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Severe Vivax Malaria: Newly Recognised or Rediscovered?

Stephen J. Rogerson*, Richard Carter

Malignant tertian” and “benign tertian” are terms that have long been used for two of the major diseases we recognise as malaria. The former is generally considered to be synonymous with Plasmodium falciparum and the latter with P. vivax infection. As the names “malignant” and “benign” suggest, the current dogma is that P. falciparum can be severe and life-threatening while P. vivax tends to be milder. However, two studies published in this issue of PLoS Medicine challenge this dogma.

The Two New Studies

Ric Price and colleagues, in a prospective study based in Timika, southern Papua in Indonesia [1], and Blaise Genton and colleagues, in a prospective study in the Wosera region of Papua New Guinea [2], report similar rates and outcomes of severe malaria due to P. vivax or P. falciparum. The two studies had different settings, and the cultural and ethnic characteristics of the patient populations were also different. Price and colleagues collected data from all patients attending the outpatient and inpatient departments of the only hospital in the region, using systematic data forms and computerised hospital records. In contrast, Genton and colleagues investigated patients presenting at two rural health facilities.

In both settings, clinical and severe disease was most common in young children, with severe disease being most common in children under five years old, around 30% of whom had severe P. vivax infection. In Timika, in children under five years attending the health centre, around 9% of vivax and 12% of falciparum infections were classified as severe malaria. However, respiratory distress was defined less stringently in the Wosera (more than 40 breaths/minute in the Wosera) than in Timika (more than 50 breaths/minute in this age group). When cough and diarrhoea (which are poorly specific for malaria) were used as exclusions in the Wosera study, severe malaria rates in children under five years fell to 7% and 4% of P. falciparum and P. vivax infections, respectively. In the Wosera, anaemia occurred in about 20% and 40% of severe cases of vivax and falciparum, respectively, while respiratory distress occurred in 60% and 40% of severe cases of vivax and falciparum, respectively. Neurologic symptoms were present in 25% of severe cases of either species.

The cases of cerebral malaria due to P. vivax reported in both studies, occurring in all age groups, are intriguing, because this malaria complication has rarely been reported previously in association with P. vivax infection. In P. falciparum, cerebral malaria is primarily attributed to sequestration of infected erythrocytes in cerebral vessels. As P. vivax does not sequester, coma must arise by other means—perhaps of systemic metabolic origin—in vivax malaria. This pathogenesis may also underlie some cerebral malaria presentations in children.

Both studies, inevitably, have limitations. First, co-morbidities, including concomitant bacterial or viral infections, which could have decreased the malaria-attributable fraction of disease [3], were not actively investigated. Second, microscopy was used for parasite detection and speciation, which routinely leads to

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Abbreviations: G6PD, glucose-6-phosphate dehydrogenase; PvDBP, P. vivax Duffy binding protein

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in *P. vivax*, severe anaemia defined 40% of severe falciparum cases, but only 20% of severe vivax cases. Thus the Wosera data are also consistent with parasite drug resistance as a factor in anaemia. If these conjectures are correct, the recent adoption of dihydroartemisinin–piperaquine treatment in Papua [5] may lead to a significant decrease in severe malarial anaemia.

Other factors, such as host genetics, could also have influenced the differences in severe disease manifestation between study sites. It has been shown, for example, that children in Papua New Guinea with the red cell genetic polymorphism “South East Asian ovalocytosis”, a trait common in this population, are almost completely protected from cerebral malaria [6]. In Timika, indigenous Papuans were much more likely to be severely anaemic than were immigrants. Might host genetics have contributed to the high anaemia rates reported in the Timika study?

### Interactions between Vivax and Falciparum

There is a view that malarial disease severity in New Guinea may be lower overall than in Africa. For example, case fatality rates for *P. falciparum* among hospitalised children in New Guinea ranged from 1.6% to 3.5% [7,8] versus 2% to 9% in recent African studies [9–11]. This difference raises the question of whether *P. vivax*, which is common in New Guinea but rare in Africa, may actuallyameliorate the severity of *P. falciparum* where the two species are co-endemic.

