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Trial of pyrethroid impregnated bednets in an area of Tanzania holoendemic for malaria Part 1. Operational methods and acceptability

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In five Tanzanian villages, nets impregnated with permethrin or lambdacyhalothrin were given out. The people received them enthusiastically and brought their nets for re-impregnation at six monthly intervals. Bioassays showed that the insecticidal power of permethrin impregnated nets remained adequate for six months unless the nets were washed. Nets with 30 mg lambdacyhalothrin/m^2 retained high insecticidal power despite washing, but this dose caused temporary cold-like symptoms in those sleeping under freshly treated dry nets. Methods by which durable bednets might be made affordable by Tanzanian villagers are discussed.

Key words: Bednets, impregnated; Permethrin; Lambdacyhalothrin; DDT spraying; Bioassays

Introduction

The use of pyrethroid impregnated mosquito nets (bednets) is probably the most important new tool for malaria vector control since the introduction of house spraying with residual insecticides over 40 years ago. There have been several field trials of impregnated nets since the idea emerged in 1983–5, with the best documented successes in The Gambia (Snow et al., 1988) and Hainan Island, China (Li Zuzi in Curtis et al., 1990). In China over 2.4 million nets have been impregnated (W.H.O., 1989).

Almost all the trials have been carried out in areas of low or medium endemicity and a short trial in a holoendemic area of Papua New Guinea gave rather disappointing results (Graves et al., 1987). In much of wet tropical Africa malaria transmission is extremely intense, and it is not uncommon for a person to receive hundreds of bites from infective mosquitoes per year. In many such areas conventional house spraying may fail to interrupt transmission (Molineaux and Gramiccia, 1980) and in any case it may be too expensive or logistically demanding to implement except in

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restricted areas. The spread of chloroquine resistance is a growing constraint on the ability of health services to limit mortality and morbidity due to malaria.

The lack of feasible alternatives for malaria control has already led the UNICEF/WHO Joint Nutrition Support Programme (JNSP) to propose large scale use of permethrin treated bednets as part of its attempts to improve child health in Zanzibar.

We have attempted to evaluate community-wide use of pyrethroid impregnated nets as a means of controlling holoendemic malaria in five villages in north-east Tanzania. The trial lasted over three years, and included comparison with DDT house spraying in one village. This paper describes the operations of treating and distributing the nets and the acceptability of them to the villagers. Three further papers (Magesa et al., 1991; Lyimo et al., 1991; Msuya and Curtis, 1991) report the effects on the mosquito populations and the prevalence and incidence of malaria infection.

Study area

Most villages near Muheza, Tanzania, consist of wattle and daub houses with palm thatch roofs; a minority of the houses have mud brick walls and corrugated iron roofs. Three of the study villages — Kumbamtoni, Mindu and Mng'aza — are of this type. Their populations are respectively 356, 1563 and 300 and the numbers of houses are 70, 186 and 57. The people are mainly farmers of maize, coconuts, oranges, rice, cassava and bananas. The area also includes several estates of houses for workers in the sisal industry. These houses are made of concrete brick with tiled roofs. Two such estate villages — Mlingano and Umba — are included in our study. Their populations are respectively 673 and 532; their numbers of houses are 108 and 77.

Study design

The study was divided into three phases (Table 1). The design permitted pre- and post-intervention comparisons within each village and between-village comparisons with contemporary controls during phase 2.

TABLE 1

Interventions in the five villages in the three phases of the project

	From	To	Estate villages		Traditional villages		
			Mlingano	Umba	Kumbamtoni	Mindu	Mng'aza
Phase 1	Sept '86	Sept '87	U	U	U	U	U
Phase 2	Oct '87	Apr '89	P	U	U	D	P
Phase 3	May '89	Mar '90	P	P	L	L	P

U, no vector control.
P, permethrin impregnated nets.
D, DDT house spraying.
L, lambdacyhalothrin impregnated nets.

Because of the different types of house in the traditional and estate villages and the possible relevance of this to mosquito behaviour, during phase 2 we considered Umba as a control for Mlingano, and Kumbamtoni as a control for Mindu and Mng'aza.

The experimental villages are separated from each other by several kilometres and in most cases they are at least 600 metres from neighbouring settlements. However, the Umba workers' housing lies close to a collection of traditional houses which we could not provide with nets during phase 3 because of insufficient supplies. To attempt to create a barrier zone to prevent immigration of infective mosquitoes from these houses into our experimental area we sprayed them with lambdacyhalothrin (30 mg/m^2) during phase 3.

