FIELD EVALUATION OF MALARIA RAPID DIAGNOSTIC TESTS FOR THE DIAGNOSIS OF *P. FALCIPARUM* AND NON-*P. FALCIPARUM* INFECTIONS

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Abstract. The objective of this study was to evaluate various malaria rapid diagnostic tests as a tool in the detection of *P. falciparum* and non-*P. falciparum* infections in field conditions. Four field surveys were conducted in malaria-endemic areas of Palawan and Davao del Norte, Philippines to validate the various rapid diagnostic tests, namely Diamed OptiMAL 48 (DiaMed AG, Switzerland), ParaHIT *f* (Span Diagnostics, India), Orchid OptiMAL, and Paracheck *Pf* (both from Orchid Biomedical Systems, India). The results of the various rapid diagnostic tests were compared to those of microscopy. Sensitivity, specificity and detection rates according to the level of parasitemia were used as parameters to describe the performance of the various rapid diagnostic tests in the field. Practical and operational assessments were also done. The results of the study show that the sensitivity and detection rates were generally lower than previously reported, with sensitivities ranging from 4.8% to 20.6%, except for Diamed OptiMAL 48, which had sensitivities of 78.8% to 96.8%, and detection rates of 50.0% to 96.8%. The rest had detection rates ranging from 0.0% to 50.0%. All the specificities ranged from 18.2% to 100.0%. Improper conditions at the time of manufacturing, storage, transport, and utilization may affect the validity of the results. Rapid diagnostic tests for malaria provide practical means of detecting malarial infections, especially in endemic areas. However, issues regarding variability in performance must to be addressed before they can be used as mainstream diagnostic tools.

INTRODUCTION

The key to effective management of malaria and one of the main interventions of the Global Malaria Control Strategy is timely and accurate diagnosis. In many instances, however, current diagnostic approaches do not allow satisfactory diagnosis of malaria. Clinical diagnosis, for instance, is often times unreliable because the symptoms of malaria are non-specific. Malaria microscopy, currently considered the "gold standard", requires technical skill and equipment that are usually unavailable and inaccessible in most malarious areas, thus, the widespread interest in rapid diagnostic tests (RDTs), as these offer opportunities for early diagnosis of malarial infection. These tests require only finger-prick blood samples to be tested using immunochromatographic kits that detect *Plasmodium*-specific antigens. The tests are simple and easy to perform. They do not require electricity, special equipment or extensive training. The results are available in less than 30 minutes, with detection capabilities that are generally comparable to those achieved by clinical microscopy (WHO, 2000).

The RDTs that are currently available on the market detect two types of parasite antigens: histidine-rich protein-II (HRP-II) and *Plasmodium* lactate dehydrogenase (pLDH). HRP-II is a water-soluble protein produced by the trophozoites and young gametocytes of *P. falciparum.* HRP-II-based kits can therefore detect *P. falciparum* infection only. pLDH is produced in the sexual and asexual forms of the parasite.

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pLDH-based tests are able to differentiate between *P. falciparum* and non-*P. falciparum* infections.

Before RDTs can be used as a mainstream diagnostic tool for malaria, extensive evaluation of its performance, usage, handling and storage, need to be undertaken. Assessing practical and operational issues related to the use of the different RDTs will also help in formulating guidelines before their actual deployment in the field, as well as giving feedback to manufacturers, by utilizing quality design principles for the optimal use of this technology in malaria control.

MATERIALS AND METHODS

Study site

Four field surveys were conducted in malaria-endemic areas of the municipality of Talaingod in Davao del Norte Province, and the municipality of Quezon and Puerto Princesa City in Palawan Province, Philippines (Fig 1).

Malaria is, by far, the most serious of the parasitic diseases affecting the residents of Talaingod, where it is the major cause of morbidity in all age groups. From 1998 to 2000, slide positivity rates increased from 18% to 30%. Fifty-nine percent of the malaria cases were due to *P. falciparum* and 40% were due to *P. vivax*. Mixed infections were noted in only 1% of identified malaria cases (Department of Health, unpublished data, 1998 to 2001). The municipality of Quezon and Puerto Princesa City had an Annual Parasite Incidence (API) rate of 18.3% in 2001 (DOH, unpublished report, 2001).

