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# Short Report: Assessing the Impact of Indoor Residual Spraying on Malaria Morbidity Using a Sentinel Site Surveillance System in Western Uganda

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*Abstract.* A single round of indoor residual spraying (IRS) using lambda-cyhalothrin was implemented in a district of Uganda with moderate transmission intensity in 2007. Individual patient data were collected from one health facility within the district 8 months before and 16 months after IRS. There was a consistent decrease in the proportion of patients diagnosed with clinical malaria after IRS for patients < 5 and > 5 years of age (52% versus 26%, $P < 0.001$ and 36% versus 23%, $P < 0.001$, respectively). There was a large decrease in the proportion of positive blood smears in the first 4 months after IRS for patients < 5 (47% versus 14%, $P < 0.001$) and > 5 (26% versus 9%, $P < 0.001$) years of age, but this effect waned over the subsequent 12 months. IRS was effective in reducing malaria morbidity, but this was not sustained beyond 1 year for the proportion of blood smears read as positive.

Malaria is the leading cause of morbidity and mortality in Uganda, responsible for up to 40% of outpatient visits, 25% of hospital admissions, and 14% of hospital deaths (Uganda Ministry of Health, unpublished data). Malaria control efforts in Uganda include case management with artemisinin-based combination therapy (ACT), widespread coverage with long-lasting insecticide treated nets (LLINs), and intermittent preventive therapy in pregnancy. To expand its malaria control activities, the Uganda National Malaria Control Strategic Plan 2005–2010 has included indoor residual spraying (IRS) as one of the major malaria control interventions. Uganda aims to establish and sustain a system of high-quality IRS services that cover at least 85% of all targeted structures in areas of unstable transmission while piloting and potentially scaling up IRS in stable malaria transmission areas.

Kanungu District is a district in southwest Uganda where IRS was implemented with support from the President's Malaria Initiative (www.pmi.gov). This district experiences perennial malaria with moderate transmission intensity and an entomologic inoculation rate estimated to be six infectious bites per person year in 2002.[1] During February and March 2007, ~45,000 households covering a population of 190,000 persons were sprayed with the synthetic pyrethroid lambda-cyhalothrin wettable powder formulation (ICON 10% WP; Syngenta, Sweden). IRS was targeted to ~70% households that are situated in areas below an altitude of 1,200 m, resulting in coverage of ~90% of targeted households. This first round of spraying in Kanungu was to be followed by serial IRS in the targeted subcounties. Because of logistical constraints, the next round of IRS has been delayed but is scheduled to occur in mid-2009.

Accurate evaluation of the impact of interventions is necessary to optimize malaria control efforts. In 2006, the Uganda Malaria Surveillance Project (UMSP) established a sentinel site surveillance system that routinely collects individual-level data on all patients presenting to the outpatient department of selected government health facilities representing areas of varying malaria transmission intensity. These data are intended to monitor secular trends in malaria morbidity and to assess the impact of control interventions as needed. The system is operational at several health facilities, including Kihihi Health Center in Kanungu District, where surveillance began in August 2006. All health workers including laboratory personnel received training in malaria diagnosis and case management at the start of the surveillance program. The sensitivity and specificity of field microscopy compared with expert microscopy was 92% and 95%, respectively, and there was no turnover of laboratory staff throughout the period of observation.[2] Data were entered in Access (Microsoft, Redmond, WA) and included patient demographics (age, residence), malaria blood smear results, and clinical diagnoses. Pre-IRS data included 8 months before completion of IRS (August 2006 to March 2007) and post-IRS data included 16 months after the completion of IRS, divided into 4-month time blocks (April 2007 to July 2007, August 2007 to November 2007, December 2007 to March 2008, and April 2008 to July 2008). Data were included only for patients residing within Kanungu District. To estimate the impact of IRS on malaria morbidity we evaluated the following two indicators: 1) the proportion of patients presenting to the health center given a clinical diagnosis of malaria (number of patients diagnosed with clinical malaria/total number of patients seen at the health center), 2) the proportion of blood smears read as positive (number of patients with a positive blood smear/number of patients with a blood smear done). A diagnosis of clinical malaria is made by the health care provider and may include any of the following: 1) patients not sent to the laboratory for a blood smear, 2) patients with a positive blood smear, and 3) patients with a negative blood smear but still given a diagnosis of malaria. Pre- and post-IRS data for these two indicators were compared using time series analyses adjusted for age, residence, rainfall, sex, and temporal trends using an autoregressive, integrated, moving average (ARIMA) model (Stata version 10; Stata Corp., College Station, TX). Using time series analysis allowed us to measure the effect of IRS while controlling for other predictors of malaria incidence such as rainfall and seasonality.[3] Results were expressed in terms of risk differences (pre-IRS proportions – post-IRS proportions) with 95% confidence intervals. $P < 0.05$ was considered statistically significant.

