Diagnostic Accuracy of Malaria Microscopy in the Highlands of Central Kenya: Implications for Proper Treatment

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Abstract

Over-diagnosis of malaria is a problem in many African countries and appears to be occurring in the highlands of central Kenya. Blood-smear microscopy, the standard technique for malaria diagnosis in this area, relies heavily on technician skill. Hence, Rapid Diagnostic Tests (RDTs) are increasingly considered the gold standard for diagnosis, but are often not available in resource-constrained settings. We compared the results of microscopy and RDTs performed on finger-prick blood samples from 250 patients referred to laboratory malaria testing at one private and two government health facilities in/near Meru, Kenya. Across the three sites, 97.1%-100% of microscopy-diagnosed *Plasmodium*-positive samples were found negative by RDT. Of the three study sites, the government district hospital had the highest microscopy-based positive rate (27.3% as compared to 5.9% and 9.3% in the other two settings). These results indicate alarming levels of inaccurate malaria diagnosis in the Meru region. Many factors may play a role in this phenomenon, and it is likely that a "systems level" approach is necessary to remedy this problem.

Key words: *Malaria, Diagnosis Accuracy, Kenya, RDT, Microscopy, plasmodium*

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Introduction/Background

Malaria is one of the most prevalent infectious parasitic diseases in the world. In 2010, the World Health Organization reported 216 million cases of malaria and over 655,000 deaths. Though approximately half the world population is at risk, over 90% of cases occur in sub-Saharan Africa (World Health Organization World Malaria Report, 2009; Murray *et al.*, 2012). That region experienced a 30% decline in deaths from 2004 to 2010, but remains the global epicenter of the disease (Murray *et al.*, 2012). In 2009, 67% of the Kenyan population of 38.6 million was at risk for malaria, with over 8 million cases of malaria being reported annually (WHO World Malaria Report, 2009).

While it is undeniable that malaria infection is a serious problem in sub-Saharan Africa, recent studies suggest that the actual number of malaria cases may be lower in some locations than the reported incidence suggests. A prospective study in the Sudan showed a rate of false-positive malaria diagnoses of 75.6% (Salwa *et al.*, 2009). A similar study in Tanzania reported a false-positive rate of 75.1% and linked misdiagnosis to increased patient mortality due to failure to treat alternative causes of severe infection (Reyburn *et al.*, 2004). Furthermore, a study of seventeen hospitals across Kenya showed that revised clinical practice coupled with improved laboratory diagnostic techniques can save health systems large sums of money (Zurovac *et al.*, 2006). Thus, while malaria continues to be a major health concern in many parts of Africa, unnecessary anti-malarial treatment and lack of treatment of other, overlooked infections may be wasting valuable healthcare resources, increasethe development of resistant malaria infections, and lead to excess patient mortality from other febrile illnesses.

Over-diagnosis of malaria that has been noted in other areas of the world may also be occurring in the Meru region of central Kenya. Malaria in Kenya is typically restricted to below 1600m, though epidemics have been known to reach higher elevations (Arness *et al.*, 2003). The elevation of the Meru region varies from ~1000-2000m, suggesting that *Plasmodium* transmission might not be widespread because of limited distribution or survival of*Anopheles* mosquito vectors. Local clinics and hospitals, however, report a high number of malaria cases as well as treatment of individuals year-round. Maps published by the Kenyan Ministry of Health and MARA (Mapping Malaria in Africa, Figure 1) show the presence of seasonal malaria in Meru. This discrepancy between the predicted incidence and seasonality and the reports of local practitioners warrants a detailed surveillance-based investigation.

In the highlands of central Kenya the common malaria *Plasmodium* parasite species are *P. falciparum* and *P. vivax,* both transmitted by *Anopheles* species mosquitoes (Arness *et al.*, 2003; Baliraine *et al.*, 2009). Parasite transmission and the geographic range of malaria is affected by ecological factors such as humidity, altitude (a proxy for ambient temperature), density and movement of susceptible humans, and availability of suitable mosquito breeding sites (Malakootiet *al.*, 2011). Like much of Kenya, the Meru region experiences two rainy seasons, a short one in November and an extended one lasting from late March through May. In areas like Meru where environmental indicators suggest lower-level risk and epidemic or seasonal disease patterns, accurate testing of suspected malaria is especially important, because presumptive diagnoses (either positive or negative) are less likely to be accurate. Such testing could reduce unnecessary treat-

ment for malaria, thereby reducing costs and improving accuracy of diagnosis. Accurate testing would allow for recognition and proper treatment of non-*Plasmodium* infections that produce febrile symptoms.

