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# Health system effectiveness of symptomatic malaria case management in Papua New Guinea

Vincent Minconetti ,[1,2] Clara Champagne,[1,2] Michah Muri,[3] Clara Are,[3] Philemon Goi,[3] Yangta Ura,[3] Melvin Kualawi,[3] Diana Timbi,[1,2,3] Joseph Giduthuri,[1,2,3] Myo Minn Oo,[1,2,3] Leo Makita,[4] Osama Seidahmed,[1,2] Amanda Ross,[1] William Pomat,[3] Manuel W Hetzel [1,2]

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We remember Mr. Leo Makita, long-term manager of the PNG National Malaria Control Programme, who passed away in May 2024.

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For numbered affiliations see end of article.

**Correspondence to**
Vincent Minconetti;
vincent.minconetti@swisstph.ch

## ABSTRACT

Effective case management is crucial for malaria control efforts and is a cornerstone of malaria control programmes. Yet, although efficacious treatments exist, malaria case management often faces challenges, such as poor access to treatment providers, supply-chain issues, non-compliance with guidelines or substandard medication. In Papua New Guinea (PNG), progress in control efforts has stagnated in recent years. This study identifies barriers to and areas for improvement in malaria case management in PNG.

A cascade of care model was used to estimate the health system effectiveness of malaria case management. Data from nationwide surveys conducted between 2013 and 2021 were used to quantify steps along a symptomatic case management pathway. Potential risk factors for cascade decay, including demographic, socioeconomic and health system characteristics, were investigated using mixed-effect logistic regression.

The main bottleneck along the case management cascade was treatment-seeking, with only 40% (95% CI: 37% to 46%) of symptomatic malaria cases attending a formal health facility. A further important bottleneck was confirmatory parasitological diagnosis, provided to 77% (95% CI: 68% to 80%) of patients attending a health facility. Younger patients and those living in high transmission regions were more likely to receive a diagnostic test.

Measures to improve the effectiveness of malaria case management in PNG should include increasing access to, utilisation and quality of formal health services. Further investigations to elucidate local determinants of treatment-seeking may support the National Malaria Strategic Plan's emphasis to optimise the delivery of proven interventions within the existing system.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies have assessed the readiness and performance of malaria case management in formal health facilities across Papua New Guinea. Their findings highlighted the necessity for improvements to meet national malaria control objectives. To better understand where to concentrate efforts, a systematic assessment of the continuum of care is essential.

### WHAT THIS STUDY ADDS

⇒ This study identified barriers to and areas for improvement in the effective delivery of malaria case management in Papua New Guinea. Using a cascade of care approach, this study provides an insight into potential levers to improve malaria case management.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings indicate the need for improving access to care, particularly for remote and poor communities, in order to improve overall effectiveness of malaria case management. This may inform future subnational tailoring of malaria interventions and strategies.

## INTRODUCTION

Prompt diagnosis and effective treatment play a crucial role in mitigating malaria morbidity and preventing malaria deaths.[1 2] Yet, despite the availability of efficacious therapies,[3] many malaria patients still fail to be treated promptly and effectively. Lack of access to healthcare providers, delay in care seeking, provision of incorrect treatment regimens by healthcare providers or non-adherence to the prescribed regimen by the patient remain challenges in many settings.[4 5] In addition, substandard or counterfeit medication can result in treatment failures and the spread of drug resistance.[6]

Another threat to effective case management is overtreatment. In 2010, the WHO started promoting a 'test and treat' approach, where only patients with parasitological confirmation by malaria rapid diagnostic tests (mRDT) or microscopy are to be provided with an antimalarial in order to improve the

targeting of efficacious drugs, prevent overtreatment and mitigate the risk of antimalarial drug resistance development.[3 7 8]

Outside sub-Saharan Africa, Papua New Guinea (PNG) has the highest malaria transmission. In 2021, over 94% of malaria deaths and 87% of clinical cases reported in the WHO Western Pacific Region were attributed to PNG,[2] and a recent resurgence in malaria cases in the region was most pronounced in PNG.[2] The goal of the National Malaria Strategic Plan 2021–2025 (NMSP)[9] is to achieve a malaria-free PNG by 2030, aligned with the plans of regional malaria elimination of the Asia Pacific Leaders Malaria Alliance.[10] The NMSP includes as one key objective universal and timely malaria case management, which involves promptly diagnosing cases of malaria and providing appropriate treatment based on the National Malaria Treatment Protocol (NMTP). It requires malaria cases that were confirmed by microscopy or mRDT to be treated with artemether-lumefantrine (AL) as first-line treatment for uncomplicated *Plasmodium falciparum* malaria, AL plus primaquine as first-line treatment for uncomplicated *P. vivax* malaria, and dihydroartemisinin-piperaquine as second-line treatment.[11] The formal healthcare system in PNG follows a decentralised model, that is, based on providing primary healthcare at health centres and aid posts, while the NMCP supports community health workers in some provinces of the country.[12]

