MAGNETO-OPTIC TECHNOLOGY HITS THE FIELD:

A pilot program to implement a new malaria diagnostic device in Southern Benin

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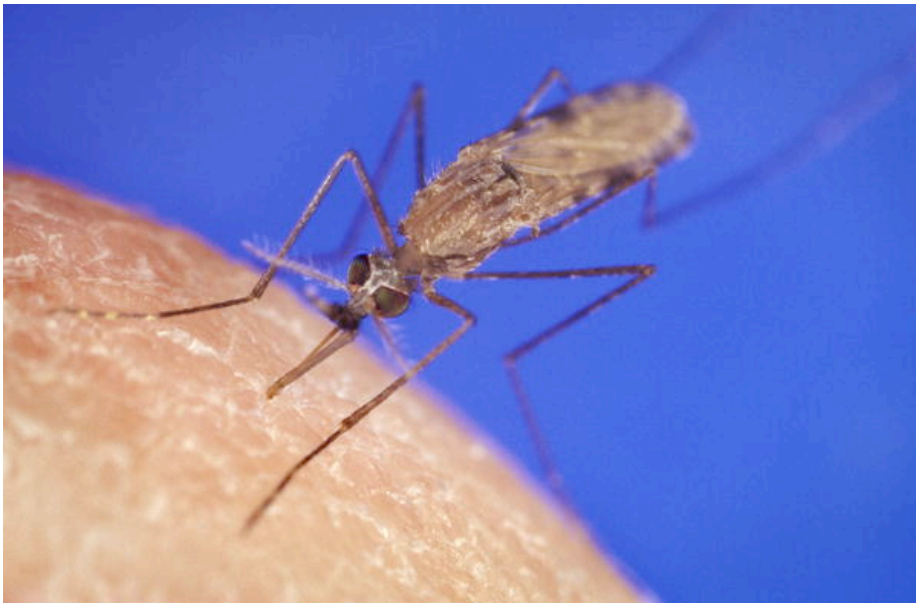


Courtesy of: http://www.cbc.ca/gfx/pix/malaria_mosquito020717.jpg

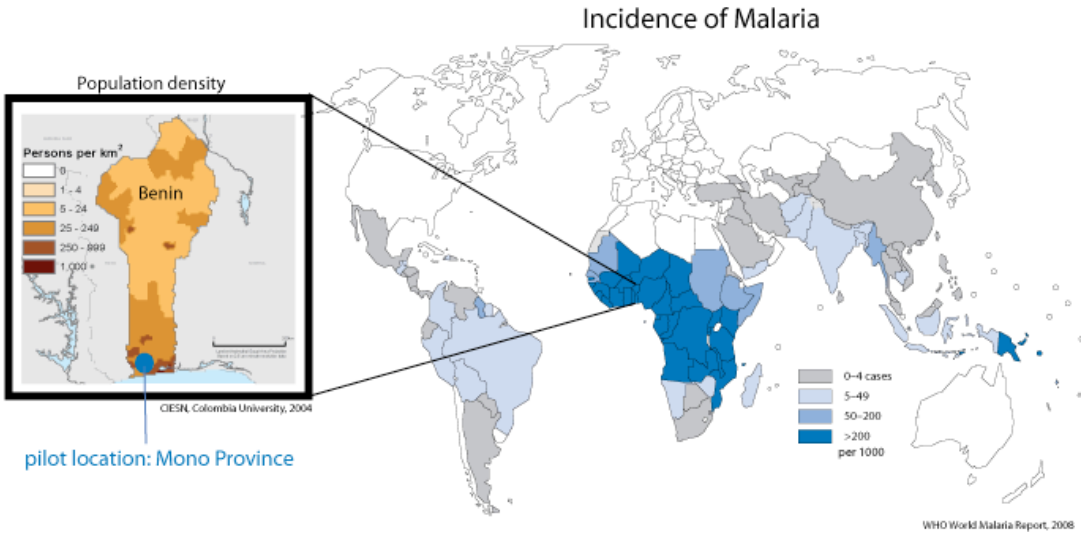
EXECUTIVE SUMMARY
Malaria is an illness caused by a mosquito-borne protozoan parasite that produces the symptoms of fever, anemia, convulsions, and in some cases, coma and death. Today, malaria is endemic in 100 countries worldwide, puts 300-500 million at risk of infection every year in sub-tropical South Asia and Africa, and is the leading cause of death of African children. There presently exists an effective treatment for malaria based on derivatives of the drug artemisinin, but recent reports of artemisinin-resistant strains of malaria serve as reminders of the constant battle against malaria drug resistance. In order to fight malaria with an eye on slowing the development of drug resistance, it is necessary to improve access to better diagnosis tools and correctly administered treatment. The diagnostic methods currently in practice, including microscopy and Rapid Diagnostic Tests, are wanting in coverage due to costly implementation, low detection sensitivity, instability in the tropical environments, and/or unreliability in monitoring the progress of treatment and/or recurrences. We advocate the implementation of a new diagnostic device using magneto-optic technology (MOT), the “MOT device”, which has been shown to diagnose even very low levels of malaria infection with greater accuracy and lower cost than current techniques. To assess the challenges in ensuring widespread distribution of the MOT devices, we propose a pilot program (Mono-MOT) that will launch in 2010 and establish small, locally run malaria health centers to use these MOT devices and administer malaria treatments to 25,000 residents in Southern Benin, Africa. The information gained from this pilot could ultimately be used to more effectively disseminate diagnostics and treatments on a larger scale.