In addition, anti-*Plasmodium* drugs can be toxic. Several anti-malarials are known to cause adverse reactions in patients, though the cost-benefit equation differs when they are used for treatment versus prophylaxis (AlKadi, 2007). Each medication has contra-indications and cumulative toxicity can result in serious complications. Though no formal studies to measure adverse reactions to anti-malarials have been conducted in Meruregion, local physicians have anecdotally reported cases of severe liver failure and other conditions they attribute to cumulative toxicity, perhaps from over-diagnosis of malaria.

There are several methods currently being used in Kenya to diagnose malaria. Presumptive treatment (PT) is used in some high-transmission areas where anti-malarial treatment is provided to any patient presenting with a fever, without a laboratory confirmation. Many areas employ more stringent clinical symptom-based diagnoses. Alongside clinical diagnoses many health facilities also employ basic laboratory capacity. The least-expensive and most common laboratory diagnostic tool involves microscopic examination of blood on slides to detect, count and identify *Plasmodium* species. Results typically are available within an hour depending on the daily workload. When multiple technicians with ample time undertake microscopic diagnoses, this can be the gold standard of malaria diagnosis. In many instances, however, equipment is limited or of low quality, confirmatory testing absent and examination time is constrained by high patient volumes. Furthermore, microscopy technicians who believe that patients are being treated presumptively for malaria regardless of blood film results may be less motivated to properly examine the slide.

Rapid Diagnostic Tests (RDTs) are increasingly being used to diagnose malaria, especially in low-resource settings (Kamau, 2007). RDTs typically consist of a small plastic cassette with an attached membrane test strip. The test strip is impregnated with monoclonal antibodies for the target *Plasmodium* antigen, and immunochromatographic assay reveals coloured test lines, indicating infection or non-infection. These results are typically available in 5-20 minutes with minimal human interpretation or training needed. There are now over twenty different manufacturers of malaria RDTs and over sixty different products available (Kamau, 2007) with sensitivity and accuracy comparable to microscopy.RDTs are currently not widely used in Kenya (WHO World Malaria Report, 2011), but a plan for nationwide distribution was announced in November 2012 by the Ministry of Public Health and Hygiene (Musliime, 2012).

Accordingly, we undertook a study to evaluate the accuracy of malaria diagnosis in and around Meru, a region that experiences seasonal and spatially variable risk. The objective was to evaluate the accuracy of diagnosis of malaria by comparing the number of malaria cases diagnosed by microscopy with those determined by RDT. Secondly, we analyzed patient demographic data for patterns in age, gender, clinical symptoms, and elevation of patient residence.

Materials and Methods

During one week in mid-June 2011, RDT and microscopy results were collected from patients at three health facilities in and around Meru. A private hospital, a large government hospital and a small government dispensary were chosen for the study. Meru District Hospital is a large government facility with 306 beds and a diagnostic laboratory with 6-10 laboratory staff present at a given time. The Kinoru dispensary, a small, government clinic located just off the main Meru intersection, has a simple diagnostic laboratory with one or two technicians who oversee all testing. St. Theresea'sKiirua Mission Hospital is a private health facility located ~30 km into the hills north of Meru, with two laboratory technicians present at most times.

This study was undertaken as part of quality control/quality assurance comparing the use of RDTs and slide microscopy under the mandate of the Kenya Methodist University to provide community health surveillance in the Meru region. Although human subjects were not directly involved in this laboratory testing quality control project, approval for the study by the Kenya Methodist University Institutional Review Board was obtained. No data allowing for individual identification of participants was collected.

