THE EFFECT OF PERMETHRIN IMPREGNATED BEDNETS ON THE INCIDENCE OF *PLASMODIUM FALCIPARUM*, IN CHILDREN OF NORTH GUADALCANAL, SOLOMON ISLANDS

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Abstract. The effect of permethrin impregnated bednets was studied for the first time amongst a large community in North Guadalcanal, Solomon Islands. The community was divided into two; one covered 23 villages with 860 people who were given bednets impregnated at 0.5 g/m^2, and the other 20 villages with 520 people was used as control. Parasitological data were collected by regular prevalence surveys and examination of records of malaria patients who have sought treatment in clinics. Entomological data by landing catches using human bait. The entomological results showed a 71% reduction of *Anopheles farauti*. Even though there was no significant reduction observed with *An.punctulatus*, as the density was already very low, the number biting indoor was much lower than those outdoor of houses with treated bednets.

Parasitologically there was a steady decline in the incidence between surveys with *Plasmodium falciparum* in the under 10 years old. Even though there was no significant reduction in the other variables measured, there was a steady increase in the clearance rate between surveys which might also be due to easy accessibility to chemotherapy. The study showed the significant benefitial effect of permethrin impregnated bednets, which was found to be still effective up to twelve months, against stable *P.falciparum* malaria in children.

INTRODUCTION

Indoor spraying with residual insecticides has for a long time been the main method of malaria control throughout the world. However, with increased problems of escalating costs of materials, deficient administration, technical problems associated with vectors and parasites, and a complexity of socio-anthropological factors, results have been far from satisfactory. Inefficient and wide scale refusal of spraying by householders is considered a major problem in the Solomon Islands.

Further it has been observed that some vector species avoid sprayed surfaces (Taylor, 1977; Avery and Paik, 1974) and this situation exists in the Solomon Islands where nationwide spraying with DDT has been carried out since 1970. In order to combal the increasing incidence of malaria in the country other methods of vector control are being examined to either replace or supplement residual spraying. Bednets have been in use as a protection from mosquitos in many tropical countries including the Solomon Island, and were found to prevent biting by mosquitos (Port and Boreham, 1982). They can therefore compliment malaria control program by helping to reduce transmission. Bradley *et al* (1986) reported in the Gambia that spleen and parasite rates were less in children sleeping under bednets than those not using them, even though the findings of Snow *et al* (1987) in the same country did not show similar results. The Expert Committee on Integrated Vector Control (WHO, 1983) recommended investigations on the use of bednets impregnated with pyrethroid insecticides as part of research on community participation in vector control.

The idea of clothing and fabrics impregnated with an insecticidal and repellent compound has been successfully tested against nuisance mosquitos in North America (Shreck *et al*, 1978; 1984; Lindsay and McAndless, 1978). There is now much interest in the application of pyrethroid insectcides to bednets to improve their effectiveness against malaria vectors. Entomological evaluation of permethrin treated bednets has been reported by Darriet *et al* (1984); Loong *et al* (1985); Lines *et al* (1986), and Snow *et al* (1987). We also knew of further trials by Charlwood and Groves (1987) conducted in Papua New Guinea, Hii *et al* (1987) in Sabah, Malaysia, and Li (1986) in China.

In this paper we report the results of the first 18 months of a trial with permethrin impregnated bednets on the transmission of *P.falciparum* malaria in children in an area on North Guadalcanal, Solomon Islands.

MATERIALS AND METHODS

Study area

The study area is situated in North Guadalcanal 20 km east of Honiara, the national capital. Two areas where villages did not accept DDT spraying were chosen for the study (Fig 1). The area south of the trunk road running horizontally from west to east and flanked on the west by the Ngalibiu river and east by the Metapona River was selected for the evaluation of impregnated bednets. An oil plantation extends south about 2 km from the trunk road and the study villages are situated south of the plantation.