Previous studies have evaluated the readiness and performance for malaria case management in formal health facilities across PNG. Their findings indicated the need for improvements in this area to meet national malaria control objectives.[13–15] In order to have a better understanding of where to focus efforts, a systematic assessment of the continuum of care is crucial.

Effective coverage with malaria case management (ie, the use of an efficacious antimalarial regimen by all patients requiring treatment) depends on access to healthcare and on the quality of care provided by healthcare providers.[16] Cascades of care are one way of quantifying the concept of effective coverage and identifying shortfalls within real-world health systems that lead to decays in intervention effectiveness.[17] The concept of effective coverage was first described by Tanahashi in the late 70s.[18] It is based on this concept of cascade of care that describes the extent of interaction between services and their intended recipients. Conceptually, this interaction spans from resource allocation to achieving the desired outcome, encompassing key aspects of service provision. By evaluating coverage along a cascade of care, health programme managers can identify bottlenecks, analyse constraining factors, and select targeted measures for improvement in service delivery. Conceptual effectiveness cascade models exist in various versions. All versions of cascades are simplifications of the treatment-seeking process used to visualise the effectiveness decay.[17]

In this study, a case management cascade was populated primarily with primary data collected across PNG in order to identify barriers and areas for improvement in malaria case management in PNG. A better understanding of factors that affect effective case management coverage can assist stakeholders in the PNG health system in identifying targeted measures to improve case management and reduce the malaria burden in the population.

## METHODS

### Cascade of care

Estimating the effective coverage of symptomatic malaria case management relies on a collection of indicators that capture the procedural steps along the case management process. For the purpose of this study, a cascade with six procedural steps required for providing effective case management according to national guidelines was constructed. The outcome of effective treatment coverage of a symptomatic malaria case is defined as sequential completion of all steps along the cascade. For the test and treat approach, the notion of access to healthcare is an important part of the provision of effective coverage.

The conceptual starting point for quantifying the steps of the cascade is a symptomatic malaria case. The first step required for a symptomatic person to obtain effective treatment is the initiation of a treatment-seeking action. The following steps are a confirmatory diagnosis (by mRDT or microscopy) and the compliance by care providers with the recommended first-line antimalarial therapy. According to national policy, malaria diagnosis and treatment are provided for free at all public healthcare facilities. Finally, patient adherence to the treatment regimen was included as well as the efficacy of the first-line treatment. In the cascade model, each step is dependent on the completion of the previous step. The definitions, data sources and key assumptions for each cascade step are outlined in table 1. Where fever patients were used as denominators for calculating the proportion seeking treatment or obtaining a confirmatory diagnosis, it was assumed that compliance with the step was independent of whether a fever was due to malaria or not.

### Data sources

Data from national surveys conducted by the PNG Institute of Medical Research was used to quantify the steps in the cascade of care. First, data from Malaria Indicators Surveys (MIS) was used to estimate the proportion of household members reporting a febrile illness who sought care in a formal health facility. Data from MISs conducted in 2013/2014, 2016/2017 and 2019/2020 was pooled. The MISs were conducted across all 22 provinces of PNG, with a random sample of approximately five villages per province. Within each village, up to 30 households were randomly sampled. The methodology is described in detail elsewhere.[19] All household members who reported a febrile illness in the 14 days prior to the survey were eligible for an interview on treatment seeking.