As a small country, both in size and population, our future hinges on the quality of our people. -- Hassanal Bolkiah

INTRODUCTION

A country depends on the health and productivity of its citizens to achieve prosperity. In developing countries constrained by poverty, natural disasters, or violent politics, widespread disease in the workforce can bring on social and economic collapse. A classic example of a disease that acts as such a socio-economic threat is malaria, a parasitic mosquito-borne illness that annually infects 300-500 million people in over 100 endemic countries, and causes nearly a million deaths, mostly of children in sub-Saharan Africa. Although malaria was successfully eradicated from the developed world (including the United States) by the 1950s, it continues to be the leading cause of death from a single infectious agent in the regions of South America, South Asia and Africa, as shown in the map below[6,34].

Estimated incidence of malaria per 1000 population in 2006, from *the World Health Organization World Malaria Report 2008*



Malaria is caused by four parasitic protozoan strains: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*. The parasite is reproduced and transferred from host to host in the saliva of the female *Anopheles* mosquito. Once injected, the parasite starts its life cycle in the human liver, then invades red blood cells, creating a variety of symptoms including fever, vomiting, anemia, convulsions, and in acute cases, brain damage, coma and death. *P. vivax* and *P. ovale* can lie dormant in the liver indefinitely, giving rise to recurrent illness years after the initial bite. *P. falciparum* is the deadliest form of malaria, and is responsible for nearly all lethal malaria cases in children and pregnant women.

Undoubtedly a burden on health, malaria is also a serious socioeconomic disability. Every year, malaria drains Africa of over 30 billion U.S. dollars in health costs and lost productivity[2]. Gallup and Sachs[23] found that, for countries with intensive malaria, the per capita average purchasing-power parity of GDP, a useful rough estimate of a country's economic health, was one-fifth of that for malaria-free countries. When all the standard economic factors such as initial poverty level, location and life expectancy were taken into account, Gallup and Sachs additionally found that on average, between 1965 and 1990, the income per capita for countries with severe malaria risk grew 0.4% (a few of these malaria-ridden countries had negative growth) while the income per capita for other countries grew 2.3%, and that a 10% reduction in the malaria index (an estimate of the fraction of the population afflicted with *falciparum* malaria, derived from data from the World Health Organization, WHO) corresponded to a 0.3% rise in annual economic growth. In short, severe malaria stunts the economic growth of a region as well as the physical health.

Current anti-malarial strategies fall into three broad categories: control strategies for reducing the *Anopheles* mosquito population and insect bites (distributing insecticide-treated bednets, spraying insecticides in homes and breeding areas, draining ponds), medical and research strategies for diagnosing and treating malaria (medical training, diagnostic techniques, drug development), and

strategies for refining political and economic infrastructure to sustainably fund international malaria treatment programs. This report focuses on necessary improvements access to treatment and accurate diagnosis.