Field evaluation of malaria RDTs

RDT and microscopy. Following an algorithm for RDT use in endemic areas (Fig 2), field evaluation was conducted through active case detection surveys done in Talaingod in the months of February, September, and November 2002, and in Palawan in April 2002. Patients with a history of fever with or without chills, sweating and headache in the past two weeks with no history of anti-malarial treatment during the same period were included.

Blood samples for thick and thin blood films were collected through finger-prick. Thick and thin blood films were prepared, processed and stained with Giemsa following WHO standards (WHO, 1994).

A research microscopist provided initial microscopy results. For quality control, all positive slides and 10% of randomly selected negative slides were re-examined by a reference microscopist who was blinded to the initial results. In cases where there was qualitative discrepancy, the slides were returned to the initial reader for re-evaluation. If the second reading of the research microscopist still did not agree with the quality control reading, the latter was considered the final reading. If both results were positive for malaria parasites, the mean parasite count was reported as final.

Blood for RDT testing, obtained through finger-prick, was collected in kit-provided capillary tubes. Procedures followed were according to the manufacturers' instructions.

All four RDTs were tested across different parasitemia levels. Degrees of parasitemia were categorized into two: <100 parasites/μl (low), and ≥100 parasites/μl (high).

RDT kits, storage, handling and transport. The RDT kits used were: Diamed OptiMAL (Diamed AG, Switzerland), Orchid OptiMAL (Orchid Biomedical Systems, India) (HRP II-based), Paracheck *Pf* (Orchid Biomedical Systems, India), and ParaHIT *f* (Span Diagnostics, India) (pLDH-based). Most of the kits are in cassette format, except for Diamed OptiMAL 48, which is in dipstick format.

The RDTs were purchased by the World Health Organization (WHO) Geneva Office, delivered to the WHO Western Pacific Regional Office (WHO/WPRO), and subsequently transferred to the Department of Parasitology, College of Public Health, University of the Philippines, Manila. These were stored in room temperature (normally air-conditioned during office hours). The kits were transported to the field study site in an insulated container.

Due to poor performance, the ParaHIT *f* kits were used only in the first two surveys, while Orchid OptiMAL and Paracheck *Pf* were used only in the first three surveys.

Fig 1–Map of the Philippines showing the study sites.

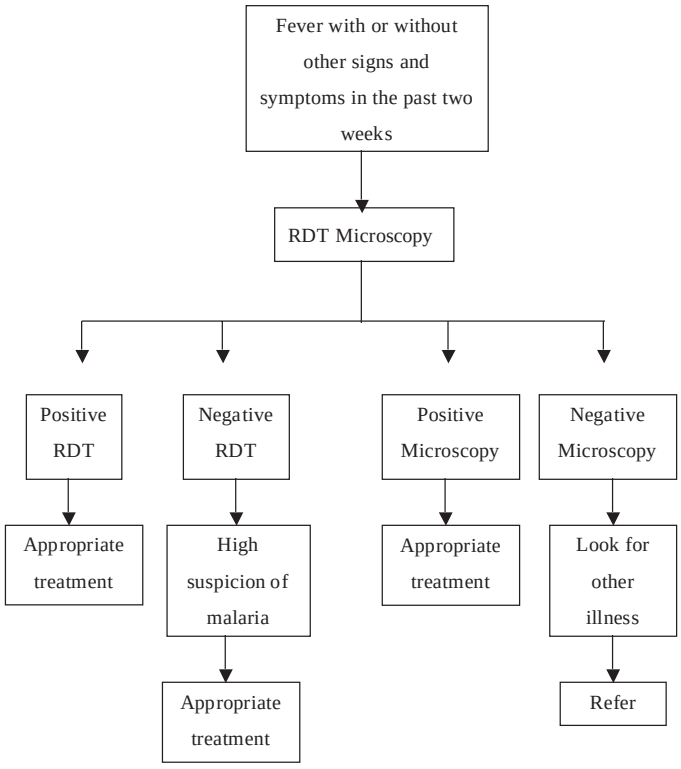

Fig 2–Suggested algorithm for RDT use in remote endemic areas.