The area west of the Ngalibiu river, bounded by the sea on the north and the trunk road on the south, up to the Red Beach was identified as the control area. The study area has a population of 860 people in 23 villages while the control area has 520 in 20 villages. The climate is oceanic tropical. The wettest period of the year is from December to April, with June being one of the driest months. The mean daily maximum temperature is approximately 33°C and the mean daily minimum is 21°C, with a mean daily average of 27°C. The annual rainfall is around 2,080 mm.

All provinces in the country were under DDT residual spraying coverage with 75% DDT wettable powder and 25% emulsion concentrate, as the main vector control measure. However due to operational and logistic difficulties the quality of spraying had been poor. Ground application of ULV malathion spray was a supplementary measure in some problem areas and in and around major towns. Larviciding with temephos (Abate) was also carried out in some major towns and around airports.

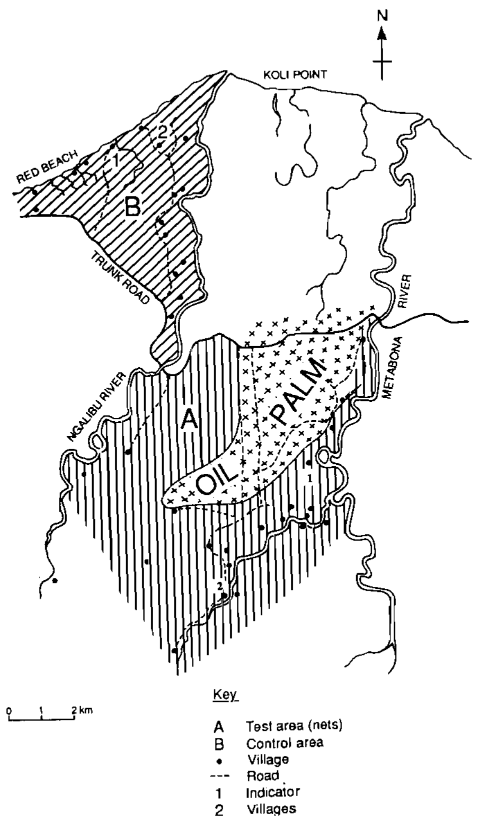

Fig 1—Map of the test area and the control area in North Guadalcanal showing the study villages.

An annual mass drug administration program had been in operation in North Guadalcanal since 1984. It normally commenced in March and extended for 12 weeks. It consisted of three days of radical treatment followed by weekly single dose with a schizontocidal and gametocidal drug On each fourth week pyridoxine/pyrimethamine (Fansidar) was substituted for primaquine to counter chloroquine resistant strains. But in 1986 this program was interruped by a major tropical cyclone and in 1987 it was discontinued due to very poor compliance.

Intervention measures

A census of the population of the study area was carried out to determine the number of bednets required for distribution. On 1 September

1986, 580 nylon bednets, 240 double and 340 single, impregnated with permethrin at dosage of 0.5 g/m^2 were distributed to the people. Two types of nylon bednets were used, rectangular nets 1.4 m × 1.8 m made from Australian manufactured netting and bell shaped nets 1.5 m high and 8.5 m circumference from Taiwan. The rectangular nets were strong and used as double nets, and the smaller size bell shaped ones as single ones. The nets were impregnated with permethrin (Ambush 50% EC) using the method described by Schreck and Self (1985).

The purpose of the trial was explained to the people when the villages were visited for census. The importance of everyone in the family to sleep inside bednets was emphasized. The advice on how to use the nets, their benefits, the protection they would provide against mosquitos and other household insect pests were given by health education staff visiting the villages and also in radio health programs.