DRUG RESISTANCE

Currently, there exists an excellent treatment for malaria, the Arteseminin Combination Therapy, or ACT. Artemisinin is a compound extracted from the *Artemesia annua* or sweet wormwood plant in China, and is heralded by the international community as the best first-line treatment against malaria[7,30]. Unfortunately, no known malaria treatment can yet "solve" the malaria problem permanently, due to the constant and accelerating rate of drug resistance. It is now projected that the development of drug resistance in South Asia is much faster than the 12-17 years it takes to produce and market a new drug[40]. In keeping with these predictions, the New York Times has already confirmed rumors of the first cases of Artemisinin resistance in Cambodia[18].

Antimalarial drug resistance appears to be driven by three main factors: partial treatment, monotherapeutic treatments, and misdiagnosis. **Partial treatment** comes in many forms, for example, from patients using medications that are false, diluted, or expired, or discontinuing a treatment before completion. This exposes the parasite to minor doses of treatments, increasing the likelihood that the parasite will develop a drug-immune mutation. **Monotherapies** (treatments with a single drug), confer drug resistance more easily than combination therapies, in which several unrelated anti-malarials are administered together. In the latter case, the parasite would need to develop resistance to all of the different anti-malarial components to survive, reducing the probability of drug resistance. Despite the existence of ACTs, and the WHO's mandate to ban all monotherapies in 2002[7,16] monotherapies are still in use among the rural poor and are highly popular on the black market, and access to combination therapies is not adequate[34]. **Misdiagnosis** is responsible for two serious problems: the overprescription of malaria medications leading to drug resistance and wasted resources, and the mistreatment of other serious endemic diseases such as yellow fever, typhoid fever, cholera, and HIV/AIDS, that may require immediate action.

Current efforts, such as those to increase access to ACTs through a global buyer co-payment plan[5,7,24] or through new methods to cheaply produce artemisinin in large quantities[27,28], have been focused on the first two drivers. In this report, we focus on the third driver, misdiagnosis.

DIAGNOSTIC METHODS IN PRACTICE

The most effective way of diagnosing malaria is currently microscopy of blood smears, in which trained technicians can diagnose malaria, determine the severity of the infection, and determine the organism that causes it. However, it is costly and difficult to implement the use of high-powered microscopes, the materials for creating blood smears, and the complex training required to analyze them fully outside of large cities.

The more attractive alternative that's widely used today is the Rapid Diagnostic Test[9,12,13,14,15,35], which consists of a small, disposable kit that mixes a drop of the patient's blood with an absorbent chemical strip to detect specific molecules (antigens) the parasites produce. When an infection is present, the RDT will give a positive reading, indicated by a color change. There are two main types of RDT's currently available. The most common one detects histidine-rich protein 2 (HRP-2) antigen, a protein secreted by only *P. falciparum*, and the other detects the enzyme lactate dehydrogenase (LDH), which is secreted by all four strains.

Relative to microscopy and other more laboratory-intensive procedures such as polymerase-chain reaction (PCR) based assays, RDT's seem ideal. They are rapid (giving results in 15-20 minutes), portable, and require no laboratory equipment or highly trained specialists. Unfortunately, the kits are expensive ($1.50-$4.50 per diagnosis) and expire quickly in the extreme weather conditions common in malarial regions. They are also unable to detect low levels of infection, to distinguish between moderate and severe infections, or to determine which parasitic organism is causing the infection. Since HRP-2 and LDH remain in the blood for months after the parasite has been removed, RDTs continue to return a positive diagnosis after malaria treatment has been completed, rendering them ineffective for monitoring the progress of treatment or diagnosing recurrences.

Lastly and most importantly, the lack of affordable diagnostics means many patients in rural areas are diagnosed “presumptively”, i.e., by assessment of clinical symptoms without any specific diagnostic test.

