The effects of untreated bednets on malaria infection and morbidity on the Kenyan coast

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Abstract

A study was conducted in order to determine whether children that slept under untreated bednets were protected against both malaria infection and clinical disease compared with children not sleeping under bednets. The study was conducted in Kilifi District, Kenya, during the malaria season (June–August, 2000) and involved 416 children aged ≤10 years. Data collected from a cross-sectional survey showed evidence of protection against malaria infection among children sleeping under untreated bednets in good condition compared with those not using nets (adjusted odds ratio [AOR] = 0.4, 95% CI 0.22–0.72, P = 0.002). There was no evidence of a protective effect against infection when comparing those that used untreated bednets that were worn and those not using nets (AOR = 0.75, 95% CI 0.34–1.63, P = 0.47). When these same children were followed-up during the malaria season, there was evidence of a lower rate of clinical malaria among those that used untreated nets in good condition (adjusted incidence rate ratio = 0.65, 95% CI 0.45–0.94, P = 0.022), while the rate of clinical malaria among those that used untreated bednets that were worn was similar to that of those that did not use bednets. In the face of persistent failure of communities to take up net retreatment, there is hope that untreated nets will offer some protection against malaria infection and disease compared with not using nets at all.

Keywords: malaria, Plasmodium falciparum, bednets, Kenya

Introduction

Insecticide-treated bednets (ITBNs) have been shown to be effective in reducing malaria morbidity and overall childhood mortality in randomized controlled trials conducted in various areas across Africa (Choi et al., 1995; Lengeler et al., 1998). The only randomized controlled trial of untreated bednets was conducted in The Gambia and indicated that untreated bednets offered no significant protection against clinical malaria (Snow et al., 1988). Several cross-sectional or case–control studies have also suggested that untreated nets do not confer any significant protection against clinical malaria (Genton et al., 1994; Snow et al., 1998). However, a more detailed recent review of the available trial and cross-sectional evidence suggests that nets not treated with insecticide do offer some protection against infection and disease (Guyatt & Snow, 2002).

Due to a shortage of randomized controlled trials of untreated bednets, evidence for or against untreated bednets remains inconclusive. Strictly randomized controlled trials of untreated bednets would be ethically inappropriate in the face of the overwhelming evidence of protection afforded by treated nets. Comparative data under non-trial conditions on net use and the risks of malarial infection or disease remain our only source of evidence. Here, we describe a series of observations made on the effects of untreated bednets on the prevalence of malaria infection and clinical disease in an area of moderate seasonal malaria transmission on the coast of Kenya.

Materials and Methods

Study area

The study area was part of a wider area previously used for an ITBN trial conducted between 1993 and 1995 in Kilifi District on the Kenyan coast (Snow et al., 1993; Nevisi et al., 1996). The area has an average annual entomological inoculation rate of 10 (Mbogo et al., 1995) with 2 peak malaria transmission seasons; in June–August following the long rains and in November–December following the short rains. A fixed geographical area was defined which comprised 72 households that were already enrolled in studies of clinical malaria. Census data from these households were used to identify children aged ≤10 years. A total of 486 children were identified and consent sought from their parents or guardians and 416 children were enrolled. This study was conducted from June to August 2000.

Household interviews

Interviews and observations related to bednet use and other methods of mosquito avoidance were carried out in the study households in June 2000. During the interviews, information was collected about whether the child slept under a net and where the net was obtained, whether the nets were treated and when they were last treated. Fieldworkers asked to see the nets to assess their condition. The nets were described as (i) 'intact' (no visible holes); (ii) 'satisfactory' (<5 small holes that the user could tie into knots without compromising the net as a barrier); and (iii) 'worn' (>5 holes that the user could not tie into knots without compromising the barrier effect of the nets). Nets were also considered 'worn' if they were badly damaged, e.g. by fire or had large tears.