Operational assessment of RDTs. Practical and operational issues related to the use of RDTs were assessed by reviewing the labels, packaging and product inserts of the different kits. The kits were assessed and compared according to general description, kit content, ease of performance, readability of results and cost.

Data handling

All qualitative and quantitative data were encoded and double encoded using EpiInfo Version 6.0 software. Validation of encoded records was also done to ensure accuracy and to cross-check discrepantly encoded records. The parameters derived included slide positivity rates (SPR), *Plasmodium* species rates, sensitivity and specificity of RDT against microscopy, and percentage detection according to the level of parasitemia.

Ethical considerations

This study was conducted in accordance with ethical principles based on the Declaration of Helsinki, consistent with the Good Clinical Practice Guidelines and was approved by the Ethics Review Board of the institution. The rights, safety and well being of patients were of foremost consideration. Informed consent was obtained from each patient enrolled. Confidentiality of patients' records was observed. Patients who were found to be positive for malaria were provided with standard medications from the Department of Health.

RESULTS

Microscopy and RDT

A total of 519 symptomatic patients were included in the study: 119 in the first survey in Talaingod, 212 patients in the second survey in Palawan, 86 and 102 patients in the third and last surveys in Talaingod, respectively.

During the first survey, 63.0% of the patients were positive on microscopy, with *P. falciparum (Pf)* in 85.3%, *P. vivax (Pv*) in 4.0%, and *P. malariae (Pm)* in 2.7%. Mixed infections were seen in 7.9%. During the second survey, 70.3% were slide positive, of which 91.9% were infected with *Pf,* 5.4% with *Pv*, and 2.7% with mixed infections *(Pf* and *Pv)*. In the third field survey, 77.9% of the patients were slide positive, with *Pf* in 94.0%, *Pm* in 4.5%, and mixed infection (*Pf* and *Pm*) in 1.5%. In the last field survey, 54.9% were slide positive, with *Pf* in 92.9%, and *Pm* in 7.1%. No mixed infections were detected (Table 1).

Variability in the sensitivities of the RDTs was apparent in all surveys. Diamed OptiMAL had the widest range of sensitivity, from 11.4% during the first survey, to 96.8% in the third survey. The sensitivities of Orchid OptiMAL also varied from 6.3% to 20.6%. Paracheck *Pf* had the lowest sensitivities from 4.8% to 12.1%. ParaHIT *f* had sensitivities of 9.6% and 66.7%.

Specificities also showed wide variation. Diamed OptiMAL had specificities that ranged from 18.2% to 91.8%. Orchid OptiMAL demon-

strated higher specificities from 87.3% to 98.0%. Paracheck *Pf* also had high specificities from 93.0% to 100.0%, while ParaHIT *f* had specificities of 82.6% and 95.0% (Table 2).

RDT detection rates for low levels of parasitemia also showed marked variability. Diamed OptiMAL had relatively low rates in the first and second surveys with 40.0% and 50.0%, respectively, compared to the third and fourth surveys of 100.0% and 90.9%, respectively. Orchid OptiMAL was able to detect parasites only during the first survey with a 40.0% detection rate. Paracheck *Pf* only detected parasites in the second survey, with a low 16.7% detection rate, and ParaHIT *f* detection rates were at 80.0% and 33.3% in the first two surveys.

For high parasitemias, greater than or equal to 100 parasites/μl, detection rates were likewise variable. Diamed OptiMAL rates ranged from 9.2% to 96.8%, while detection rates of Orchid OptiMAL were from 6.2% to 21.5%. Paracheck *Pf* had consistently low detection rates from 4.8% to 11.8%, while ParaHIT *f* had detection rates of 65.6% and 50.0% in the first and second surveys, respectively (Table 3).