This often means a local health expert prescribes malaria treatment to anyone with a fever. The WHO considers this practice inadequate[40] and a cause for over-prescription and wasted resources[7].

MAGNETO-OPTIC TECHNOLOGY (MOT)

Researchers last year at the Universities of Exeter and Coventry[10,11,29] developed two very promising devices for diagnosing malaria, one requiring a fingerprick blood sample and the other involving a non-invasive laser scan of the fingernail. The technology makes use of the fact that the parasite converts a human's natural way of storing iron in blood, the water-soluble heme molecule, into a solid crystal form, hemozoin. When parasites infect red blood cells, this crystalline hemozoin accumulates until the cells rupture, and is then released into the bloodstream. Unlike HRP-2 or LDH, hemozoin is only present in blood if an active malaria infection is present, making it an ideal diagnostic target.

MOT was first introduced in the 1980s and is used mostly in computer-based information systems, as a way to read, write and store data[37]. The British team of scientists gave the technology a biological application by recognizing hemozoin's unique magnetic properties. The hemozoin crystals, distinctly rectangular in shape, are essentially bar magnets with a Polaroid twist: like the crystals in Polaroid, they absorb light more strongly along one direction than the other. When a magnetic field is applied, they flip from being randomly oriented in the blood to being aligned with one another. By tracking what happens to light passing through an aligned sample, the presence of hemozoin (and hence of the parasite) can be easily and very precisely determined.

Evaluations from a preclinical trial showed that there was excellent correlation among MOT testing, RDT results and clinical confirmation[29]. The MOT devices are currently undergoing larger-scale field tests in a remote village in Kenya and positive results are expected[10,11]. We strongly advocate for their expanded use in place of RDT's because of their:

- *sensitivity* - they are able to easily detect low amounts of P. ovale in the blood. With this level of sensitivity, signs of reinfection can be easily checked.
- *rapidity* - they deliver a positive or negative reading in under a minute, compared to RDT's 15-20 minutes
- *accuracy* - they consistently give the same diagnosis as the more extensive diagnostic procedures, such as light microscopy and assays based on PCR[29]
- *affordability* - depending on the lifetime and final market cost of the devices, individual diagnoses could cost only a few cents
- *user-friendliness* – tool would provide an easy-to-read yes/no diagnosis for each sample

The development of an effective, convenient, low-cost diagnostic device is good news for the malaria community, and has the potential to slow drug resistance and reduce the consequences of misdiagnosis. However, the *existence* of a new device is not sufficient to provide any solutions to malaria. As is the case with nearly all anti-malaria campaigns, one of the most challenging tasks is the successful *implementation* of new technologies. Before MOT devices could be widely distributed and made effective in malarial regions, answers to the following questions are needed:

1. *How can the devices be distributed such that they are available to the maximum number of patients?*
2. *How can patients receive information about malaria and the new devices?*
3. *What are the costs of putting the devices out into communities?*
4. *Who will administer the device? How will they be trained in using the device, extracting blood samples, and reading diagnoses?*
5. *How will patients get treatment if they do have malaria?*
6. *How well do the devices hold up in tropical climates, potentially in the hands and houses of the rural poor?*

To answer these questions, we propose a pilot program, the ***Mono-MOT*** program, which would function as an information-gathering test of MOT devices in practice. We propose a 5-year pilot program that will start in 2010 and establish local MOT-device health centers serving 25,000 residents in Southern Benin, Africa. Mono-MOT would provide information for an impact-assessment on the implementation of

these new diagnostic tools, serving as a stepping stone to a widespread campaign of slowing malaria drug resistance and improving the quality of malaria diagnosis.