Patients included in the study had visited one of the three participating health facilities, had been seen by the attending physician, and referred to the microscopy laboratory for malaria tests as part of normal hospital practice. A total of 259 patients were consented to participate in the study, and the analysis included 128 at Meru District Hospital, 68 at the Kinorudispensary and 54 from the St. Theresea's Mission Hospital. Patient age, gender, and region of residence were recorded. There were no asymptomatic controls compared for this study.

Those patients for whom a malaria slide test was recommended proceeded to the laboratory as directed by the attending physician. Standard finger-prick blood samples were obtained by a hospital technician for microscopic evaluation. An additional drop of blood from that finger-prick was applied to an RDT kit. Our study used SD Bioline antigen RDTs that differentiate between *P. falciparum ("P.f.", targeted by HRP-2 antigen)* and the other *Plasmodium* species (*P. vivax*, *P. malariae*, and *P. ovale,* collectively labeled *"Pan"*). Slides were evaluated by the laboratory technicians of that hospital using their normal procedures, while RDTs were evaluated by a member of the study team. The readers of each method were effectively "blinded" to the results of the other test. The samples were taken from 9am to 5pm over the course of 2-3 consecutive days at each site.

In addition to the blood sample, personal information was recorded for eventual association with laboratory tests including age, gender, village of residence, and chief complaints that brought the patient to the hospital. No data to identify individual patients were recorded.

Approximate elevations of the residences were acquired by Google Earth. About 90% of the villages of residence were identified and assigned an approximate elevation. When a village was located, the elevation of the primary school was used as a default value for all residents of that village.

Results

A total of 259 blood samples were tested by using both methods, but 9 were discarded because of unclear RDT readings. Of 250 valid comparisons, only one was RDT-positive for *Plasmodium* infection (Table 1). That one sample was also microscopy-positive. There were no samples that were microscopy-negative and RDT-positive.However, 44 samples were microscopy-positive but RDT-negative. An additional 205 samples were both RDT-negative and microscopy-negative.

The percent of cases determined to be positive by microscopy varied by facility (Table 2). The Kinoru dispensary and KiiruaMission Hospital exhibited 5.9% and 9.3% microscopy-positive prevalence, respectively, while at Meru District Hospital the proportion was 27.3%. At both the Kinorudispensaryand Kiirua Mission Hospital all of the microscopy-positivesamples were found to be negative by RDT. Meru District Hospital had the one RDT-positive sample. Thus, 97.1% of its microscopy-positives were unconfirmed by RDT.

Statistical analysis revealed a significant difference between the elevation of patient residences by study site (Table 3). The samples fromKiirua Mission Hospital and Kinoru Dispensary were not significantly different from each other, but the elevations associated with the Meru District Hospital samples were significantly lower than those of the other two facilities (p-values of <0.001 and 0.009 as compared against Kinoru dispensary and Kiirua Mission Hospital, respectively).

None of the self-reported clinical symptoms were significantly correlated with microscopy results at the 0.05 significance level.

Discussion

This study reveals a striking discrepancy between RDT and microscopy results at three healthcare facilities in the immediate Meru region. Our study found a high proportion of false positive microscopy-based diagnoses at all three study sites. Furthermore, the proportion of positive microscopy-based diagnoses at Meru District Hospital was three times as high as at the other two study sites.

Many factors that impact laboratory diagnosis could explain the high levels of inaccuracy and the difference among sites. These facilities generally have few laboratory staff, heavyworkloads, and the possibility of low quality or contaminated laboratory equipment or reagents.Technician awareness of the treatment provided to patients regardless of parasite testing results may lead them to allocate their energy toward other tests, or to tasks that have a stronger impact on treatment. Furthermore, the presence of interns at Meru District Hospital may have impacted microscopy diagnosis. Any efforts to remedy this situation must be comprehensive and consider systemic challenges to accurate testing as well as technological upgrades and enhanced technician training.

Other studies have shown that true positive malaria cases are more likely at lower elevations. We observed that Meru District Hospital's patients reside at lower elevations than the patients of the other two facilities (Table 3). Perhaps the tendency for Meru District Hospital microscopy technicians to determine higher rates of malaria infection is due to knowledge about their patient's residence. Future research could examine whether diagnostic laboratories located at borderline altitudes, serving populations both at higher and lower risk for infection, are more susceptible to misdiagnosis.