Data collection

A mass blood survey was carried out in the villages in the test area in August 1986, ten day before the distribution of treated bednets. Thereafter the survey was repeated every two to three months. Thick and thin films were made on a slide from finger prick blood, and were stained with Giemsa. Each thick film was exammined for five minutes corresponding to approximately 100 fields and classified as positive or negative for *P.falciparum, P.vivax, P.malariae,* or mixed infections. The gametocyte positives were also noted and the thin films were used to identify the *Plasmodium* species. As with parasitological activities, preintervention entomological baseline studies were carried out in two villages in the test area and two in the control area. These included observations on indoor and outdoor density by means of man-biting catches carried out for three hours from 1800 to 2100 hours twice a month. They were continued after the intervention measures. Twelve all night hourly catches indoor and outdoor were carried out once a month in the test area, where *Anopheles punctulatus* was prevalent. Four collectors participated in the catches as described by Haddow (1954). Indoor man-biting catches were made from a bedroom in a village house from 2200 hours to 0300 hours on consecutive nights, with and without impregnated bednets hanging in the room. Simultaneous outdoor catches were also made.

Evaluation of bednets

One of the bednets from among those treated and distributed on 1 September 1986 was retained in the laboratory for evaluation in the experimental huts. Once a fortnight the impregnated bednet together with a clean one from the laboratory as control were tested in two experimental huts situated 20 metres apart. A man slept inside the net in each hut with the base of each net raised 30 cm above the floor for entry of mosquitos. The exit traps were emptied every two hours and the dead one lying on the floor were taken in the morning. The mosquitos from the exit traps were maintained in the laboratory and their mortality after 24 hours was recorded.

Also commencing November 1986 bioassay tests were carried out each month in the villages on the impregnated bednets issued to the people, and on a clean bednet from the laboratory as control. Ten to fifteen *An.farauti,* fed on sugar were introduced to each bednet, exposed for 15 minutes and removed to paper cups. Their mortality after 24 hours was noted. Samples of impregnated bednets from all villages in the study area were tested.

RESULTS

Parasitological findings

The results of mass blood surveys of the population in the test area and in the control area were grouped into three categories; children under 10 years, adolescents from 10 to 15 years, and those above 16 years. The division into three categories was on the basis that children under 10 years retired to bed early and were protected by the bednets. The 10 to 15 years age group behaved somewhat intermediate between children and adults. Although the surveys were expected to be carried out every two to three months the one due on March 1988 was missed and so was an early one for the control area. However a steady decline in the *P.falciparum* infection rate during the period of twelve months since the intervention was observed in the test area. But this decline in the *P.falciparum* infection rate was also observed in the control area. The transition frequencies

Table 1

Transition frequencies between consecutive surveys from negative to positive (incidence) and from positive to negative (clearance) of *P. falciparum* infections in children under 10 years in the test area during 5 mass blood surveys, 1986-1987.

Surveys	Incidence				Clearance			
	(− −)	(− +)	Total	a	(+ +)	(+ −)	Total	b
1-2	25	3	28	0.1071	9	9	18	0.5
2-3	18	2	20	0.10	3	21	24	0.875
3-4	25	1	26	0.0385	0	2	2	1.0
4-5	21	2	23	0.0869	0	1	1	1.0

a = proportion of incidence
b = proportion of clearance

Table 2

The number of fever cases seeking treatment at a clinic in test area and the percentage of them positive for malarial parasites before and after intervention with impregnated bednets.

Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Fever Cases	58	67	173	44	37	48	45	80	56	12	10
+ ve (%)	45.4	62.8	57.2	47.7	37.8	56.3	46.6	47.5	62.5	25.0	40.0
Average	←	551	→	←			45.4				→

between consecutive surveys were determined for children under 10 years. The transition from negative to positive (incidence) and from positive to negative (clearance) is shown in Table 1. The numbers N − −, N − +, N + +, N + −, denote those negative (−) at first survey and positive (+) at next, etc. The incidence gradually decreased in the test area from the first to fourth surveys and increased slightly on the fifth. Correspondingly, clearance increased steadily from the first to the fifth. The monthly record of fever cases in the test area seeking treatment at a clinic and the numbers among them diagnosed as malaria are given in Table 2. There were higher numbers reporting during February and March and correspondingly higher percentage of malaria cases in March. There was no significant reduction of malaria cases reproted at the clinic since the intervention.