Practical and operational assessment

All RDTs were packed with capillary tubes

Table 1
Slide positivity (SPR) and species rates among study participants in Davao del Norte and Palawan, 2002.

	Field surveys			
	1 Davao Norte (Feb 2002)	2 Palawan (Apr 2002)	3 Davao Norte (Sep 2002)	4 Davao Norte (Nov 2002)
No. of participants	119	212	86	102
No. of slide positives	75	149	67	56
SPR	63.0%	70.3%	77.9%	54.9%
P. falciparum only	85.3%	91.9%	94.0%	92.9%
P. vivax only	4.1%	5.4%	(-)	(-)
P. malariae only	2.7%	(-)	4.5%	7.1%
Mixed infections	7.9%	2.7%	1.5%	(-)

(-) negative findings

Table 2
Sensitivities and specificities of different RDTs for *P. falciparum* in Davao del Norte and Palawan, 2002.

RDT brand	Field surveys							
	1 Davao Norte (Feb 2002)		2 Palawan (Apr 2002)		3 Davao Norte (Sep 2002)		4 Davao Norte (Nov 2002)	
	Sensitivity %	Specificity %	Sensitivity %	Specificity %	Sensitivity %	Specificity %	Sensitivity %	Specificity %
Diamed OptiMAL 48	11.4	91.8	80.9	47.8	96.8	18.2	78.8	22.0
Orchid OptiMAL	8.7	98.0	20.6	87.3	6.3	90.9	(-)	(-)
Paracheck *Pf*	8.6	100.0	12.1	93.0	4.8	90.9	(-)	(-)
ParaHIT *f*	66.7	82.6	9.6	95.0	(-)	(-)	(-)	(-)

(-) not tested

Table 3
RDT detection rates of different RDTs according to the degree of parasitemia in Davao del Norte and Palawan, 2002.

RDT brand	Field surveys							
	1 Davao Norte (Feb 2002)		2 Palawan (Apr 2002)		3 Davao Norte (Sep 2002)		4 Davao Norte (Nov 2002)	
	<100/μl	≥100/μl	<100/μl	≥100/μl	<100/μl	≥100/μl	<100/μl	≥100/μl
Diamed OptiMAL 48	40 (2/5)	9.2 (6/65)	50 (3/6)	82.2 (111/135)	100 (1/1)	96.8 (60/62)	90.9 (10/11)	75.6 (31/41)
Orchid OptiMAL	40 (2/5)	6.2 (4/64)	0 (0/6)	21.5 (29/135)	0 (0/1)	6.3 (4/63)	(-)	(-)
Paracheck *Pf*	0 (0/5)	7.7 (5/65)	16.7 (1/6)	11.8 (16/135)	0 (0/1)	4.8 (3/62)	(-)	(-)
ParaHIT *f*	80 (4/5)	65.6 (40/61)	33.3 (1/3)	50 (9/18)	(-)	(-)	(-)	(-)

(-) not tested

of varying materials and diameters for use in blood collection. Diamed OptiMAL 48 kits had 1.5 mm-diameter marked soft plastic tubes, which required fine handling and posed some difficulty during blood collection. Orchid OptiMAL and Paracheck *Pf* had larger 3 mm-diameter soft plastic capillary tubes, which were easier to handle. ParaHIT *f* had a 1.5 mm-diameter glass capillary tube, which required fine handling, but allowed easier flow due to faster capillary action.

A buffer solution was included in each kit which was generally easy to dispense. All RDTs tested were in cassette format except for Diamed OptiMAL which came in a dipstick format. Both cassettes and dipsticks had provisions for labeling. Unlike the more sturdy cassettes, the Diamed strips, being lighter, were easily blown away in open field surveys.

The recommended storage temperature for all the RDT kits ranged from 2 or 4 to 30 degrees centigrade. Manufacture and expiry dates, as well as lot numbers, were found to be the same for all the components of the kits except for the Diamed OptiMAL 48 kits, where the expiry dates and lot numbers in the buffer, well, and test strip canister were noted to vary.