It is worth noting that the study occurred in late June, in the midst of an unusually dry period. The samples were taken more than a month after the spring rainy season (March through May), so true malaria cases could be expected to be at, or close to, their annual nadir. This timing suggests that the level of inaccuracy recorded was at its most exposed state. Had the study taken place during or shortly after one of the rainy seasons, laboratory inaccuracies could have been masked by a higher number of true malaria cases.

The purpose of this study was to evaluate the situation of malaria laboratory diagnosis at a small, representative sample of health facilities in the immediate vicinity of Meru. The three facilities chosen, however, do not include the small private pharmacies and clinics that often diagnose conditions and dispense medication. Some medical contacts in the area suspect that the volume of unnecessary anti-malarials distributed without any laboratory results at these facilities could be higher than what we observed in this study. A more robust study would seek to include these facilities and would include facilities in nearby Isiolo and other lowland communities, so as to have a "control" group from a truly malaria-endemic region.

Our study was limited to those people referred to the laboratory for a microscopy blood-slide test for malaria. Thus, our study does not include the sizable population who self-diagnose, or who are diagnosed by their physician without a laboratory test. A more comprehensive analysis would include these patients; however, such a study design must be more complex to eliminate clinician bias, feedback, etc.

Conclusion

Misdiagnosis was a prominent feature of malaria laboratory testing at the three facilities in our study, and likely throughout the Meru region. The level of inaccurate laboratory results is alarmingly high, and could be resulting in adverse health impacts for the general population. Further studies are necessary to map true malaria risk and complete a more thorough analysis of malaria diagnosis procedures.

Of the three study sites, Meru District Hospital had the highest proportion of microscopy-based positive malaria diagnoses. The causes of the diagnostic inaccuracy are likely complex and systemic in nature, and comprehensive solutions should address facility infrastructure and staffing, supplies, and consider implementing new diagnostic technologies.

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References

AlKadi, H.O. (2007). Antimalarial Drug Toxicity: A Review. *Chemotherapy. 53(6)*, 385-391. Viewed on 20 March, 2012. http://www.gnmhealthcare.com/pdf/10-2007/18/1465954_AntimalarialDrugToxicityA.pdf

Arness, M.K., Bradshaw, R.D., Biomndo, K, &Shanks, G.D. (2003). Epidemiology of highland malaria in western Kenya. *East Afr Med J., 80(5)*,253-9. Viewed on 20 March, 2012.http://

www.ncbi.nlm.nih.gov/pubmed/16167741

Baliraine, F.N., Afrane, Y.A., Amenya, D.A., Bonizzoni, M., Menge, D.M., Zhou, G., etal. (2009). High prevalence of asymptomatic Plasmodium falciparum infections in highland area of western Kenya: a cohort study. *J Infect Dis. 200(1),*55-74.Viewed on 20 March, 2012. http://jid.oxfordjournals.org/content/200/1/66.short

Bell, D., & Perkins, M. (2008). Making malaria testing relevant: beyond test purchase. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 102*, 1064-1066.Viewed 12 February, 2012. http://www.sciencedirect.com/science/article/pii/S0035920308002204

Breman, J.G., Alilio, M.S.,& Millis, A. (2004). Conquering the Intolerable Burden of Malaria: What's New, What's Needed: A Summary.*Am J Trop MedHyg., 71(2),* 1-15.Viewed 12 February, 2012.http://www.ajtmh.org/content/71/2_suppl/1.short

Dixon, D.S. (1950). Paludrine (proguanil) as a malarialprophylactic amongst African labour in Kenya.*East Afr Med J. 27(3)*, 127-30.Viewed on 20 March, 2012. http://www.cabdirect.org/abstracts/19502901555.html

Eckhoff, P. (2011). A malaria transmission-directed model of mosquito life cycle and ecology. *Malaria Journal, 10,*303.doi:10.1186/1475-2875-10-303.Viewed on 20 March, 2012.http://www.biomedcentral.com/content/pdf/1475-2875-10-303.pdf

