treatment surveys was much lower than the pretreatment MIBR of 26 infective bites/person/month. In fact, the total MIBR for the 4 post-second treatment surveys (28 infective bites/person) was similar to the MIBR for the single pretreatment survey (26 infective bites/person). Post-second treatment MTPs (range 0-64 L3/person/month) were also much lower than the MTP before treatment (127 L3/person/month). The total MTP for the 4 post-second treatment surveys (83 L3/person) was still much lower than the pretreatment MTP.

Discussion

Lymphatic filariasis, caused by nocturnally periodic *W. bancrofti*, was widespread in Lihir where surveys in 9 villages gave an overall microfilarial carrier rate of 24%. There was pronounced small-area variation in the prevalence of patent infection amongst villages; microfilarial carrier rates in villages located in the swampy area of the west coast were 3 to 7 times higher than in villages on the relatively dry east coast. As observed for other areas in Papua New Guinea, the intensity of microfilaraemia generally increased with age, and the prevalence of patent infection was similar in both males and females (8-10). However, both the prevalence and intensity of microfilaraemia were low compared to other places in the country. Microfilarial carrier rates determined for 5 villages in the Mount Bosavi region of the Southern Highlands ranged from 22% to 92% with a mean parasite intensity of 490 mf/ml (9). Overall parasite rates of 52% and 68% have been reported for villages in the Western Province (10) and East Sepik Province (8) respectively. Nevertheless, the overall prevalence of patent infection on Lihir was higher than what has been reported for most places outside the Pacific region (11). The lower sensitivity of the thick film method compared to Knott's method may be explained by the high prevalence of low-density microfilarial carriers.

Anopheles farauti was shown to be a very efficient vector of *W. bancrofti*. The mean number of infective larvae per infective mosquito of 5.3 in the samples dissected before the second DEC treatment was higher than what has been reported for other *Anopheles* species. Krafsur and Garrett-Jones (12) found a mean of 2.8 infective larvae in *An. funestus* in Tanzania, and Bockarie et al. (5) working in Papua New Guinea found a mean of 2.7 and 2.8 for *An. punctulatus* and *An. koliensis* respectively. Despite the DEC treatment, the total MTPs for the 6 surveys (370 L3/person) was higher than the annual transmission potentials (ATP) reported for many endemic areas outside Papua New Guinea where *W. bancrofti* is anopheline-borne (11). As has been recently shown for other areas in Papua New Guinea (5) culicine mosquitoes do not appear to be involved in filariasis transmission in Lihir.

The low prevalence of obstructive filarial disease observed on Lihir may suggest a recent importation of the disease or recent increase in transmission intensity. The latter is more plausible because lymphatic filariasis has been endemic in the New Ireland Province for many decades (13). Reduction in vector densities during the DDT era resulted in a dramatic reduction in filariasis transmission in many parts of Papua New Guinea (14). When spraying ceased in 1984, filariasis transmission was on the increase again in some places including Lihir. However, it should be pointed out that obstructive filarial disease is uncommon in parts of Papua New Guinea where *W. bancrofti* is transmitted mainly by *Anopheles* mosquitoes. Out of 427 people examined by Backhouse and Haydon (15) in Rabaul, in the nearby East New Britain Province, only 3 (0.7%) had elephantiasis despite the fact that 19.4% were microfilaraemic. On the other hand, in areas in Irian Jaya (western half of New Guinea island) where culicine mosquitoes were important vectors of *W. bancrofti* the prevalence of elephantiasis was as high as 14.8% in a community with a microfilarial carrier rate of 26.8% (16). Iyengar (17) had noted that in areas of *Anopheles*-borne filariasis, in New Guinea, the "elephantiasis rate is rarely higher than 1%".

Despite the fact that less than half the estimated population of Wurtol and Talis received two treatments of DEC, a significant reduction in the intensity of *W. bancrofti* transmission was maintained for at least 9 months after two mass treatments with DEC. The cohort of people who were bled before and after treatment had a 46% reduction in prevalence of microfilaraemia and a 94% reduction in intensity of infection 7 months after the second treatment. A statistical significance was not obtained for the reduction in the prevalence of patent infection probably because of the small sample size (22 people). However, the reduction in prevalence and intensity of infection following two mass treatments was clearly reflected in the significant reduction in the *W. bancrofti* infection rate of *An. farauti*. The low MIBR and MTP recorded 7 months after the second treatment, when MBR was highest, indicates that the overall reduction in MIBR and MTP after the second treatment could not be attributed to the low MBRs during the other 3 post-second treatment surveys. Studies in the East Sepik Province of Papua New Guinea have shown a highly significant positive correlation between the annual transmission indices, AIBR and ATP, and prevalence of patent infection (18).

The focality of filariasis on Lihir and the high numbers of infective larvae found in *An. farauti* suggest that the vector-parasite relationship may be that of facilitation. In countries like Solomon Islands and Togo where lymphatic filariasis has been eradicated through vector control, anopheline mosquitoes were the principal vectors and facilitation was thought to be the vector-parasite relationship (19). It appears from our studies on Lihir that the transmission of anopheline-borne filariasis could be interrupted if biannual DEC treatment is continued for 3 to 5 years.

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