Emtomological findings

The man-biting catches of *An. farauti* for three hours from dusk, the peak biting time in Kemami, one of the indicator villages in the test area, and in Gilutae, a village in the control area are given in Table 3. The average man biting density from October 1986, after the intervention, compared with the average man biting density before intervention showed a reduction except in March. The average reduction rate was 71%. During the same period the control village showed a high man-hour biting density.

The average monthly man biting densities of *An.punctulatus* taken in 12 hour all-night catches are shown in Table 4. A slight increased density was noticed during the period March to July, but generally the density was very low. There was no significant reduction in this vector density as a

Table 3

The average monthly density (number/man/hour) of *An farauti* in the test area and in the control area before and after the intervention.

Kemami (Test area)-Average catch per man per hour

1985			1986							1987					
Oct	Nov	Dec	Feb	Mar	Jun	Jul	Aug	Oct	Dec	Jan	Feb	Mar	Apr	May	Jun
15.0	24.7	24.0	13.7	8.7	15.7	1.7	16.7	2.0	2.0	1.2	3.3	16.2	7.7	0	2.2
Average ← 15.0 →								← 4.375 →							
Reduction								86.7	86.7	92.0	78.0	-8.0	48.7	100	85.3
								← 71.3 →							

Gilutae (Control) average catch per man per hour

1985						1986			1987						
Jun	Jul	Aug	Sep	Oct	Nov	Jan	Jul	Nov	Jan	Mar	Apr	May	Jun	Jul	Aug
22.3	20.0	84.5	50.1	32.1	16.7	7.5	9.0	65.3	43.8	42.6	42.0	24.7	25.2	22.9	29.9
Average ← 28.3 →									← 37.1 →						

Table 4

The monthly man hour densities of *An.punctulatus* from all night catches from indicator villages in the test area after intervention.

	1986		1987									
Month	Sep	Oct	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Outdoor	3.0	0.8	1.5	0.6	11.4	3.8	4.8	30.2	1.4	7.4	3.7	1.3
Indoor	0.5	0.1	0.6	1.6	2.3	0.6	1.4	0.2	0.2	1.1	0.4	0.4

result of the intervention. In six sets of catches of *An.punctulatus* in the bed room of a village house and outdoor, a mean of 3.4 indoor and 19.2 outdoor with treated net hanging inside, and 7.5 indoor and 12.0 outdoor without the net were recorded. These results suggested less *An.punctulatus* density indoor in the presence of a treated bednet at least during the early weeks of treatment. The catches of *An.farauti* from window traps of the two experimental huts with treated bednets and untreated bednets are shown in Table 5. These experiments commenced 30 weeks after the impregnation of the nets. Comparable numbers per night were taken from the two huts and a signifcantly marked mortality was shown among the females taken from the hut with treated bednet. Bioassay tests were carried out on 64 bednets from the ninth to the fiftieth week after impregnation. As much as 51 nets were tested after the twenty fifth weeks. All tests gave 100% kill up to 50th week. Four tests carried out after 50 weeks subsequently gave percentage kills of 33.3, 50, 52, and 60. On the basis of these results the bednets were reimpregnated at the end of 12 months.

DISCUSSION

Following the intervention measures introduced in September 1986 the *P.falciparum* infec-

Table 5

Assessment of permethrin impregnated bednets at dosage of $0.5g/m^2$ against *An.farauti* in experimental huts in Gilutae.

Weeks from date of impregnation	Huts with impregnated bednet		Hut without impregnated bednet	
	Number	24 hour mortality	Number	24 hour mortality
30	57	96.5	58	12.3
32	80	95.5	65	9.2
34	119	60.5	96	6.3
36	48	57.5	44	18.2
38	27	51.9	15	20.0
40	10	70.0	5	0.0

tion rate fell by December 1986, and remained at a low level during the following ten months. The reasons for the continued low infection rate could be attributed to the use of impregnated bednets. The previous mass drug administration campaign might have had some impact but so in the control area. The general reduction in vector density due to an unusual prolonged drought during that period might have also contributed to low transmission prevailing in parts of the country. The use of impregnated bednets would have reduced the man vector contact especially in children. The factors determining the success and failure of impregnated bednets in reducing malaria transmission are attitudes and behavior of people using them. Whether bednets are used at all and whether a good proportion of people are inside bednets during the peak biting time of the vectors are key factors which are dependent on human behavior.