Gallup, J.L., & Sachs, J.D. (2001).The Economic Burden of Malaria.*Am J TropMed Hyg., 64(2)*, 85-96.Viewed on 14 September, 2011.http://academiccommons.columbia.edu/catalog/ac:124074

Hay, S.I., Cox, J., Rogers, D.J., Randolph, S.E., Stern, D.I., Shanks, G. D.,*et al.* (2002). Climate change and the resurgence of malaria in the East African highlands.*Nature, 415*, 905-909.doi:10.1038/415905a.Viewed on 14 September, 2011.http://www.nature.com/nature/journal/v415/n6874/abs/415905a.html

Kamau, E.M. (2007). Malaria diagnosis in the community: Challenges and potential role of rapid diagnostic tests (RDTs) in the African Region. *Afr J Health Sci. 14*, 114-117.Viewed on 20 December, 2011.http://www.ajol.info/index.php/ajhs/article/view/30856

Lindsay, S.W., &Martens, W.J. (1998). Malaria in the African Highlands: past, present, future. *Bull World Health Organ. 76(1), 33–45. Viewed 20 December, 2011.*http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2305628/

Malakooti, M.A., Biomndo, K., & Shanks, G.D. (1998). Reemergence of epidemic malaria in the highlands of western Africa. *Emerg Infect Dis., 4(4), 671–676.Viewed 20 March, 2012.* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2640260/

MARA/ARMA Collaboration. (2001). Maps of malaria distribution and malaria endemic season in Kenya [Map]. Medical Research Council, Durban, South Africa.

Minakawa, N., Mutero, C.M., Githure, J.I., Beier, J.C., & Yan, G. (1999). Spatial distribution and habitat characterization of anopheline mosquito larvae in Western Kenya. *Am J TropMedHyg., 61(6)*, 1010-1016.Viewed 18 January, 2012. http://www.ncbi.nlm.nih.gov/pubmed/10674687

Munga, S., Minakawa, N., Zhou, G., Mushinzimana, E., Barrack, O.O., Githeko,A.K., *et al.* (2006). Association between land cover and habitat productivity of malaria vectors in western Kenyan highlands. *Am J Trop Med Hyg., 74(1)*, 69-75. Viewed on 20 January, 2012. http://europepmc.org/abstract/MED/16407348

Murphy S.C.,&BremanJ.G. (2001). Gaps in the childhood malaria burden in Africa: cerebral malaria, neurological sequelae, anemia, respi-

ratory distress, hypoglycemia and complications ofpregnancy. *Am J Trop Med Hyg. 64 (1–2 Suppl)*, 57–67.Viewed on April 21, 2012.http://www.ncbi.nlm.nih.gov/books/NBK2621/

Murray, C.J.L., Rosenfeld, L.C., Lim, S.S., Andrews, K.G., Foreman, K.J., Haring, D.H.,*et al.* (2012). Global malaria mortality between 1980 and 2010: a systematic analysis. *The Lancet, 379 (9814)*, 413-431.doi:10.1016/S0140-6736-(12)60034-8. Viewed April 21, 2012. http://www.sciencedirect.com/science/article/pii/S0140673612600348

Musliime, L. (2012, October 22). The Ministry of Public Health and Sanitation in Partnership with the U.S.President's Malaria Initiative Launches Rapid Diagnostic Tests. USAID.Retrieved from http://kenya.usaid.gov/news-story/1335 .

Ndenga B., Githeko, A., Omukunda, E., Munyekenye, G., Atieli, H., Wamai, P, *et al.* (2006). Population Dynamics of Malaria Vectors in Western Kenya Highlands.*J MedEntomol, 43(2),* 200-206.Viewed on 20 January, 2012. http://www.bioone.org/doi/abs/10.1603/0022-2585(2006)043%5B0200:PDOMVI%5D2.0.CO%3B2

Orostegui, L., Balu, L., Chevret, L., Habes, D., &Pussard, E. (2010). Community Management of Anti-Malarials in Africa and Iatrogenic Risk.*Journal of Tropical Pediatrics, 57(3),* 225-226.doi: 10.1093/tropej/fmq074. Viewed 20 January, 2012.http://tropej.oxfordjournals.org/content/57/3/225.short