Net impregnation

Permethrin

Permethrin was provided free of charge as 20% or 50% emulsifiable concentrates by Wellcome Research Laboratories and ICI. It was used at a target dosage of 0.2 g/m^2 of netting. The concentrate was added to water in a plastic baby-bath to make an emulsion containing 0.8% permethrin. Preliminary laboratory tests showed that nylon netting after dipping and wringing retains about 25 ml of emulsion/m^2 and that the amount of permethrin deposited is approximately equal to that in the amount of emulsion retained, i.e. there is no selective affinity of nylon for permethrin (Hossain et al., 1989). It could therefore be predicted that dipping and wringing with the 0.8% emulsion should yield a deposit of 0.2 g/m^2. Gas liquid chromatography by Wellcome Research Laboratories and ICI confirmed that this was approximately the case.

The initial impregnation was carried out at the Ubwari Field Station at Muheza by project staff wearing rubber gloves and the nets were dried in a horizontal position on plastic sheets. When the nets were distributed in the villages, householders were asked not to wash them for six months, as washing is known to remove much of the insecticidal effect (Snow et al., 1987). At the end of that period villagers were asked to wash their nets, and detergent was provided for the purpose. They were asked to bring their nets on the following day to a central point in the village where they re-impregnated their nets, wearing the rubber gloves provided and assisted by the project staff. They laid the nets on their own mattresses for drying. Any dripping of permethrin into the mattresses probably assists in bedbug control (R.W. Snow and S.W. Lindsay, pers. comm.).

Lambdacyhalothrin

This powerful pyrethroid has been shown to be highly effective in laboratory tests on netting (data of Lindsay et al., in Curtis et al., 1990). There was reason to hope that it would be more effective than permethrin in the field. However, it is an alpha-cyano pyrethroid and contact with the skin and mucosae can cause unpleasant reactions. It has not previously been field tested on nets but, by 1989, we considered that our team's considerable experience of net impregnation and close and regular contacts with the villagers justified a field test as any side-effects would be quickly detected.

Impregnation with this chemical (in the form of 'Icon' emulsifiable concentrate, made and supplied free of charge by ICI) was carried out in the same way as for permethrin, but only the project team did the dipping. Several members of the impregnation team experienced running eyes and noses, and in two cases slightly swollen faces. These symptoms were never severe and had always disappeared by the next day. It seemed that these side-effects arose more from handling impregnated dry nets than from the act of dipping the nets. Several members of the team reported sneezing when fitting newly treated nets to beds and about half of the team members who slept under these nets noticed cold-like symptoms (running noses, etc.) lasting no more than 2 weeks.

Villagers who received lambdacyhalothrin treated nets reported similar symptoms immediately after the nets were distributed. These effects were invariably mild and never caused breathing difficulties. Villagers stressed that these effects were more than compensated by the benefits of the nets in suppressing the nuisance of biting insects. When questioned after 1 year, 13 out of 71 villagers said that they recalled these symptoms.

It was considered prudent to organize the work of impregnation with lambdacyhalothrin so that skin contact with dry nets was minimised and no individual worker was engaged for more than an hour or two in tasks where handling was unavoidable. It was also decided that, whereas the target (and actual) dose for the initial impregnation was 30 mg/m^2, re-impregnation after six months should be at the reduced dose of 10 mg/m^2. After use of this lower dose there were no reports from villagers of side effects.

In a subsequent study in which nets were impregnated with a range of dosages, cold-like symptoms were reported for 3–6 days after impregnation with 30 mg/m^2, 1–3 days with 20 mg/m^2 and 1 day only with 10 mg/m^2. There are preliminary indications that after hanging a freshly impregnated net unoccupied for a few days no side effects are experienced when it starts to be used. This would be a satisfactory solution to the problem when new nets are impregnated, but would be inconvenient for re-impregnation of nets that are already in use.

Bioassays

To check that 6-monthly re-treatment was sufficient, regular bioassays were carried out with 3 min exposures of colony reared blood fed *Anopheles gambiae* held in W.H.O. bioassay cones attached to various parts of nets which were in regular use in the villages. The mosquitoes were transported to and from the villages in an insulated box. Controls were exposed to untreated netting in the villages. On return to the Field Station at Muheza the mosquitoes were held for 24 h before scoring mortality. The results are summarised in Fig. 1. These showed that the mortality on the permethrin treated nets was generally 80–90%, declining somewhat towards the end of the 6 month interval between impregnations, and reviving after them. Soot deposits on nets hung near cooking fires had surprisingly little effect on the kill. When, contrary to our requests, people washed their permethrin impregnated nets long before the time for re-impregnation, the mortality was much reduced.

