

MALARIA MORBIDITY AND MORTALITY FOLLOWING INTRODUCTION OF A UNIVERSAL POLICY OF ARTEMISININ-BASED TREATMENT FOR MALARIA IN PAPUA, INDONESIA: A RISING BURDEN OF *PLASMODIUM VIVAX* MALARIA

Jeanne Rini Poesoprodjo¹, Enny Kenangalem², Nicholas Douglas³, Lenny Burdam², Ketut Gdeumana⁴, Ferry Chalfien², Pak Prayoga², Fransciscus Thio², Angela Devine³, Jutta Marfurt³, Govert Waramori⁴, Shunmay Yeung⁵, Rintis Noviyanti⁶, Pasi Penttinen⁴, Michael J. Bangs⁴, Paulus Sugiarto⁷, Julie A. Simpson⁸, Yati Soenarto¹, Nicholas M. Anstey³, Ric N. Price³

¹Universitas Gadjah Mada, Yogyakarta, Indonesia, ²Papuan Health and Community Development Foundation, Timika, Indonesia, ³Menzies School of Health Research, Darwin, Australia, ⁴PT Freeport Indonesia/International SOS, Timika, Indonesia, ⁵The London School of Hygiene & Tropical Medicine, London, United Kingdom, ⁶Eijkman Institute for Molecular Biology, Jakarta, Indonesia, ⁷Rumah Sakit Mitra Masyarakat, Timika, Indonesia, ⁸University of Melbourne, Melbourne, Australia

Malaria control activities can have a disproportionately greater impact on *Plasmodium falciparum* than *P. vivax* in areas where both species are coendemic. We present the temporal trends in malaria-related morbidity and mortality in Papua, Indonesia before and after introduction of ACT for all *Plasmodium* species. A prospective, district-wide malariometric surveillance system was established in April 2004 to record all cases of malaria at community clinics and the regional hospital and maintained until December 2013. In March 2006, antimalarial treatment policy was changed to artemisinin combination therapy for uncomplicated malaria and intravenous artesunate for severe malaria due to any *Plasmodium* species. Over the study period a total of 418,238 patients presented to the surveillance facilities with malaria. The proportion of patients with malaria requiring admission to hospital fell from 26.9% (7,745/28,789) in the pre-policy change period (April 2004 to March 2006) to 14.0% (4,786/34,117) in the late transition period (April 2008 to December 2009). There was a significant fall in the mortality of patients presenting to the hospital with *P. falciparum* malaria (0.53% (100/18,965) versus 0.32% (57/17,691)), but this was less apparent for patients with *P. vivax* malaria (0.28% (21/7,545) versus 0.23% (28/12,397)). Between the same periods, the overall proportion of malaria due to *P. vivax* rose from 44.1% (30,444/69,098) to 53.3% (29,934/56,125) in the community clinics, and from 32.4% (9,325/28,789) to 44.1% (15,035/34,117) at the hospital. After controlling for population growth and changes in treatment seeking behaviour, the incidence rate ratio for the reduction of *P. falciparum* malaria was 0.40 (95%CI 0.40,0.41) and that *P. vivax* malaria was 0.60 (95%CI 0.59,0.60)). a universal policy of artemisinin-based blood schizontocidal treatments in Papua, Indonesia was associated with a greater decrease in the burden of *P. falciparum* compared to *P. vivax*. Widespread access of patients to safe and highly effective radical cure of *P. vivax* will be critical to malaria elimination efforts in co-endemic regions.

THE EPIDEMIOLOGY OF *PLASMODIUM VIVAX* AMONG ADULTS IN THE DEMOCRATIC REPUBLIC OF THE CONGO

Nicholas F. Brazeau¹, Cedar Mitchell², Molly Deutsch-Feldman², OJ Watson³, Andrew Morgan¹, Cory Keeler⁴, Kyaw Thwai², Melchior Mwandagarirwa⁵, Antoinette Tshetu⁵, Joris Likwela⁶, Robert Verity³, Steven Meshnick², Jonathan Juliano¹

¹University of North Carolina School of Medicine, Chapel Hill, NC, United States, ²Gillings School of Global Public Health, Chapel Hill, NC, United States, ³Imperial College London, London, United Kingdom, ⁴Department of Geography, University of North Carolina, Chapel Hill, NC, United States, ⁵Programme National de la Lutte contre le Paludisme, Kinshasa, Democratic Republic of the Congo, ⁶Kinshasa School of Public Health, Kinshasa, Democratic Republic of the Congo