President's Malaria Initiative. (2011). *Kenya Country Profile.*Viewed on 21 January, 2012. http://www.pmi.gov/countries/profiles/kenya_profile.pdf

Reyburn, H., Mbatia, R., Drakeley, C., Carneiro, I., Mwakasungula, E., Werinde, O., et al. (2004). Overdiagnosis of malaria in patients with severe febrile illness in Tanzania: a prospective study. *BMJ*, 329(7476), 1212.doi: 10.1136/bmj.38251.658229.55. Viewed on September 21, 2011.http://www.ncbi.nlm.nih.gov/pmc/articles/PMC529364/

Roberts, J.M. (1964). The control of epidemic malaria in the highlands of western Kenya. 1. Before the campaign. *J Trop Med Hyg., 67*, 161-8 Contd.Viewed on 2 January, 2012. http://www.ncbi.nlm.nih.gov/pubmed/14176374

Salwa M.E. A-Elgayoum, Abd El-Karim, Ahmed El-Feki, Babiker Ahmed Mahgoub, El-Amin El-Rayah,&Hayder A. Giha (2009). Malaria overdiagnosis and burden of malaria misdiagnosis in the suburbs of central Sudan: special emphasis on artemisinin-based combination therapy era. *Diagnostic Microbiology & Infectious Disease, 64(1),* 20-26.Viewed on 1 March, 2012.http://www.sciencedirect.com/science/article/pii/S0732889309000509

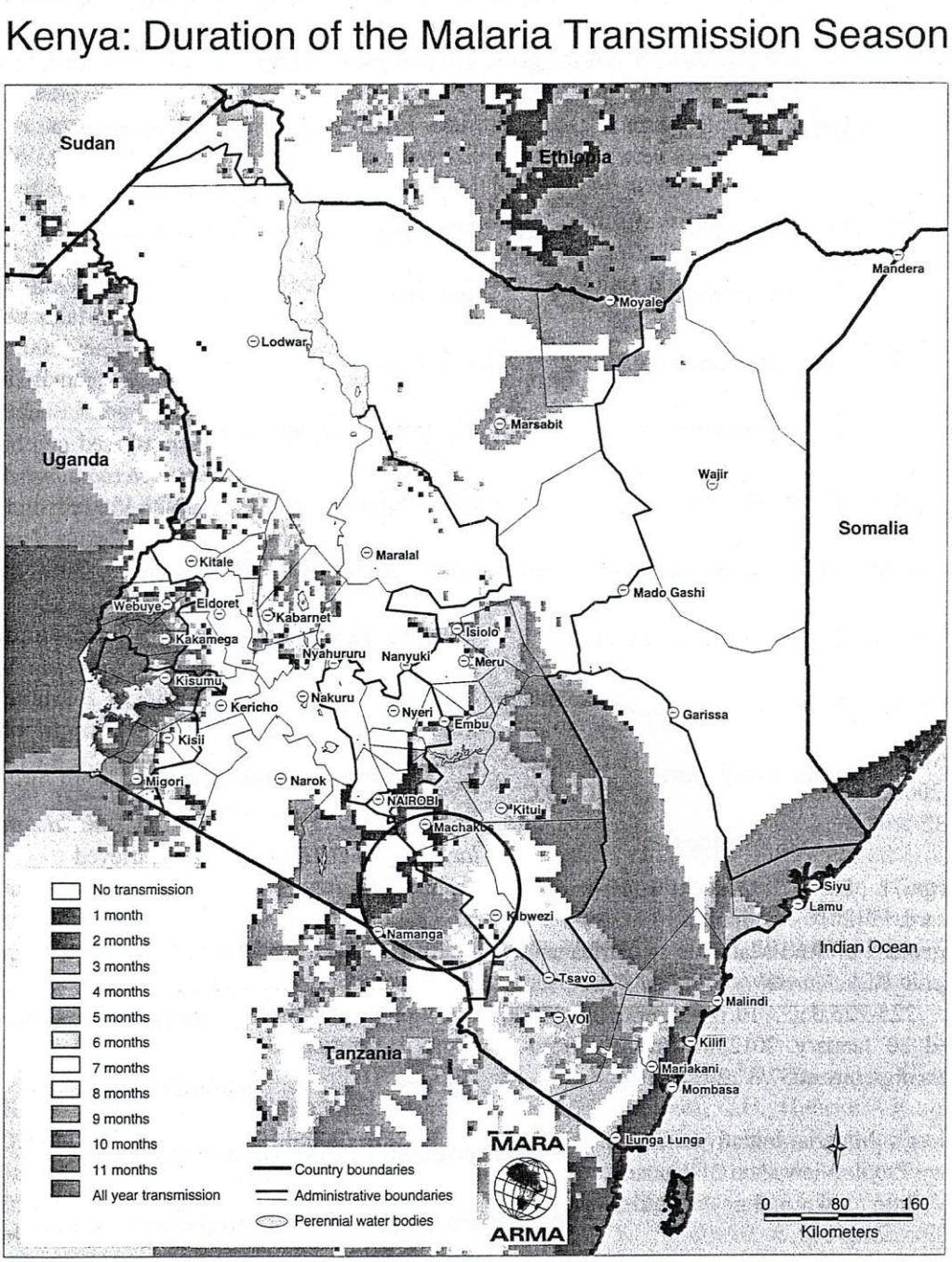
United Kingdom Department for International Development. (2010). *Malaria: Burden and Interventions, Evidence Overview.* Retrieved from http://www.dfid.gov.uk/Documents/prd/malaria-evidence-paper.pdf