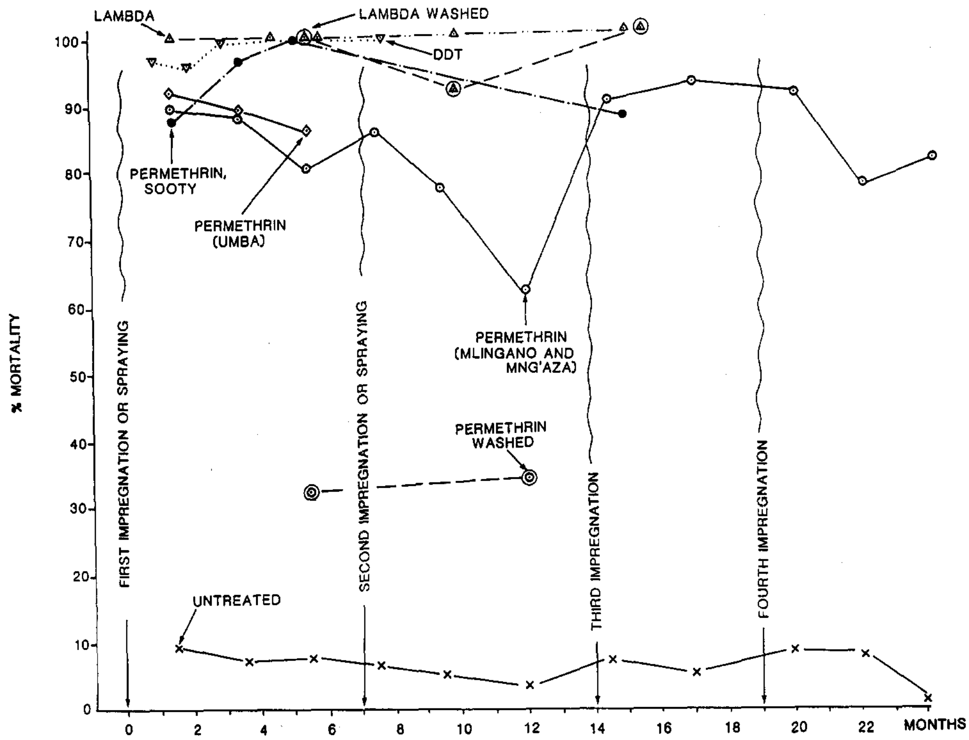

Fig. 1. Results of the bioassays in which laboratory-reared blood-fed *Anopheles gambiae* were exposed for 3 min to permethrin or lambdacyhalothrin deposits on nets or 30 min to DDT deposits on walls and roofs. The first impregnation with lambdacyhalothrin was with 30 mg/m^2 and the second and third were with 10 mg/m^2.

With a deposit of 30 mg lambdacyhalothrin/m^2, mortality remained at 100% despite washing (in agreement with the laboratory data of Lindsay et al., in Curtis et al., 1990). At the lowered dosage of 10 mg/m^2 (after the second and third impregnations), mortality continued to be 100%, except where nets had been washed, when a few survivors were recorded.

Bioassays with 30 min exposure were carried out on DDT deposits on walls and ceilings in Mindu during phase 2 of the project. Mortalities close to 100% were observed (Fig. 1).

Net distribution

Before distribution of the nets, the houses in each village were numbered and a house-to-house survey was carried out recording the number of beds and their approximate size. Sleeping places on mats on the floor were also recorded, but they were few in number.

Before distribution, nets were numbered with indelible laundry marker. Nets were available in four sizes and were given to each householder according to the sizes of the beds in his/her house. The numbers of the nets were recorded and signed for by the householder and the local political representative (Balozi). These precautions were taken in an attempt to minimise theft and selling of nets.

The nets were also marked with a washable marker — a method devised by R.W. Snow (pers. comm.) to allow any premature washing of nets to be detected.

Attitudes to, and perception of, treated nets and their use

Net distribution had been preceded by a year of regular visits to the villages by the project team to collect baseline data. At least two mass meetings in each village were held to explain our objectives and methods. Discussion at these meetings was often vigorous but eventually, at the time of net distribution, only one person in all five villages refused to have a treated net.

During our routine malaria surveys (Lyimo et al., 1991) children were questioned about whether they had slept under a net the night before. Before our net distribution, less than 10% answered 'yes'. This conforms with the rarity of nets seen in bedrooms during our mosquito collections and is apparently a consequence of the cost of nets in Tanzania (see below) and not of a dislike of them.