Second, data from national Health Facility Surveys (HFS) were used to estimate the availability and quality

**Table 1** Case management cascade steps

| Cascade step | Definition | Data source | Core assumptions and conditions |
|---|---|---|---|
| Symptomatic malaria case | Patient with fever in the last 2 weeks. A proxy for a symptomatic malaria case in subsequent steps. | MIS | Excluding patients whose symptoms start on the day of the survey, as the time is too short for most treatment-seeking actions to be initiated. |
| Treatment seeking | Proportion of symptomatic malaria cases who sought care in formal health facilities (ie, hospital, health centre, aid post). | MIS | Patients with malaria and a non-malarial fever are equally likely to seek treatment. |
| Confirmatory diagnosis | Proportion of fever cases that were diagnosed with mRDT or microscopy. | HFS | Patients with malaria and a non-malarial fever are equally likely to be offered a confirmatory diagnosis. |
| Provider compliance | Proportion of test-confirmed malaria cases that receive first-line antimalarial therapy (AL). | HFS | Provider compliance according to the NMTP[9]; first line antimalarial is AL. Dosage assumed to be correct according to the patients age/weight. |
| Patient adherence | Patient adherence to the treatment provided by the health worker. | Literature | MIS and HFS do not provide this information. Patient adherence to the AL treatment has been assumed based on a systematic review and meta-analysis.[23] |
| Treatment efficacy | Adequate clinical and parasitological response where the treatment is completed successfully with no confirmed re-infection on day 28.[50] | Literature | Based on the published therapeutic efficacy study conducted in PNG.[24] Efficacy is assumed to have remained unchanged. |
| Effective treatment coverage | Proportion of symptomatic malaria cases covered with effective treatment based on sequential completion of all cascade steps. | | Effective treatment coverage requires sequential completion of the cascade; alternative pathways are not considered. |

AL, artemether-lumefantrin; HFS, Health Facility Survey; MIS, Malaria Indicator Survey; NMTP, National Malaria Treatment Protocol; PNG, Papua New Guinea.

of malaria treatment services in randomly sampled formal primary healthcare facilities (health centres and aid posts), as described elsewhere.[15] Data from HFSs conducted in 2014, 2016 and 2021 was pooled. These surveys covered health facilities in all 22 provinces of PNG. The number of patients surveyed by region and health facility type is available in online supplemental appendix 1 for each survey.

Survey data from different years were combined in order to obtain a larger sample size. In order to analyse the management of malaria cases according to the current NMTP, only data from surveys after the nationwide roll-out of a 'test and treat' policy according to WHO guidelines in 2011 was considered.

### Statistical analysis

Each step of the cascade was quantified with a binary variable. For each step, we estimated the proportion using data from HFS and MIS, with 95% CIs. For the effective treatment coverage from all of the steps combined, we estimated the CI using simulation: 1000 random samples were drawn from the normal distributions of the proportion of each individual step, the sampled values for each step were multiplied, and the 2.5th and 97.5th percentiles of the products were extracted. This method assumes no covariance between steps, which is a limitation.

A multivariable logistic regression analysis was used to investigate factors associated with treatment seeking and confirmatory diagnosis. These cascade steps were the largest bottlenecks to effective case management based on primary survey data. Random effects were included to account for clustering resulting from the study design (patient's village of residence for the treatment-seeking model, and health facility attended for the confirmatory diagnosis model). Covariates were selected based on

plausibility and prior knowledge, drawing on a publication of data from 24 malaria endemic countries that reported household wealth, caregiver education and household location or access to health facilities as factors associated with care-seeking.[20] To investigate differences between socioeconomic strata in the treatment-seeking behaviour, a principal component analysis method was used to build a wealth index and wealth quintiles based on MIS data as per previous analyses of PNG MIS data.[21] Parameters used for the construction of the wealth index and the components selection as well as a matrix illustrating their correlation are provided in online supplemental appendices 2 and 3, respectively. The travel time from a patient's residential place to the nearest health facility was extracted from a friction map from the work of Seidahmed *et al*,[22] and divided into quartiles. Symptoms of severe febrile illness were defined as the presence of at least one of the following self-reported danger signs: difficulties breathing, loss of consciousness, convulsions or fits.

Finally, the association between compliance of HF staff with the NMTP and (1) the number of staff trained in the NMTP present at the health facility at the time of the survey and (2) availability of printed resources (posters or wallcharts) was investigated. The survey year was included in the regression model. An indicator for whether staff had been trained in 2021 was introduced into the model to take into account that ahead of the 2021 HFS, training on the NMTP had mostly been on-the-job during supportive supervision as opposed to formal classroom training conducted ahead of prior HFS.

### Patient and public involvement

This study is based on research questions emerging from discussions with the PNG NMCP. Secondary data analysis was performed using survey data based on standard methodologies. As such, patients and the public were not directly involved in the co-production of this research.