World Health Organization.(2011). *World Malaria Report 2011, Chapter 6.* Retrieved From http://www.who.int/malaria/world_malaria_report_2011/9789241564403_eng.pdf

World Health Organization. (2000). *The Abuja Declaration and the Plan of Action.* Retrieved from http://mosquito.who.int/docs/abuja_declaration.pdf

Zurovac, D., Larson, B.A., Akhwale, W., & Snow, R.W. (2006). The financial and clinical implications of adult malaria diagnosis using microscopy in Kenya. *Tropical Medicine & International Health, 11(8),* 1185-1194. doi: 10.1111/j.1365-3156.2006.01674.x. Viewed 20 December, 2012.http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3156.2006.01674.x/full

Figure 1: Duration of the Malaria Transmission Season in Kenya, Mapping Malaria in Africa (MARA)



This map is a product of the MARA/ARMA collaboration (http://www.mara.org.za). 7 months 2001, Medical Research Council, PO Box 17120, Congella, 4013, Durban, South Africa. CORE FUNDERS of MARA/ARMA: International Development Research Centre, Canada (IDRC); The Wellcome Trust UK; South African Medical Research Council (MRC); Swiss Tropical Institute, Multilateral Initiative on Malaria (MIM) / Special Programme for Research & Training in Tropical Diseases (TDR), Roll Back Malaria (RBM). Malaria seasonality model: Tanser, F et al. 2001. Paper in preparation. Topographical data: African Data Sampler, WRI, http://www.igc.org/wri/sdis/maps/ads/ads_idx.htm.

Table 1: RDT and Microscopy Results

Location	RDT Negative	RDT Positive
St. Theresa's KiiruaMission Hospital (N=54)		
Microscopy Neg	49	0
Microscopy Pos	5	0
Kinoru Dispensary (N=68)		
Microscopy Neg	64	0
Microscopy Pos	4	0
MeruDistrictHospital (N=128)		
Microscopy Neg	92	0
Microscopy Pos	35	1

Table 2:Summary Table of RDT-Microscopy Comparison

	Kinoru Dispensary	St. Theresa's Kiiru-aMission Hospital	Meru District Hospital
Number of Samples	68	54	128
% Microscopy-Positive	5.9%	9.3%	27.3%
% RDT Positive	0.0%	0.0%	0.8%
%Microscopy-Positive not confirmed by RDTs	100%	100%	97.1%

Table 3: Mean Elevation of Patient Residence by Study Site

Study Site	N	Mean Elevation (Meters)
St. Theresa's KiiruaMission Hospital	48	1693.3
Kinoru Dispensary	64	1685.7
Meru District Hospital	107	1551.5*
Total Sample	219	1621.8

* Statistically significant at the p = 0.05 level