OUR PROPOSITION

In order to collect information on challenging circumstances and to benefit the pilot population maximally, we propose Mono-MOT to be launched in an area where malaria is a devastating problem: the lagoon-rich region of the Mono province on the southern coast of Benin (see map on page 1). The estimated malaria incidence rate in Benin in 2004 was 37.5% (3 million cases)[22], many of these due to infections in the Mono province, resulting from its moderately dense population (360,000/1,400 km^2), tropical climate, and proximity to standing water. Economically, the Mono province is struggling: almost 30% of the Benise population lived below the poverty line in 2002, and the average annual salary of a rural Benise resident is US$164/year, approximately US$0.50 a day[22,38]. Fortunately, the current elected president of Benin, Thomas Yayi Boni, has made malaria a priority. Under his leadership, Benin is a signatory to a number of external malaria campaigns and has a strong National Malaria Control Program (NMCP) with the objective of eliminating malaria as a public health problem by 2030[22]. The proposed project would ideally be implemented side-by-side with the Benise government, i.e., under the auspices of the NMCP.

A small WHO-supported study in 2008 showed that community-based health provider models are feasible in Benin[22]. Benin's pyramidal national health system places special focus on Community Health Workers (CHWs), volunteers at the village-level who receive no financial compensation, work out of their homes and are formally connected to public health facilities. Currently, the NMCP trains only facility-based health-care workers to use the available malarial diagnostics (RDT's and microscopy). Mono-MOT takes advantage of the local CHW model, and expands it by giving the home-based and institutional CHWs the opportunity to administer the MOT diagnostics and malaria treatments. A community of ~100 villages in Southern Mono, including a total of 25,000 residents, would be included in this study.

If Mono-MOT is successful, elements of its infrastructure could be scaled-up and applied to larger regions, which would make the cost of the project of central importance. In the interest of including economic aspects in the model that could be later optimized for greater economic efficiency, we include elements of a microfinance scheme, in which the MOT devices are provided to local residents in the form of loans that can be used to jump-start local business. In addition to stimulating the local economy, microfinance schemes have been shown to create an environment of entrepreneurism in which local residents feel ownership over a given project, and accordingly run it more efficiently, effectively, and with less corruption than if they had been given the starting materials as donations[21,36].

Mono-MOT PROGRAM DESIGN

Industrial side economics: MOT devices should be manufactured to be light and battery-operated, and made widely available and affordable.

If one MOT device were produced per 250 people in our selection, this would mean that approximately 100 MOT devices would be required. MOT devices are currently being produced by Phillips Electronics, and research and development is required to make them more portable, durable, and cheaper. David Newman, one of the inventors of the MOT device, believes that it will be possible to lower the cost of the devices to the "cost of a portable DVD player" in the near future[1]. As a conservative estimate, we assume the devices will cost approximately US$80 in 2010, although the expected manufacturing costs could fall below US$50. A boosted interest in these devices would be invaluable in prompting cheaper and more efficient manufacturing.

An infrastructure is necessary to distribute MOT devices, train local community health leaders to administer MOT diagnostics, and monitor existing malaria treatments.

Twenty college-educated health "consultants" would be hired from universities (or ideally, medical schools) in and around the Benise capital city Porto Novo for the annual salary of $400/year (2.5 times the average rural salary), to receive and provide training on integrating accepted malaria diagnostic procedures. This includes the use, upkeep, and repair of MOT devices, the identification of signs and symptoms of malaria and other diseases, the safe extraction of blood samples, and the administration of malaria treatments. They would also be instructed on how to better educate local communities on the importance of insecticides, bednets, and correct usage of medications.

In addition to health consultants, the organization would also recruit approximately 100 local "MOT-CHWs" to serve each group of approximately 250 residents. These local MOT-CHWs are the existing CHW's, or if none exist, carefully selected individuals who are respected in their communities with a willingness to serve. In exchange for signing a contract to become a “malaria expert” for their communities, they would receive free training and support from the health consultants, free materials to collect blood samples, and would be eligible to purchase highly subsidized stocks of ACT malaria treatments. They would also receive a loan of a single MOT device using the following microfinance-flavored system:

a. ***MOT device loans*:** Local MOT-CHWs would put down a downpayment of US$2 to receive the devices, and they would be required to pay back the subsidized price of US$30 within 5 years. If the MOT-CHWs default on their MOT-device debt for reasons that do not warrant an extension, they will be required to give up the devices, lose access to training, and other members of their community will be recruited as replacement MOT-CHWs. If the devices have been lost or sold, the cost of the device would be borne by the organization funding the enterprise. Which is to say, only in the case of debt default will the MOT devices be treated as full “donations” to Benise communities.