The interviews also sought to find out whether the households used mosquito coils or local repellants. In this region the repellants used are specific plants that are burned to produce smoke that is believed to repel mosquitoes and other insects. Additional information was collected on whether the mother of each child had had any formal education.

Cross-sectional surveys

A cross-sectional parasitological survey was conducted in July 2000. Thin and thick films were made from finger-prick blood samples of each study participant. Slides were examined microscopically using X1000 magnification and the number of parasites per 200 white blood cells (WBC) recorded. Parasite density/μL of blood was calculated assuming an average leucocyte count of 8000 WBC/μL of blood.

Surveillance for fevers

Combined active and passive case detection was maintained during the 14-week peak malaria season in the months of June to August 2000. Each study partici-
The pant was visited in their homestead every week by a fieldworker and an auxiliary temperature taken using an electronic thermometer (Becton-Dickinson, Oxford, UK). Fever was defined as an auxiliary temperature $\geq 37.5^\circ C$. Thick and thin films were made from any child with a fever either in the field or in the study clinic where sick children would be referred. All febrile children with a detectable parasitaemia were treated with sulfadoxine–pyrimethamine (sulfadoxine 25 mg/kg, pyrimethamine 1.25 mg/kg) as a single dose and paracetamol (15–20 mg/kg). Parents were encouraged to take their children to the study clinic any time the child had symptoms of fever and many episodes were detected through this passive case detection.

Data analysis
All the data was incorporated into Visual FoxPro, version 6.0 databases (Microsoft Corp., Seattle, WA, USA) by double-entry. The data sets were then checked for discrepancies that were then resolved. All the analysis was conducted using Stata Statistical Software, version 7.0 (Stata Corp., College Station, TX, USA).

From the cross-sectional data, $\chi^2$ tests were used to compare proportions infected (slide-positive for Plasmodium falciparum) by net use. Logistic regression was used to estimate the association between parasite prevalence and net use after adjusting for potential confounders (i.e. age, mother’s education, and the use of mosquito coils and local repellants).

Clinical cases of malaria were defined as children presenting during the surveillance period with an axillary temperature $\geq 37.5^\circ C$ associated with a P. falciparum density of $\geq 5000$ parasites/µL of blood. If cases occurred $\leq 14$ d apart, only the first episode was included in the analysis. Poisson regression was used to estimate the association between malaria incidence and net use after controlling for potential confounders.

Results
Of the 416 children aged $\leq 10$ years recruited for this study, 288 (69%) had a bednet. Of the 288 nets, 28 were treated $\leq 1$ year ago, 46 had never been treated, and 214 were treated $> 1$ year ago—the majority (82%) of which were treated $> 2$ years ago. This study had only 19% power to detect a difference in the proportion infected between the treated net group (nets treated $< 1$ year ago) and the no net group; hence, the treated net group was not included in any further analysis. Those with nets that had never been treated and those that were treated $> 1$ year ago were considered as untreated nets.

Nets that were described as ‘intact’ and ‘satisfactory’ were grouped together as nets in good condition. Of untreated nets, untreated nets in good condition. Of untreated nets, 55 (14%) that slept under an untreated bednet that was worn, and 205 (53%) that slept under an untreated bednet in good condition.

Of the 260 nets, 209 (80%) were given free to community members during the previous trial of ITBNs and 207 (99%) of these were treated at least once during their lifetime. Forty-three nets (17%) were donated by a non-governmental organization working in the District (PLAN International) and 8 (3%) were purchased from the private sector.