Maitland and colleagues have suggested that the earlier age peak for *P. vivax* disease may protect against the later-acquired *P. falciparum* through species-transcending immunity [12]. Studies have shown that symptoms of *P. vivax* or *P. falciparum* infection are, indeed, significantly reduced by recent previous *P. vivax* infection (but not *P. falciparum* infection) [13]. In contrast, the two new studies in *PLoS Medicine* report that mixed species infections had worse outcomes than infections of either species alone [1,2]. If previous vivax infection does protect against severe *P. falciparum* infection, further investigations are needed so that policies for *P. vivax* control can balance reduction in severe vivax with possible loss of vivax-associated protection against severe *P. falciparum* infection.

### Malaria Severity Depends on Context

The findings of the two new studies [1,2] should be considered from a wider biological and historical perspective, which shows that malarial disease severity is highly context dependent. For example, from the 16th through the 19th centuries in England, mortality rates associated with “marsh agues”—probably due largely to vivax malaria—gradually fell from high to negligible levels. This fall occurred either because of attenuation of *P. vivax* infection through adaptation of parasite and/or host, or through environmental change, such as reduced exposure to other diseases or improved nutrition [14]. Indeed, host under-nutrition and co-infections, including HIV, helminth, and acute bacterial or viral infections, can all influence the outcomes in malaria [3]. Access
to antimalarial drugs and presence of parasite drug resistance are clearly also relevant to the clinical outcome.

*P. vivax* infection is characterised by relapse in which dormant liver stage parasites in the liver (hypnozoites) induce a later period of symptomatic blood-stage infection. This relapse is particularly characteristic of *P. vivax* infection, though *P. falciparum* can cause long intervals between relapses. Relapse may occur after many months or years and is much more common in areas of high transmission. The burden and severity of malaria is determined by the level of endemicity, existence of co-infections, access to treatment, and presence of parasite resistance. It is important to note that the current reports of severe *P. vivax* malaria come from New Guinea, where drug-resistant *P. vivax* was first reported. This drug resistance could itself be a driver of severity together with the particularly high regional malaria transmission force. Were severe *P. vivax* to be found more widely, it would have significant implications for control of the infection, especially as *P. vivax* increasingly becomes a significant problem in the Americas and parts of western Africa. The availability of the *P. vivax* genome (GenBank accession no. AAKM00000000), it will be possible to compare isolates associated with severe or uncomplicated disease. However, connecting genetic differences with pathogenic potential may not be straightforward [17].

Better disease control (see Box 1) might include preventive strategies (vaccines, insecticide-treated bed nets, and intermittent preventive treatment), more effective curative treatment (finding the most suitable alternative to chloroquine), and better relapse prevention (long-acting drugs such as dihydroartemisinin–piperaquine decrease early relapse compared to other artemisinin-based combination therapies [5]). Elimination of dormant parasites in the liver (hypnozoites) is especially difficult because available drugs can cause severe haemolysis in individuals with glucose-6-phosphate dehydrogenase (G6PD) deficiency. A simple point-of-care assay for G6PD deficiency, or new, safer drugs that target liver stage parasites, would be invaluable tools for eradication of hypnozoites.

Vaccines against *P. vivax* are in development. One target is the *P. vivax* Duffy binding protein (PvDBP), which mediates merozoite invasion of erythrocytes [18, 19]; human vaccine studies using this target are likely to begin this year. Another target is the *P. vivax* gamete surface protein Pvx25, a candidate for a transmission-blocking vaccine. Indeed, this vaccine candidate is already in Phase I human trials [20]. Should either candidate progress to large-scale trials, it will be critical to examine impact on both *P. vivax* infection (including, potentially, increased chronicity of infection and anaemia following PvDBP vaccination) and *P. falciparum* infection. While New Guinea is an ideal site in which to evaluate such vaccines, evaluation must also be done in low-transmission areas where most *P. vivax* infections are symptomatic and, where diminished symptomatology could dangerously postpone treatment. The two reports by Price et al. and Genton et al. provide information about disease burden critical to improved decision making for the public health management of *P. vivax* malaria [1, 2].

**The Way Forward for Vivax Malaria Control**

With calls for increased efforts to control malaria internationally, it will be important to ensure that *P. vivax* receives appropriate attention. We still lack reliable estimates of its global burden, and are only now starting to appreciate certain aspects of disease presentation of *P. vivax* malaria infection. The burden and severity of *vivax* in different settings requires further study. With the availability of the *P. vivax* genome (GenBank accession no. AAKM00000000), it will be possible to compare isolates associated with severe or uncomplicated disease. However, connecting genetic differences with pathogenic potential may not be straightforward [17].

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