Key baseline patient and diagnostic characteristics before and after IRS are presented in Table 1. A total of 36,275

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TABLE 1
Key patient and diagnostic characteristics before and after IRS

| Characteristic | Pre-IRS | | Post-IRS | | | |
|---|---|---|---|---|---|---|
| | 8/06–11/06 | 12/06–3/07 | 4/07–7/07 | 8/07–11/07 | 12/07–3/08 | 4/08–7/08 |
| Total number of patients seen | 7,554 | 8,589 | 5,355 | 4,973 | 4,231 | 5,573 |
| Proportion of patients < 5 years of age | 32% | 37% | 25% | 24% | 25% | 24% |
| Proportion of patients with malaria suspected | 66% | 71% | 51% | 50% | 50% | 51% |
| Proportion referred for microscopy if malaria suspected | 73% | 76% | 72% | 67% | 82% | 84% |
| Proportion given clinical diagnosis of malaria if blood smear positive | 78% | 95% | 98% | 93% | 90% | 87% |
| Proportion given clinical diagnosis of malaria if blood smear negative | 35% | 14% | 12% | 11% | 7% | 11% |
| Proportion of cases of clinical malaria confirmed by microscopy | 30% | 48% | 16% | 17% | 41% | 46% |

patients were evaluated over the 24-month observation period. The average number of patients seen each month was consistently higher in the 8 months before IRS compared with the 16 months after IRS (2,018/month versus 1,258/month). The impact of IRS on our two measures of malaria morbidity over time is presented in Figure 1 and Table 2. There was a significant and consistent decrease in the proportion of patients diagnosed with clinical malaria over the 16 months after IRS for both patients < 5 years of age (52% pre-IRS versus an adjusted 26% after IRS) and those ≥ 5 years of age (36% pre-IRS versus an adjusted 23% after IRS). Furthermore, there was a dramatic drop in the proportion of blood smears read as positive in the 4 months immediately after IRS. However, these differences gradually waned over the subsequent 16 months. Among patients < 5 years of age, the proportion of blood smears read as positive decreased from 47% before IRS to an adjusted risk of 14% ($P < 0.001$) in the first 4 months after IRS, gradually increasing to an adjusted risk of 30% in the 12–16 months after IRS ($P < 0.001$; Table 2). Among patients ≥ 5 years of age, the proportion of blood smears read as positive decreased from 26% before IRS to an adjusted risk of 9% ($P < 0.001$) in the first 4 months after IRS, gradually increasing to an adjusted risk of 25% in the 12–16 months after IRS, which was not significantly different from pre-IRS levels ($P = 0.56$; Table 2).