In North Guadalcanal both the behavior of villagers and the activity of *An.farauti* contributed to reduce the benefits of impregnated bednets in malaria control. The practice of people in villages to spend three to four hours of the night outdoors provided an opportunity for *An.farauti* to feed on humans without entering the houses. Under these conditions higher outdoor biting rates of *An. farauti* have been reported than indoor in North Guadalcanal with the peak biting period during the first three hours after dusk. It was therefore probable that a high degree of transmission might have occurred outdoors during the early part of the evening. Our studies on the human behavior in the villages showed that children retired to bed earlier than adults and thereby enjoyed a better protection against *An.farauti, An.punctulatus* and *An. koliensis* where they were present exhibited a typical Anopheline biting pattern with a midnight peak. Thus impregnated bednets gave adequate protection gainst these two species. A further problem encountered in the trial was the movement of people to and from the villages. Many people from other provinces settled in the area and there was considerable movement around including visits to Honiara, the national capital. It was noticed that people did not carry their bednets whenever they left the village and probably acquired infections from areas outside the study sites.

Despite these setbacks people readily accepted the use of impregnated bednets and expressed their satisfaction over lesser frequency of episodes of illness especially among children. Several people who could afford them purchased locally cotton nets of family size made in Taiwan. These nets were impregnated with permethrin when the villages were visited. The bednets were distributed generously among all people in the study area so that everyone could get protection from mosquito bites. Most families slept in a single room on the floor especially where there were several small children. In these circumstances a single room size bednet 2m × 2.6m × 2 m would have served the family better than several small ones. When the villages were visited to re-impregnate the bednets, the rectangular ones made out of Australian material were found to be in excellent condition. Only 5 out of the 240 distibuted were torn beyond use after 12 months. The Taiwanese bednets mostly had to be replaced. People were also informed that inpregnation restored the performance of a torn net approximately to that of an intact net.

The present method of impregnation using plastic bags, though satisfactory, in results was time consuming. In order to speed up the process 3 to 4 nets were soaked at one time in large plastic bags. However a large scale trial to investigate a method of dipping bednets in a bucket containing a measured quantity of insecticide emulsion was being carried out. Such a method would be handy in a self help campaign supervised by a health worker in the field.

The mortality of *An. farauti* taken in the window traps of the experimental huts with impregnated bednet cormpared to that of females from the hut with an unimpregnated bednet showed that permethrin actually killed the mosquitos. The bednets treated at dosage of 0.5 g/m^2 had a residual effect for 12 months as indicated by the bioassay tests. On the basis of this information reimpregnation of bednets was carried out at the twelfth month.

The mass drug administration might have contributed to the reduction of the infection rate during the year. It would be a logical procedure to reduce the infection rate first by a mass drug administation program and try to maintain it by the use of impregnated bednets. A systematic mass drug administration which was launched in 1984 reduced in the number of malaria cases in the whole Guadalcanal province by 58% in two years. However the program which depended on the effciency of volunteers to administer the drugs experienced many problems of manpower and logistics and the administration of the drugs for several weeks may also resulted in the avoidance of them by an increasing number of people. Thus this program was stopped in 1987.

A successful bednet trial would provide the management with further tool to combat malaria transmission. At present when both residual spraying and the mass drug administration posed problems a more easily executed bednets program could be an asset especially in the problem areas. For example where mass drug administration was less successful or less practicable, permethrin impregnated bedents could bring down transmission. In other situations treated bednets could reduce the frequency other measures applied complementarily such as residual spraying or mass drug administration. There is hope for such a situation by the promising results of the present study. Trials of permethrin impregnated bednets without mass drug administration are planned. In the present study it is hoped that following the reimpregnation of bednets, intense health education and village visits malaria infection rate would be kept at low level in the impregnated bednet areas.

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