Short Report: Detection of \textit{Plasmodium falciparum} Histidine-rich Protein II in Saliva of Malaria Patients

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Abstract. Detection of \textit{Plasmodium falciparum} parasites in patients with malaria necessitates drawing blood, which increases the risk of accidental infections and is poorly accepted in communities with blood taboos. Thus, non-invasive, cost-effective malaria tests that minimize the need for blood collection are needed. \textit{Plasmodium falciparum} histidine-rich protein II (P/HRP II) levels in plasma and saliva were compared in malaria–positive and –negative patients in Ghana. Plasma and saliva obtained from 30 thick-film positive and 10 negative children were evaluated for \textit{P}H\textit{HRP} II by ELISA. Among the 30 children with positive blood smear, 16 (53%) were \textit{P}H\textit{HRP} II positive in plasma and 13 (43%) had \textit{P}H\textit{HRP} II positive saliva. The sensitivity of \textit{P}H\textit{HRP} II detection was 53% for plasma and 43% for saliva. The specificity was 100% with no false positive for both plasma and saliva when compared with blood smear. Thus, rapid detection of \textit{P}H\textit{HRP} II antigen in saliva may be a useful non-invasive and cost-effective malaria diagnostic technique.

Malaria transmission and mortality rates remain unchanged in endemic countries lacking adequate health care and malaria control despite the use of preventive measures and treatments against malaria. A major obstacle to effective malaria control is the lack of affordable and accurate malaria diagnostics and treatment, which has led to misuse and abuse of anti-malarial drugs and the development of drug resistance in parasites.

Microscopic examination of blood smears, the conventional method for \textit{P. falciparum} detection, is currently being augmented with antigen- and PCR-based rapid diagnostic tests (RDTs) for blood. However, inaccurate microscopic evaluation of blood smears have resulted in misdiagnoses and misclassification of malaria severity. Blood taboos and increased risk of accidental infections due to needle pricks continue to impact malaria diagnosis negatively. In non-specialized laboratories, microscopic evaluation of blood smears is slow and may lead to late diagnoses and treatment, which contributes to high mortality rates.

Rapid diagnostic tests (RDTs) or “dipstick” are currently being used to detect antigens of \textit{Plasmodium} species in blood or plasma to supplement microscopic evaluation of blood smears to manage tropical febrile disease. The benefits of this approach include the rapid turnaround time and the ease of use, which allows inexperienced laboratory or clinical staff to make on-the-spot diagnoses in the absence of visible parasites. However, issues associated with cultural objections to the collection of blood in communities with blood taboos and increased risk of needle injuries and disease transmission must be addressed.

Saliva has been used in surveillance of vaccine-preventable diseases, such as measles, mumps, and rubella, and for individual diagnosis of HIV infection by detecting antibodies against the target pathogen. Although \textit{P. falciparum} HRP II antigen has been detected in erythrocytes, serum, plasma, cerebrospinal fluid, and urine, detection of parasite antigens in saliva of \textit{P. falciparum}-infected humans has not been reported. The goal of this pilot study was to test the possibility of detecting malaria parasite antigen in saliva in malaria patients. The hypothesis is that \textit{P. falciparum} histidine-rich protein II (P/HRP II) is detectable in saliva in patients with symptomatic malaria.

The study was conducted at the Korle-Bu Teaching Hospital’s Child Health Department, Accra, Ghana, after ethical approval by Morehouse School of Medicine and University of Ghana Medical School. Randomly collected samples (plasma and saliva) from children (22 months to 16 years) reporting to the Child Health Department’s diagnostic laboratory were retrospectively analyzed for this study. Malaria positive cases were confirmed by thick film slides. Parasitemia was evaluated on the number of parasites per field (+, 1–10 parasites/100 fields, ++, > 10 parasites/100 fields, ++++, 1–10 parasites/field, and +++++ > 10 parasites/field) and at least 100 fields slide were examined to rule out any negative thick film slide. Thirty thick film positive children and 10 negative children were enrolled. Red blood cells (infected and uninfected) and plasma were separated using Vacutainer Cell Preparation Tubes (CPT) with Sodium Citrate (Becton Dickinson, USA). Saliva was collected in sterile containers and aliquoted into microcentrifuge tubes and stored at −20°C. Saliva samples were centrifuged for 3 min at 14,000 rpm and the supernatants were analyzed by ELISA. Both saliva and plasma samples from the same patient were analyzed on the same plate, date, and conditions for \textit{P}H\textit{HRP} II antigen levels using a Malaria Antigen ELISA kit (CELSIA, Cellabs, Australia). This kit measures HRP II production during growth and multiplication of \textit{P. falciparum} at a specificity of 96% and sensitivity of 98% in whole blood or plasma and can detect \textit{P. falciparum} parasites at a limit of detection of 0.001% ; thus incubation periods with reagents were the same for plasma and saliva for the same patient. The plasma samples were tested at 1:2 dilution and all samples were run in duplicates by ELISA. The incubation period for primary and secondary antibodies with the samples was 1 hr each in a humid chamber and 15 min for enzyme development (substrate) in the dark at room temperature. The minimum limit of detection (cut-off level) of the kit was determined according to manufacturer’s instructions.