Differences in the impact of IRS on our two indicators of malaria morbidity over time can be explained by the factors that contribute to these measurements. The Uganda national disease reporting system relies on cases of clinical malaria. This measurement is influenced by the proportion of patients

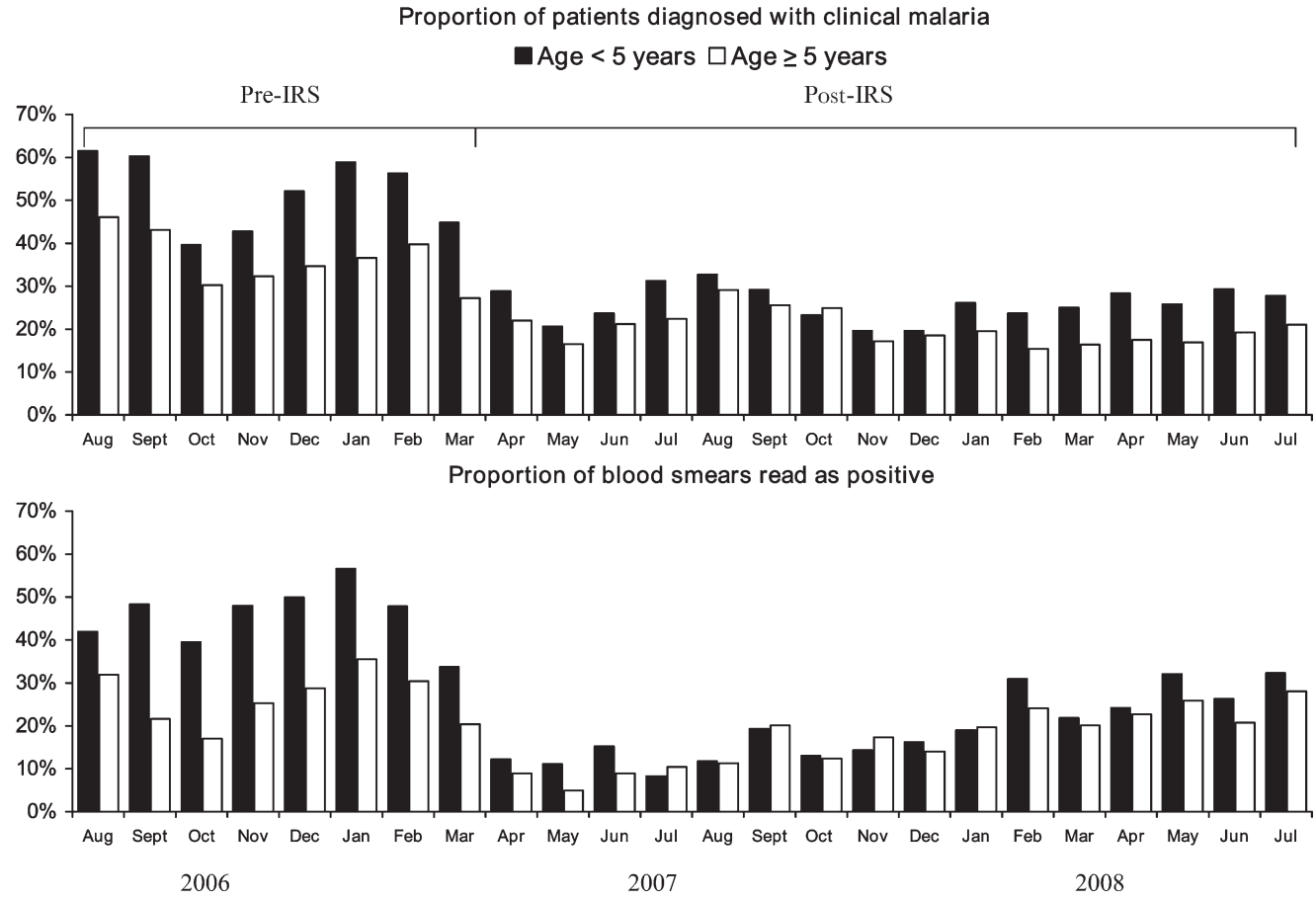


FIGURE 1. Pre- and Post-IRS crude monthly proportions of patients diagnosed with clinical malaria and blood smears read as positive.