After our net distributions, almost all children, when questioned, stated that they had slept under a net the night before. Several months after issuing the nets most showed signs of wear and tear, indicating that they were being used. We also carried out some informal checks during mosquito night biting catches and concluded that the proportion of people using nets was high. We decided against surprise visits to houses late at night to check on net usage, as this could have harmed our friendly relations with the villagers on which continuation of the trial depended.

In the days after the nets were distributed villagers reported enthusiastically, and without prompting, on the death of mosquitoes near nets and the disappearance of other pest insects, including bedbugs, fleas and even, in some cases, cockroaches.

The effect on bedbugs has been reported previously in Papua New Guinea (Charlwood and Dagaro, 1989) and The Gambia (Lindsay et al., 1989). We re-confirmed it by observations on six houses with heavy infestations. Within 3–4 weeks of introduction of permethrin impregnated nets, not a single bedbug could be found in five of the six houses. The sixth was used for light trapping and was fitted with an untreated net throughout the trial (Magesa et al., 1991). Its bedbug infestation remained as heavy as before.

Public approval of impregnation of nets was shown by the enthusiasm with which nets were brought for re-impregnation at the appointed time. The perceived benefits of nets mostly concerned biting insects, but the administrative staff at the Mlingano agricultural students' hostel also reported without prompting that, after net introduction, markedly fewer emergency malaria cases (often among non-immunes from areas of low endemicity) had to be taken to hospital since the nets were introduced. Unfortunately, no quantitative records had been kept by them from before net introduction and our malaria monitoring covered children only.

House-to-house surveys were carried out 6 or 12 months after net distribution. The results are summarised in Table 2. Reports of theft of nets were not as common as we had feared, but many nets could not be found by the survey teams. Sometimes this was because they had been taken down in the daytime and hidden from thieves or loaned to relatives in other houses. Contrary to the undertakings given at the time of issuing the nets, some were taken when people moved away and some may have been surreptitiously sold.

Compliance was very good with our request not to wash nets before re-impregnation was due.

Net durability

Table 2 indicates that some nets were so badly damaged, even after 6 months, that replacement was considered necessary. The majority of nets needed some repair and we provided pieces of netting to make patches, but unfortunately few people carried out repairs.

The nets used were rather flimsy (40 denier) nylon. They were easy to wring out after dipping, but soon developed holes because of snagging on the rough wood and mats on the beds and because of the activities of rats and children. Most of the holes started at the bottom of the nets and a later batch of nets with 20 cm light nylon sheeting borders (added at an additional cost of 25%) seem more promising (Table 2) but are still under observation.

The unbordered nylon nets at Kumbamtoni showed no more damage after 12 months than similar nets at Mlingano after only 6 months (Table 2). This better performance may have been because, in Kumbamtoni, villagers were requested not to tuck their nets under the mattresses; another possible explanation could be that at Kumbamtoni lambdacyhalothrin was used for impregnation and this may be an

TABLE 2

Results of surveys of nets in Mlingano, Mng'aza and Kumbamtoni six or twelve months after they were issued

Village:	Mlingano	Mng'aza	Mng'aza	Kumbamtoni
Type of net	nylon	nylon	polyethylene	nylon
Presence of border	no	yes	no	no
Tucked in[a]	yes	yes	yes	no
Impregnating chemical	perm.	perm.	perm.	lambda.
Months after issue	6	6	6	12
No. issued	567	117	72	193
% reported stolen	1.2	1.7	0	8.2
% not seen[b]	3.9	32.4	n.d.	21.2
% of those seen which were:				
badley damaged[c]	4.6	9.1	0	17.6
slightly damaged[d]	61.3	12.9	2.8	14.0
in good condition	34.0	77.9	97.2	68.4

[a]According to instructions from project staff.
[b]Including nets taken away to new work places by those to whom they were issued, nets hidden for fear of thieves etc.
[c]Nets which were beyond repair and required replacement.
[d]Nets which could be repaired.

irritant to gnawing rats, which the villagers considered to be the main cause of damage to nets.

Subsequently a batch of polyethylene fibre nets was obtained from the Philippines, through the assistance of Dr. L. Self of the West Pacific Regional Office of W.H.O. These appear (Table 2), and are reported to be very durable, but are only slightly more expensive than 40 denier nylon nets. They have the disadvantage that they cannot be wrung out after impregnation and have to be left to drip. To catch the drips, a system devised in the Solomon Islands by Dr. S. Meek (pers. comm.), was used. This consists of a plastic sheet hung to form a shallow sloping channel to return the drips to the treatment bath (see photograph in Curtis, 1990). The need to wait for the dripping to finish would somewhat complicate the re-impregnation process when particular nets have to be returned to their owners. A batch of polyethylene nets are now under evaluation for durability in one of the villages and for retention of their insecticidal power after impregnation.