Table 1 shows the demographic characteristics of the 3 groups. The proportion of children in the different age groups were similar in the different net use categories. Children that did not sleep under a net were more likely to use local repellants than those that slept under an untreated net that was worn (45% vs. 13%; $\chi^2 = 17.8, P < 0.001$) or an untreated net in good condition (45% vs. 22%; $\chi^2 = 21.1, P < 0.001$). Children that slept under an untreated net that was worn were more likely to use mosquito coils than those that did not sleep under a net (20% vs. 6%; $\chi^2 = 7.8, P = 0.005$) while there was no evidence of a difference in mosquito coil use among the children that did not use a net compared with those that slept under an untreated net in good condition (6% vs. 10%; $\chi^2 = 1.58, P = 0.21$). Mother’s education was higher among the children not sleeping under a net compared with those that slept under a net that was worn, although the significance was borderline (47% vs. 30%; $\chi^2 = 3.9, P = 0.05$). Mother’s education was also higher among children that slept under an untreated net in good condition compared with those that did not sleep under a net (57% vs. 47%; $\chi^2 = 2.98, P = 0.08$) although the difference was not statistically significant.

Parasite prevalence
In the cross-sectional survey, 75 (19%) children were P. falciparum-positive (at least 1 parasite/µL of blood) but only 27 (7%) had a high parasitaemia (≥ 5000 parasites/µL of blood). The Figure shows the proportion of children infected and proportion with high parasitaemia by bednet use. The proportion of children who were P. falciparum-positive was similar among those that did not sleep under a net and those that slept under an untreated net that was worn (27% vs. 23%; $\chi^2 = 0.27, P = 0.6$) while it was lower among those that slept under an untreated net that was in good condition compared with those that did not sleep under a net (13% vs. 27%; $\chi^2 = 10.4, P = 0.001$). There was no evidence of a difference between the 3 groups with regards to the prevalence of high parasitaemia (9%, 7%, 5%; $\chi^2 = 1.97, P = 0.4$).

Gender, use of mosquito coils and local repellants were not significantly associated with prevalence of parasitaemia. However there was evidence that the proportion of children infected was less in the home where the mothers had some formal education com-

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>No net (n = 128)</th>
<th>Untreated nets, worn (n = 55)</th>
<th>Untreated nets in good condition (n = 205)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>23 (18)</td>
<td>7 (13)</td>
<td>40 (20)</td>
</tr>
<tr>
<td>2–6</td>
<td>44 (34)</td>
<td>24 (44)</td>
<td>93 (45)</td>
</tr>
<tr>
<td>&gt; 6–10</td>
<td>61 (48)</td>
<td>24 (44)</td>
<td>72 (35)</td>
</tr>
<tr>
<td>Female</td>
<td>64 (50)</td>
<td>23 (45)</td>
<td>99 (48)</td>
</tr>
<tr>
<td>Local repellants</td>
<td>58 (45)</td>
<td>7 (13)</td>
<td>48 (23)</td>
</tr>
<tr>
<td>Mosquito coil</td>
<td>8 (6)</td>
<td>11 (20)</td>
<td>21 (10)</td>
</tr>
<tr>
<td>Mother’s education</td>
<td>51/109 (47)</td>
<td>15/50 (30)</td>
<td>108/189 (57)</td>
</tr>
</tbody>
</table>

*Mother’s education was not known for 40 children.
of the visit. The rate of success of follow-up was 92% for those with no nets and 96% for those that had untreated nets whether in good condition or worn.

Using a malaria definition of axillary temperature ≥ 37.5°C accompanied by a parasitaemia of ≥ 5000 parasites/μL of blood, 147 cases of malaria were observed. Twenty-eight children had > 1 episode of malaria during the 14 weeks but 5 occurred ≤ 14 d apart, therefore only 23 of these repeat episodes were included in the analysis (Table 2). Table 2 also shows the rate of malaria in the different net use categories during the follow-up period. The estimated rate of malaria episodes per 100 weeks was less among the children that slept under an untreated net whether in good condition or worn than the children that did not use a net, although these differences were not statistically significant.