TABLE 2
Absolute decrease in the probability of outcomes of interest after IRS

| | | 4/07–7/07 | | 8/07–11/07 | | 12/07–3/08 | | 4/08–7/08 | |
|---|---|---|---|---|---|---|---|---|---|
| Outcome | Age group | RD (95% CI) | *P* | RD (95% CI) | *P* | RD (95% CI) | *P* | RD (95% CI) | *P* |
| Proportion diagnosed with clinical malaria | < 5 years | 26.8% (19.5–34.0%) | < 0.001 | 26.4% (19.0–33.9%) | < 0.001 | 27.3% (20.3–34.4%) | < 0.001 | 24.6% (16.6–32.7%) | < 0.001 |
| | ≥ 5 years | 11.3% (8.0–15.0%) | < 0.001 | 10.2% (5.7–14.7%) | < 0.001 | 16.3% (11.1–21.5%) | < 0.001 | 15.7% (10.4–20.9%) | < 0.001 |
| Proportion of blood smears read as positive | < 5 years | 33.3% (27.6–39.2%) | < 0.001 | 31.1% (23.0–39.2%) | < 0.001 | 22.8% (17.5–28.2%) | < 0.001 | 17.4% (12.2–22.7%) | < 0.001 |
| | ≥ 5 years | 17.3% (9.3–25.3%) | < 0.001 | 10.9% (4.8–16.0%) | < 0.001 | 6.9% (2.3–11.5%) | 0.003 | 1.4% (–3.3 to 6.1%) | 0.56 |

RD = risk differences (pre-IRS proportions – post-IRS proportions) adjusted for temporal trends, rainfall, residence, sex, and age.

with suspected malaria sent to the laboratory, as well as the relationship between blood smear results and the diagnoses given. In this study, these factors varied considerably over time, resulting in a lower proportion of cases of clinical malaria confirmed by microscopy in the first 8 months after IRS, thus potentially underestimating the initial impact of IRS on this indicator (Table 1). In contrast, the proportion of blood smears read as positive provides a more robust and specific indicator of changes in malaria morbidity, assuming that there is no systematic bias in the selection of patients suspected of malaria who are referred for microscopy (i.e., no systematic bias in the association between deciding to send a patient to the laboratory and the probability of them having malaria) and the accuracy of microscopy results.

There have been several recent reports of dramatic reductions in indicators of malaria morbidity and mortality in Africa after IRS campaigns either alone or in combination with other wide-scale malaria control interventions. However, these reports have come from island communities,[4,5] relatively low seasonal transmission settings in Southern Africa,[6–8] or epidemic-prone highland areas.[9] In addition, they were based on specifically designed comparisons of pre- and post-intervention data from cross-sectional surveys or retrospective analysis of health facility records. Our surveillance system has the advantage of using available quality data with minimal additional investment for assessing the impact of not only IRS, but other population-level interventions as well. As IRS intervention efforts in Africa expand to higher transmission settings, it is important to generate an evidence base to help quantify impact on standardized measures of malaria morbidity and mortality. This will be important to help determine optimal insecticide formulations, spraying strategies, timing of repeated spraying, and generate data for cost-effectiveness analyses and comparisons with other control interventions. In this study, IRS was associated with a clear reduction in indicators of malaria morbidity in an area of moderate transmission intensity. However, there was limited evidence that reductions in malaria morbidity were sustained beyond 1 year. It should be recognized that this study had several limitations including an observational study design and the lack of population level data. Although we attempted to control for seasonal trends, we cannot rule out the possibility that differences seen in our measures of malaria morbidity could have been caused by factors other than IRS, including the scale-up of ACTs and increasing LLIN coverage. However ACTs were first deployed in the Kanungu district in 2006, before collection of our surveillance data, and no major ITN distribution interventions were performed in the district during our observation period. Despite these potential limitations, we feel that sentinel site surveillance systems provide a feasible and efficient means of collecting longitudinal data on measures of malaria morbidity and that the most useful measures are those that focus on laboratory confirmed cases of malaria.

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