b. ***Malaria treatment locations*:** MOT-CHWs would work out of their homes or use an existing facility with the provided diagnostic tools, malaria treatments, blood extraction materials, and information pamphlets on malaria and other local diseases. They would be able to charge affordable rates (such as US$0.05-$0.10) for each diagnostic test. Since we project any MOT-CHW serving a collection of villages would administer at least 300 tests a year, they would be able to supplement their income with minimal labor hours by at least $30 annually (not including the debt repayment). This is expected to be an attractive proposal for Benise residents, given that the full-time unemployment rate is estimated at 9% or higher, and that the average rural salary in Benin is only $164/year.

c. ***Prescribing ACT treatments*:** MOT-CHWs would be able to purchase or be loaned installments of up to 300 ACT treatments per year for the subsidized price of $0.10/treatment. They would then sell these treatments to patients, potentially at a profit of a few cents per treatment, if they are able to do so without reducing demand. The price of $0.10/treatment is currently the cheapest black-market price for the antiquated antimalarial drug chloroquine in most sub-Saharan African countries, meaning this price for ACTs should reduce black market practices and encourage the use of functioning malarial drugs. Furthermore, the WHO found that US$0.10/treatment is affordable to most individuals[7].

d. ***Education*:** The final task of local MOT-CHWs is to provide information to their communities about malaria prevention, symptoms, correct diagnosis, and treatment. Although it may not be a simple task to completely prevent presumptive treatments and black market sales, dispatching the local MOT-CHW as an educator as well as a medical professional could reduce these phenomena considerably, with a low cost to both the MOT-CHW and the organization that trains them.

e. **Monitoring and Evaluation:** The health consultants would be accessible to provide supplies and support for issues such as a malfunctioning MOT device, a need for more ACT treatments or blood extraction supplies, or any diagnosis questions. For urgent issues, monthly meetings, a centralized office staffed by a health consultant within 5 miles of the community sites, and access to local hospitals would be available. In addition, the consultants would conduct periodic household surveys to ensure that the MOT-CHWs are serving their communities and prescribing treatment only when a positive diagnosis is found (and would have the authority to revoke their right to operate if found otherwise). A simple receipt printer could be added to MOT devices, so basic records could be kept automatically for the number of positive diagnoses collected, which could be cross-checked with the number of ACT treatments distributed.

COSTS

The following table details the estimated cost of the Mono-MOT program. To run this pilot, it would be crucial to collaborate with the Benise government and/or international organizations such as the WHO, the World Bank, Roll Back Malaria (RBM), or the Global Fund to Fight AIDS Tuberculosis and Malaria (GFtFATM), so we do not detail the salaries of the managerial staff, which would depend on the

organization. To be conservative, we are assuming the current unsubsidized wholesale cost of ACTs, which is $2.40/treatment, for the first year of the program. With the RollBack Malaria (RBM) and GFtFATM among other international organizations acting on the WHO's call to globally subsidize ACTs, the price per treatment is expected to fall below US$1/treatment[7] within the next few years, so we include this reduced price in the later years of the pilot. Overall, we project it will take US$157,000 to create 100 MOT-diagnosis locations, to fully diagnose and treat 25,000 people for malaria for 5 years. This expense is a standard grant size for malaria projects funded by organizations such as USAID, the Clinton Foundation, and the Bill and Melinda Gates foundation. For perspective, in 2007, the USAID budget to fund projects specifically improving child health in Benin was US$4.5 million[39].

Table 1. The estimated costs of the Mono-MOT diagnosis project, excluding executive salaries.