Both Paracheck *Pf* and ParaHIT *f* required 15 minutes to obtain results. The Diamed kits required 20 minutes before results were obtained and were perfomed with the most number of steps. Orchid OptiMAL required the longest time to obtain results at 30 minutes.

Control and test bands were generally of low intensity in all the RDTs tested. However, the bands of the Diamed OptiMAL were more prominent than the rest. For Orchid OptiMAL, control bands were frequently unclear and incomplete.

Generally, an individual RDT test would cost around US$0.60-2.50, but this depends on the volume of the order and where the RDTs are purchased. Rough estimates of the costs are US$0.60-0.70 for ParaHIT *f* and Paracheck *Pf,* while Diamed tests are from US$1.00-1.40 each. Orchid OptiMAL was not available commercially at the time of the study (Table 4).

DISCUSSION

Malaria RDTs provide blood-based diagnosis in areas where microscopy is unavailable. In all the field surveys, the SPR were more than 50%, indicating that the majority of patients with a history of fever in the past two weeks prior to consultation had *Plasmodium* infection. In such areas, RDTs could help differentiate between

Table 4
Qualitative comparison of all RDTs tested.

	Diamed OptiMAL 48	Orchid OptiMAL	Paracheck *Pf*	ParaHIT *f*
Brand description	OptiMAL Rapid Malaria Test	OptiMAL Rapid Malaria Test	Rapid Test for *P. falciparum* Malaria	A Rapid Test for diagnosis of *Plasmodium falciparum* Malaria: An IC Test Device
General				
Manufacturer	Diamed AG, 1785 Cressier s/Morat, Switzerland	Orchid Biomedical Systems, India	Orchid Biomedical Systems, India	Span Diagnostics Ltd, India
Type and packaging of test	Wells, dipsticks in canisters	Cassettes in individual pouches	Cassettes in individual pouches	Cassettes in individual pouches
Content of package/box	Each box of 48 tests contains: dipsticks in canister, conjugate wells, wash wells, well holder, buffer vials, pipettes sterile lancets, disinfectant swabs, informational insert	Individually pouched, cassette with pipette and desiccant, buffer dropper bottle, sterile lancets, disinfectant swabs, informational insert	Individually pouched, cassette with pipette and desiccant, buffer dropper bottle, sterile lancets, disinfectant swabs, informational insert,	Individually pouched, cassette with pipette and desiccant, buffer dropper bottle, sterile lancets, disinfectant swabs, informational insert
Storage temperature	2º-30ºC	4º-30ºC	4º-30ºC	4º- 30ºC
Labels	Printed outside box and in contents	Provided only for each pouch	Printed outside box and in contents	Printed outside box and in contents
Manufacture and expiry dates and batch numbers	Different for kit and various components	Uniform for kit and components	Uniform for kit and components	Uniform for kit and components
Other provisions				
Capillary tube	1.5 mm diameter soft plastic, with flattened opposite end; requires fine handling; may be difficult to collect blood; with marker for amount of blood	3 mm diameter soft plastic; allows easier handling; no marker for amount of blood	3 mm diameter soft plastic; allows easier handling; no marker for amount of blood	1.5 mm diameter fine glass; allows easier handling and collection of blood; no marker for amount of blood
Individual tests				
Space for labeling	On flag at one end of dipstick	On cassette itself	On cassette itself	On cassette itself
Sturdiness	Test strip may be easily blown away	Sturdy; compact in cassette	Sturdy; compact in cassette	Sturdy; compact in cassette
Buffer solution				
Amount of buffer needed per test	100 µl	300 µl	300 µl	300 µl
Dispensing	Soft plastic dispenser; buffer drops easily	Soft plastic dispenser that is opened by puncturing tip of dispenser with bottle cap; buffer drops easily	Soft plastic dispenser that is opened by puncturing tip of dispenser with bottle cap; buffer drops easily	Soft plastic dispenser that is opened by puncturing tip of dispenser with bottle cap; buffer drops easily
Actual procedure				
Amount of blood required	10 µl	5 µl	5 µl	5 µl
Waiting time for results	20 minutes	30 minutes	15 minutes	15 minutes
Number of steps	10 steps	7 steps	8 steps	6 steps
Ease of performance	More complicated to perform; need to set up wells and coat with appropriate buffer	Easy to perform	Easy to perform	Easy to perform
Transferability to local health centers	May not be easily transferable	May be easily transferable	May be easily transferable	May be easily transferable
Results				
Clearing of test strips	Good blood clearing	Poor blood clearing	Poor blood clearing in some tests	Good blood clearing
Appearance of control and test bands	Generally of light intensity	Generally of light intensity; control band not appearing in a few, broken in many	Generally of light intensity	Generally of light intensity
Cost				
Cost per test (US$)	~1.40	Not available commercially	~0.60-0.70	~0.60-0.70