Stronger (70 denier) nylon nets which can be wrung out are now available and will be evaluated for cost/durability in parallel with the net types mentioned above.

During our project three nets are known to have been damaged by fire. However, the nets burned slowly and there was plenty of time for an occupant to escape. A burning test with a polyethylene net gave similar results.

Economics of bednets in Tanzania

The retail cost of a double-bed-sized net in Tanzania in March 1990 was about TSh 3000/-. The price has been increased steadily over the last few years as the Tanzanian shilling has been gradually devalued. At the official exchange rate, 3000/- was equivalent to 15 U.S. dollars in March 1990. At unofficial exchange rates the price has remained fairly steady at about 10 dollars.

The retail price of 3000/- for a net is not affordable by most Tanzanians. The official minimum monthly take-home wage is 2100/- and most workers need to supplement their wages in some way to feed and clothe their families. Subsistence farmers have little access to cash.

Nets can be bulk-purchased from the factories in Asia for only 2.5–4 dollars, depending on size and quality. Most of these prices represent the cost of the netting and it would be very difficult to organise tailoring in Tanzania from imported netting at prices competitive with the Asian factory product. The retail price of imported nets could be much reduced if they were treated for Customs purposes as a medical appliance and import taxes (currently 80%) were removed. The price can also be made more manageable by import support as in the UNICEF programme which plans to purchase nets abroad for dollars and to sell them for shillings (at the official exchange rate) in Zanzibar.

The employers at the Mlingano estate have been impressed by the impregnated nets and have agreed to use their access to foreign currency through a Dutch aid project to purchase replacement nets for their employees.

By such means it should be possible to reduce the price of a net to about 1000/-. For those who cannot afford that price it is possible to make bed or eave curtains from locally available fibres (Lines et al., 1988). We are carrying out a number of tests in experimental huts with impregnated polypropylene bedcurtains and sisal eave curtains and it appears that they are better than nothing, but not so good as bednets (Curtis et al., in prep.).

Similar economic arguments apply to the cost of impregnation (0.25–0.4 dollars for permethrin) and, by the same methods, net treatment could be made available for about 50–80/-. We have already had discussions in one village about the formation of a community fund for this purpose.

Comparison of impregnated nets with DDT house spraying

Conventional DDT house spraying was carried out in Mindu. There were none of the complaints about this technique which are sometimes raised, e.g. objections to entry into houses by the spraymen. The latter problem was probably avoided because the spraymen were locally recruited. Training them took much more time than showing householders how to dip nets, but because net distribution required more thorough house-to-house surveys and registration, the preparation required roughly the same effort. Both DDT spraying and net treatment required repetition at 6-monthly intervals. However, much more effort was required for re-spraying the walls — about 60–80 person-days for the 186 houses at Mindu. Dipping the nets from the same houses in lambdacyhalothrin took about 12–15 person-days of work by the team. Dipping of the nets in permethrin, which can be done by householders, would have involved even less work for the team.

Conclusions

(i) Treated nets are welcomed in Tanzania, even by those with no previous experience of using a mosquito net.

(ii) The main benefit perceived by the villagers is protection against biting insects, mosquitoes and bedbugs being the most frequently mentioned.

(iii) 6-monthly re-treatments were apparently adequate to maintain insecticidal activity using a dose of 0.2 g permethrin/m^2 provided that nets were not washed until just before re-treatment. With lambdacyhalothrin at 30 mg/m^2, 100% kill in bioassays was recorded even on washed nets.

(iv) Using lambdacyhalothrin instead of permethrin causes some unpleasant side-effects to those involved in treatment and to those sleeping under a net recently treated at a dose of 30 mg/m^2. At a dose of 10 mg/m^2 this problem was only reported for one night after treatment.

(v) Because nets are so expensive, relative to Tanzanian incomes, we anticipated major problems of theft and selling of nets; these turned out to be only minor problems in our trial.

(vi) Nets must be as durable as possible. More durable nets may be slightly more expensive at first, but would probably more than repay the extra outlay by a prolonged effective life. Polyethylene nets appear to have this advantage, but are slightly less convenient to impregnate.

Overall, it is clear that impregnated nets offer a logistically straightforward method of controlling biting by malaria vectors, much simpler to set up and maintain than conventional house spraying. The main obstacle to the widespread use of treated nets in Tanzania is not acceptability but affordability. The question of whether treated nets can control mosquito biting sufficiently to control malaria in Tanzanian conditions is dealt with in subsequent papers in this series.

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