Purpose	Estimated cost per unit (US$)	Total Estimated Cost (US$)	Total Estimated Cost for Years 2-5 (US$)
A 2-day conference to train the health consultants to train and serve local MOT-CHWs	$20/person per day for room and board, 20 consultants	$800	*if 50% turnover rate, conference held for new recruits* $400/yr, 4yrs: $1,600
Annual salary for Health Consultants	$400/person/year, 20 consultants	$8,000	$8,000/yr, 4yrs: $32,000
MOT devices for distribution **	$80/device, 100 devices needed	$8,000	*Assuming an 80% return on $30 repayment MOT device loans,* - $2,400
Sufficient ACT treatments to treat 50% of the population (usual incidence of malaria is 1 in 3)	$2.30/person/treatment, 12,500 treatments (factoring in the selling price to the MOT-CHWs)	$28,750	$1/person/treatment from global subsidy, 12,500 treatments, 4yrs: $50,000
Lancets for blood samples	0.6 cents/lancet, 1/person/year	$150	$600
Other blood extraction materials (i.e. gloves, sterile capillary tubes)	gloves: 4 cents/pair, a pair/patient other supplies: $500/year	$1,500	$6,000
Administrative costs: offices, transportation, technicians, repair, unexpected expenses	$6,000/year	$6,000	Projected administration costs: $4,000/year $16,000
Total projected expense		**$53,200 for the first year**	**$103,800 for 4 years ($25,950/year)**

KEY CHALLENGES: ***The following issues will be the main challenges for Mono-MOT.***

1. The MOT devices are still in the early stages of development.
Of the two devices available, the more invasive one (requiring a finger prick blood sample) is currently being miniaturized. Although projected costs for the device could be as low as $30, there still exists economic uncertainty in the details. Since the device is being refined by Phillips Electronics, the current MOT device model is not available to the public sphere to discuss durability, portability, product lifetime, and product price. As a result, Mono-MOT would either need to be launched after Phillips had produced their first product on the market, or in conjunction with Phillips to maintain their devices under patent (around 2010). However, this may be an additional advantage of the Mono-MOT project: in addition to collecting information on MOT device dissemination, it would effectively test early models of the Phillips MOT devices and highlight issues that need to be resolved before the devices are produced on a large scale. Laboratory product stability tests and may not capture the complex factors that could degrade the device in the hands and homes of Benise residents.

2. Funding and incentives may be complicated by the current global economic crisis.
Current concerns over the global economy are resulting in reduced donations to charities, and more careful allotment of international funds. This pilot, however, is a reasonable expense that could provide

valuable information on controlling malaria, which could ultimately remove a severe impediment on the economic growth of Africa, Southeast Asia and South America, as well as reduce the need for other forms of humanitarian aid. It is also predicted that this recent economic downturn will have the greatest effect on the world's poor, increasing the incidence of disease and poverty. Sustainable schemes to reduce malaria for the minimal economic cost, such as those including microfinance elements, will be in demand.

3. The sample size is too small to make a large enough impact to yield useful results in terms of significant malaria infection reduction.
The size of this pilot was calculated to evaluate the project's success and to gather information on the difficulties of integrating a new technology into the field. However, since malaria is a vector-born illness, one of the greatest advantages of improved malaria treatment, the reduction of mosquitoes carrying the malaria parasite, would not be observable. Only in a large-scale international campaign could the overall reduction of malaria-carrying mosquitoes be assessed. However, we feel Mono-MOT is a necessary step to in laying the groundwork for such large-scale campaigns.

4. Communities may be reluctant to use new diagnosis techniques.
Communities may be wary of new techniques, and feel more comfortable consulting familiar "experts" or buying malaria treatments on the black market, "just in case". Using local professionals as educators is probably the best defense against these concerns. We project that using the local MOT-CHWs as community educators will eventually spread basic knowledge about accurate malaria diagnosis and treatments, and cause a cultural shift in how people think about malaria, but this needs to be evaluated.

5. The sites of health centers need to be carefully placed.
In order to be sure that new malaria centers are not competing with existing health centers that also distribute ACTs, it will be necessary to do research on the local communities to accurately map the locations and popularity of existing health centers. MOT-malaria health centers are not intended to strip citizens from other valuable programs or compete with existing infrastructure.