Table 5
Temperature and humidity levels during the four field surveys.

	Temperature	Humidity (%)	Month
Field Site 1 (Davao del Norte)			
Day 1	23.2º-31.6ºC	74	February
Day 2	24.0º-32.5ºC	70	February
Day 3	23.2º-31.6ºC	81	February
Field Site 2 (Palawan)			
Day 1	24.3º-28.2ºC	83	April
Day 2	23.8º-27.6ºC	91	April
Day 3	24.2º-32.8ºC	75	April
Field Site 3 (Davao del Norte)			
Day 1	23.6º-30.4ºC	86	September
Day 2	23.1º-31.2ºC	86	September
Day 3	24.2º-32.0ºC	79	September
Field Site 4 (Davao del Norte)			
Day 1	24.8º-31.8ºC	81	November
Day 2	24.7º-33.7ºC	82	November
Day 3	23.9º-33.4ºC	81	November

(Source: PAGASA, Davao City, Philippines)

malaria and other causes of fever. The use of a good RDT, therefore, can make possible early and accurate diagnosis, which will lead to appropriate and timely treatment.

P. falciparum malaria was seen in more than 90% of infected cases, while malaria due to *P. vivax*, *P. malariae*, and mixed infections were seen in only a minority of patients. In this setting, all four RDT kits tested can play an important role in the early diagnosis of symptomatic individuals. However, there are limitations that may affect RDT performance. One limitation of the HRP II-based kits is that they cannot diagnose relapse in patients with *P. vivax* infection, which still remains an important advantage of microscopy and the pLDH-based kits. Furthermore, HRP-II based kits may not be used as an indicator of treatment efficacy (Perkins and Crawley, 2001), unlike enzyme-based tests that can be used to follow treatment outcomes.

The sensitivities of all the kits tested in the field surveys were generally poor, except for Diamed OptiMAL, which had sensitivities ranging from 78.8% to 96.8% in the last 3 surveys. Specificities, meanwhile, varied from poor to excellent, ranging from 18.2% to 100%. RDT detection rates, were generally poor for *P. falciparum* parasitemias of 100 parasites/μl or more, except for Diamed OptiMAL, which had detection rates ranging from 75.6% to 96.8% in the last 3 surveys. The 1999 WHO Expert Committee on Malaria (2000) recommended a 95% sensitivity at 100 parasites/μl as a target for RDT performance. Our study found wide variability and unexplained poor sensitivity, as has been described elsewhere (Jelinek *et al*, 1999; Forney Jr *et al*, 2001; Iqbal *et al*, 2001; Rubio *et al*, 2001; Huong *et al*, 2002; Mason *et al*, 2002). In this study, variability was evident in both high and low levels of parasitemia, as opposed to other studies where sensitivities were observed to be more variable at lower parasite densities, and false negative results occurring at higher parasitemias (Iqbal *et al*, 2001; Huong *et al*, 2002; Mason *et al*, 2002).