Poisson regression was used to estimate the incidence rate of malaria episodes by net use after adjusting for age, use of local repellants, use of mosquito coils, and mother’s education. After adjusting for these confounders, the incidence rate of malaria episodes in children sleeping under an untreated net in good condition was 0.65 (95% CI 0.45–0.94, P = 0.02) times that of children that did not sleep under a net. Even after controlling for household clustering of data, the estimated effect of untreated nets in good condition was similar but there was a reduction in the power of the association (P = 0.06). There was no evidence of a difference in the incidence rate of malaria in children that slept under an untreated net that was worn and those that did not sleep under a net (adjusted incidence rate ratio = 0.87, 95% CI 0.52–1.44, P = 0.59).

Discussion

The prevalence of infection and incidence rates of malaria were lower among children that slept under an untreated net in good condition compared with those that did not sleep under a net. These results are consistent with earlier observations in The Gambia and Tanzania (Bradley et al., 1986; Campbell et al., 1987; Abdulla et al., 2001; Clarke et al., 2001). Clarke’s study in The Gambia was similar in design to ours although based upon only 25 clinical episodes of malaria. They reported a protective odds ratio of 0.65 (95% CI 0.29–1.46, P = 0.29) when comparing episodes of malaria among untreated net and non-net users.

The observation in this study that owning a net in good condition lowered both the proportion of children infected and the incidence of malaria episodes is important. After most ITBN trials it has proved difficult for the users to sustain net retreatment once they have to pay for it. In Kilifi, during the ITBN trial, net retreatment was provided free but at sentinel dipping stations and the retreatment rate was between 61 and

Table 2. Number of malaria episodes and bednet use among 388 children aged ≤ 10 years, Kilifi District, Kenya, June–August 2000

<table>
<thead>
<tr>
<th></th>
<th>No net (n = 128)</th>
<th>Untreated nets, worn (n = 55)</th>
<th>Untreated nets in good condition (n = 205)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fevers detected</td>
<td>115</td>
<td>51</td>
<td>156</td>
</tr>
<tr>
<td>Number of malaria episodes</td>
<td>58</td>
<td>22</td>
<td>62</td>
</tr>
<tr>
<td>Person weeks</td>
<td>1649</td>
<td>753</td>
<td>2744</td>
</tr>
<tr>
<td>Unadjusted estimated rate of malaria episodes per 100 weeks (95% CI)</td>
<td>3.5 (2.7–4.5)</td>
<td>2.9 (1.8–4.4)</td>
<td>2.3 (1.7–2.9)</td>
</tr>
</tbody>
</table>
67% (Snow et al., 1999). However, when a cost-retrieval system was introduced, net retreatment rates dropped to 7% in the Gambia, net retreatment coverage dropped from 85% during the trial to 14% when cost-retrieval was introduced (Cham et al., 1997; Muller et al., 1997), and childhood mortality went back to the pre-intervention levels (D’Alessandro et al., 1995).

In a study in Tanzania, Winch et al. (1997) found that people were able to understand the benefits of the nets more than that of the insecticide. Even in the context of an effective social marketing programme, there is poor uptake of net treatment compared with the uptake of nets themselves (Armstrong-Schellenberg et al., 2001). This was thought to be due to cost and social issues such as a lack of full understanding of the way the insecticide works and fears that the insecticide has detrimental effects.

From previous studies, there is little doubt that treated nets would be the best method of preventing morbidity and infection but following the recurrent failures in sustaining net retreatment, it is encouraging to note that untreated nets in good condition offer some protection when compared with lack of net use. It was also encouraging to note that more than 6 years after the nets were given out in this area, 74% were still in good condition.

The recent economic analysis of untreated vs. treated nets suggest that untreated nets have an intermediate cost-effectiveness when having no nets at all and using treated nets (Guyatt & Snow, 2002). If communities in malaria-endemic areas are unable to take up net retreatment but take up nets, which they then view as useful and therefore keep in good condition, children may still gain substantial protection from both infection and disease. Before the widespread availability of permanently treated nets, interventions that depend upon consistently treated nets (mosquito nets) as a malaria control strategy in a rural area of The Gambia, West Africa. Transactions of the Royal Society of Tropical Medicine and Hygiene, 82, 212–215.


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