6. Studies show that antimalarial drug resistance actualizes in South Asia and spreads to Africa. Our initiative is set in Benin.
We chose to make our pilot small in order to do an impact-evaluation, and we propose it in Benin because it is a country with an urgent human need for better anti-malarial health care. However, most antimalarial drug resistance develops in broad regions of South Asia where mortality due to malaria is relatively low. As a result, this pilot alone is expected to have little effect on slowing the acceleration of drug resistance. However, if this pilot is successful, it would facilitate the distribution of MOT devices to all malaria-affected populations including those in South Asia, where widespread accurate diagnosis and treatment is the best means for slowing drug resistance.

ADVANTAGES OUR PILOT BRINGS

1. Ready-access, affordable, accurate treatment
The greatest advantage of our pilot is that it gives *all* residents access to quick, cheap, and accurate diagnosis and treatment for malaria. This reduces the probability of complicated and lethal malaria cases and improves the quality of life for those who previously did not have access to diagnosis or treatment. Since the health centers will be located directly in the communities, the sick will not need to travel long distances or spend time waiting in long lines for first-line diagnosis.

2. Well-trained, locally based staff
A close relationship between the health consultants and MOT-CHWs ensures that the quality of ACTs and MOT devices will be warranted, that MOT-CHWs have the resources and treatments they need, and that correct diagnosis and treatment will be monitored. Although a great advantage of the MOT device is that it gives a clear, reliable diagnosis of malaria without much technical intervention, the program still puts a great emphasis on the education and training of individuals to administer treatment regimes accurately. The fact that workers on the ground would be almost exclusively Benise citizens provides

employment, a way to educate patients with cultural sensitivity, and also provides a local face to malaria expertise.

3. Low implementation costs
Because MOT devices do not use any chemical strips or microscopes to detect malarial parasites, storage issues are hugely simplified. Health consultants could exchange uncharged for charged MOT-device batteries monthly. Also, ACTs, depending on the formula, can have shelf lives up to 3 years without refrigeration[20]. As a result, health centers would not require electricity.

4. Versatility
Various organizations are already at work in Benin using different infrastructures and different mandates to improve public health. Our simple, locally-run health centers could serve as nucleation points to bring together other public health organizations that can provide information about subjects such as water safety, HIV/AIDS, yellow fever, typhoid fever, cholera, and other endemic diseases. Where larger communities already have health centers, the training and clinical operations in this project could easily be incorporated into those existing organizations.

5. Saving lives
In addition to being a fact-finding mission, this pilot would improve the quality of life for the people in the sample, and it is projected to save the lives of approximately 1,100 children[22]. Providing these communities with access to malaria diagnosis and treatment would decrease morbidity and mortality in ways that could have a ripple effect on these communities, spreading more awareness for malaria control and treatment, and enabling its residents to be more active in the local economy. This could potentially contribute to a reduction in poverty for the residents of our sample.

6. Opportunity for cutting costs through microfinancing
Our program's cost comes from two main factors: ACT treatment expense and the uncertainty in the final price of MOT devices. If the price of ACTs and MOT devices were to fall to the projected prices of $0.10-$0.20/treatment and $25/device, respectively, this pilot's budget could be adjusted and the project made more sustainable by implementing a more rigorous microfinance scheme, in which CHWs purchase the ACTs and MOT devices with interest payments that go towards funding the program.

MOVING FORWARD
The development and dissemination of an affordable, durable, and reliable diagnosis tool may make accurate diagnosis possible in areas without access to hospitals, electricity, or highly trained technicians, as well as in countries with serious financial limitations. The most valuable aspect of this project is the wealth of information it would provide, which could be used to suggest improvements in:

- *the design of the MOT devices*
- *methods to more effectively select and train local MOT-CHWs*
- *ways to better ensure the MOT devices and ACT treatments are being used correctly*
- *ways to more effectively integrate the program with existing health professionals, hospitals, and malaria programs*
- *ways to achieve economic sustainability through adjustment of factors such as the selling price of treatment, the size of Act and MOT subsidies, size of interest payments (if present), etc.*

Mono-MOT can potentially inspire larger projects that get effective malaria treatment into hospitals, as well as out to areas that are currently off the map. Better diagnosis, together with improvements in current malaria strategies, is needed to achieve the ultimate goal of the NMCP and eliminate malaria as a public health problem by 2030[22].

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