The poor performance of RDTs in the field has serious implications on case management and may compromise malaria control efforts. This may be attributed to either the manufacturer or the end user. Loss of sensitivity may be due to improper preparation of test strips. Possible causes include loss of activity of the gold conjugate or inadequate concentrations of monoclonal antibodies. Loss of specificity may be caused

by loss of equivalence of the pan-malaria and the *P. falciparum*-specific bands on the nitrocellulose membrane. False positive signals may be due to too large a blood volume (>10 μl, depending on the type of kit), inappropriate dilution/concentration of buffer, or contamination of the sample (WHO, 2003a,b).

Poor sensitivity or false negative results may be explained by factors such as poor flow characteristics, Chase buffer failure, and monoclonal antibody failure. Poor flow characteristics may be influenced by membrane variability, irregular flow of sample on the membrane, and sample variation (fresh blood *versus* lysed blood, and EDTA anticoagulant concentration). Chase buffer problems may include incorrect formulations of buffer for the RDT batch, buffer diluted with the wrong pH, and viscosity of the sample preventing buffer flow. Monoclonal antibody failure may be due to weak antibody concentration, as well as the physical effects of humidity on exposed strips, causing loss of activity (WHO, 2003a).

Poor specificity or false positive results may be explained by a number of reasons, among them, persistent HRP-II remaining as circulating or sequestered antigen after the treatment of *P. falciparum* malaria for several days to weeks, and physical overload of the absorption pads with blood sample. Cassette tests, in particular, can allow backflow of sample and conjugate, which can lead to entrapment at the detection line. These happen, for example, in tests read as negative at the correct reading time, which then become positive on re-reading 12 to 24 hours later. Other reasons may include high titers of non-specific antibodies, usually due to viral infection or the presence of rheumatoid factor (WHO, 2000).

The effect of ambient conditions at the time of testing can also greatly influence the validity of the results. Critical kit components may be subject to deterioration in adverse transport and storage conditions, where exposure to high humidity may result in the loss of activity of the gold conjugate. Furthermore, excess heat and humidity may lead to a loss of monoclonal antibodies from the strip (WHO, 2003b)

Humidity in areas like the Philippines ranges from 70% to 91% in field conditions, according to the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). The temperature and humidity levels of all the field sites around the time of the surveys exceeded the prescribed limits of the RDT kits (Table 4). This may explain the poor performance of the RDTs at the time of testing.

An ideal RDT should be able to tolerate temperatures of at least 40ºC, with peaks of 50ºC, and storage for up to 2 years (WHO, 2000). While most manufacturers recommend that RDTs be stored between 2º and 30ºC, the use of RDTs in remote areas may entail transport and storage in tropical conditions beyond the limits of RDT stability. It is important that users minimize exposure of RDTs to extreme conditions (WHO, 2003a).

Inadequately trained personnel may perform procedures erroneously. It is important to select appropriate and responsible individuals who can be trained not only to perform RDT procedures accurately, but also who can transport and store kits properly. Serious consideration of these issues will not only help ensure the reliability of the test results, but also minimize the waste of limited resources.

Striking differences were noted between the RDT kits tested. Diamed Optimal had the most number of procedures, while Orchid OptiMAL test strips were noted to have problems related to the readability of the results. This may have implications for the transferability of RDT technology to peripheral health workers and volunteers. Current market costs were also different. Diamed OptiMAL was almost double the price of Paracheck *Pf* and ParaHIT *f.* The final costing will depend on the distributor and the volume of the order.

If increased reliance on RDTs is expected, it is important to ensure the reliability of the test results. Negative RDT results, therefore, must be interpreted with caution, even with the use of a reportedly highly sensitive RDT. Depending on the situation, treatment may have to be given in cases where there is a high suspicion for malaria, based on clinical symptoms. This may be especially justifiable for patients living in high transmission areas. In certain cases, there may be a need for confirmatory microscopy, particu-

larly in chloroquine-resistant areas, where more expensive antimalarials will have to be given.

This study has demonstrated and described some problems regarding the performance of RDTs, such as the variability in sensitivity, specificity and detection rates in both high and low parasitemia levels. Malaria RDTs cannot be considered as mainstream diagnostic tools. Further investigations focusing on quality assurance of these RDTs need to be performed.

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