Although *Plasmodium vivax* has long been considered absent from Sub-Saharan Africa, recent reports of *P. vivax* infections among Duffy-

negative hosts in Sub-Saharan Africa continue to accumulate. However, to date, no studies have performed a nationally representative survey of *P. vivax* in a Sub-Saharan African country. To overcome this critical gap, we used data collected from the 2013-2014 Standard Demographic Health Survey in the Democratic Republic of the Congo (Study ID: DRC DHS-II) to screen over 17,000 adults for *P. vivax*. Overall, we detected 472 cases of *P. vivax* (weighted prevalence: 2.96%, 95% CI: 2.28%, 3.65%). Among the 489 clusters that were sampled in the DRC DHS-II, the number of *P. vivax* cases ranged from 0 - 9 (weighted prevalence range: 0 - 46.15%). Among the 472 *P. vivax* cases, three infected hosts were Duffy-positive (0.64%) and 175 were co-infected with *P. falciparum* (31.70%). To identify the epidemiological and spatial risk factors associated with *P. vivax* infection, we evaluated over 30 covariates with generalized estimating equations. Among these covariates, individual-level wealth, access to health insurance, and precipitation were identified as significant predictors of *P. vivax* infection. However, *P. vivax* infections did not appear to cluster spatially (Moran's I: 0.02, $p > 0.05$), possibly due to interference by *P. falciparum* ($p < 0.05$). To evaluate the effect of scalable antimalarial interventions on *P. vivax* versus *P. falciparum*, we calculated the relative risks of bed-net use, housing materials, and health-insurance using inverse-probability weights with an ensemble supervised machine learning approach. Among these three interventions, only housing materials demonstrated a reduction in *P. vivax* cases [RR: 1.95 (1.11, 3.42)], while all three interventions reduced *P. falciparum* cases. Future work will include *P. vivax* phylogenetics and creating a Bayesian hierarchical spatial prediction model. The return of *P. vivax* to Sub-Saharan Africa is a renewed threat that complicates malaria elimination efforts. The results of this study will aid the DRC government in its efforts to halt the spread of *P. vivax*.

TRENDS IN OUTPATIENT MALARIA CASES AND THE EFFECTS OF MALARIA CONTROL IN THE DEMOCRATIC REPUBLIC OF THE CONGO

Filippo Lechthaler¹, Barbara Matthys², Giulia Lechthaler-Felber², Joris Losimba Likwela³, Hypolite Muhindo Mavoko⁴, Junior Matangila Rika⁴, Meschac Mutombo Mutombo², Laura Ruckstuhl², Joanna Barczyk², Estifanos Shargie⁵, Helen Prytherch², Christian Lengeler²

¹Bern University of Applied Sciences, Bern, Switzerland, ²Swiss Tropical and Public Health Institute, Basel, Switzerland, ³Soins de Santé en Milieu Rural (non-profit organization SANRU), Kinshasa, Democratic Republic of the Congo, ⁴University of Kinshasa, Kinshasa, Democratic Republic of the Congo, ⁵The Globa Fund to Fight AIDS, Tuberculosis and Malaria, Geneva, Switzerland

The Democratic Republic of the Congo (DRC) has the second highest case load from malaria in the world after Nigeria. Malaria control interventions have been strengthened in line with the Millennium Development Goals. We analyzed the effects of these interventions on malaria at health facility level using a retrospective trend analysis of malaria cases between 2005 and 2014, with data collected from outpatient and laboratory registers based on a representative sample of 175 health facilities across the country. We applied a time series analysis to assess trends of suspected and confirmed malaria cases by health province and for different age groups. a linear panel regression model controlled for non-malaria outpatient cases, rainfall, light intensity, health province and time fixed effects, to examine the relationship between the interventions and malaria case occurrences and positivity rates. Overall, recorded suspected and confirmed malaria cases in the DRC have increased. a sharp increase in confirmed cases from 2010 coincides with the introduction of the new treatment policy and the resulting scale-up of diagnostic testing. Controlling for confounding factors, the introduction of rapid diagnostic tests (RDTs) was significantly associated with the number of tested and confirmed cases. The evolution of the positivity rate does not indicate a downward trend in morbidity due to malaria. The sharp increase in confirmed malaria cases from 2010 is associated with improved diagnostic availability, mainly the introduction of RDTs. Before that, a great part of malaria cases were treated based on clinical suspicion. This finding points