Of the 30 children testing positive for blood smear, 16 (53%) had detectable \textit{P}H\textit{HRP} II antigens in their plasma (Table 1). Thirteen (43%) patients of the 30 positive blood smears were \textit{P}H\textit{HRP} II positive for saliva samples (Table 1).
All patients that were \( P/HRP II \) positive for saliva were also positive for plasma. Three patients (P006, P008, and P011) were \( P/HRP II \) positive in plasma but negative for saliva samples. Surprisingly, P006 had a mean OD reading (0.144) that is slightly below the cut-off level of 0.161 compared with the other 2 (P008 and P011) \( P/HRP II \) negative saliva. This observation suggests that P006 may have \( P/HRP II \) in the saliva that is undetectable in the kit used for this study. The 10 negative blood smears were also negative for \( P/HRP II \) antigen in both plasma and saliva. In our study the minimum limit of detection (cut-off level) was an OD reading of 0.161, which was determined according to the manufacturer’s instructions. In addition, all 13 saliva specimens had lower titers (OD, 0.166–0.427) of \( P/HRP II \) with a mean of 0.209 ± 0.07. The sensitivity of \( P/HRP II \) detection test for plasma was 53% and 43% for saliva whereas specificity was 100% for both specimens when compared with blood smears.

Rapid and accurate malaria diagnosis enables effective malaria control by eliminating malaria-associated morbidity and mortality in resource-poor countries. In Africa, fevers are treated presumptively as malaria in the absence of laboratory-confirmed diagnosis,\(^7\) which results in the extensive overuse of anti-malaria drugs.\(^{16}\) Light microscopy, the conventional method for malaria diagnosis, remains unavailable to a huge segment of patients.\(^{16,19}\) Thus, integrating detection of circulating antigens of malaria parasites in saliva with RDT technology will considerably improve parasite detection and diagnosis of malaria.\(^1\)

Malaria detection and epidemiological surveys in developing countries often require collection of blood samples from severely anemic children and communities with blood taboos. In central Africa, blood is considered an essential constituent “vital force” by sorcerers.\(^7\) Therefore, collection of blood specimens—regardless of the volume for definitive or confirmatory diagnosis—is poorly accepted.\(^7\) Thus, a non-invasive approach will greatly enhance cooperation of patients.

PCR methods have been used to detect malaria parasites in the blood.\(^{6,20}\) Although PCR-based methods are more sensitive and specific than existing techniques, the process is
lengthy and requires specialized, costly equipment and reagents, as well as laboratory conditions that are not possible in the field. Sensitivity of detection in saliva was not enhanced in this study due to limitations of the commercially available kit used, which is designed to detect higher levels of \( P/\text{HRP II} \) in whole blood or plasma than is found in saliva. Therefore, development of a kit or test that is sensitive enough to detect lower levels of the antigen present in saliva could be a more appropriate approach to malaria diagnostics and in epidemiological surveys, thus, substituting blood samples with saliva specimens.

The detection of \( P/\text{HRP II} \) in saliva offers a practical alternative to \( P/\text{HRP II} \) detection in blood for malaria diagnosis and offers some distinct advantages over blood. Collection of saliva is non-invasive, simple, safe, stress free, painless, and can be done by individuals with limited training, including patients. It will not require blood cell lysis that diminishes HRP II antigen availability and detection. No special equipment is needed for collection and it allows for multiple or serial collections outside of the hospital.

Detecting parasite antigens in saliva to determine presence or absence of parasites could be valuable for communities with blood taenos and reduce compliance problems associated with collection of blood. Furthermore, it will provide a cost-effective approach for the screening of large populations in epidemiological surveys while being affordable, rapid, non-invasive, and safe for patients and technicians in resource-poor environments.

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