## RESULTS

The pooled MIS sample included 945 individuals who self-reported recent febrile illness episodes. The pooled HFS sample included 1581 patients with a febrile illness. After exclusion of observations with missing data, the numbers of observations used in the regression models were 938 and 1573, respectively. The distribution of the samples by survey and cascade step is provided in online supplemental appendix 4.

### Malaria cases management cascade

Initial treatment seeking from a formal healthcare provider was identified as the major bottleneck to effective coverage with malaria treatment (figure 1A). Only 40% (95% CI: 37% to 46%) of survey participants with febrile illness symptoms indicative of malaria sought care in a health facility. While regional differences were apparent

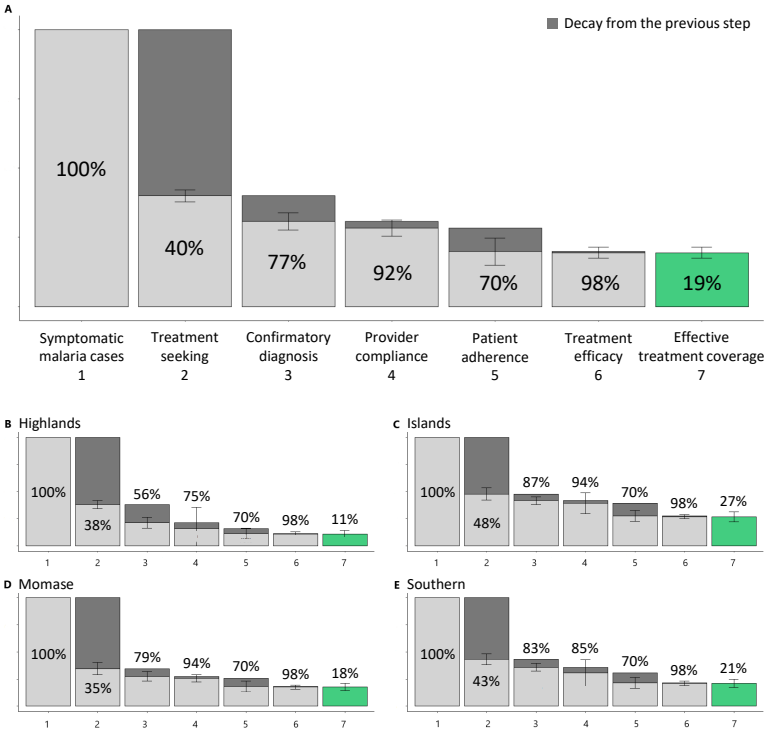


**Figure 1** Malaria cases management cascade in PNG: percentage of infections for each step. The bar heights illustrate the decay along the case management cascade applying the proportion of individuals complying with each cascade step (percentage values in the bars, light grey shading) to a total of 100 symptomatic malaria patients (100%). Error bars represent 95% confidence intervals.

(figure 1B–E), this initial step led to the most notable decay in effective coverage everywhere. For those seeking treatment at a health facility, the compliance subsequent steps in the case management cascade was relatively high. First, 77% (95% CI: 68% to 80%) of patients with a fever and suspected to have malaria who attended a health facility had a confirmatory diagnosis (mRDT or microscopy), and of those tested positive, 92% (95% CI: 83% to 94%) were provided with the first-line antimalarial AL. Factoring in patient adherence with the full 3-day treatment regimen and treatment efficacy based on available literature,[23 24] the estimated proportion of symptomatic malaria cases in the community covered with effective antimalarial treatment was 19% (95% CI: 15% to 23%).

### Factors associated with seeking treatment

Determinants of treatment seeking were estimated for 938 individuals, excluding 7 observations without data for age (table 2).

Although there were differences in treatment seeking between the investigated risk factors, after adjusting for the effect of other covariates, none of the risk factors was found to be a statistically significant predictor of treatment seeking (table 2). There was no evidence of a statistically significant association between treatment-seeking and travel time to the nearest health facility, region or sex. The only significant difference was found between survey participants >15 years of age who had a lower odds of seeking treatment than children <5 years of age (adjusted OR (aOR)=0.64, 95% CI: 0.43 to 0.97). We identified a collinearity between travel time to the nearest health facility and wealth quintile. A heat map showcasing this correlation is available in online supplemental appendix 5. Due to the more difficult interpretation of socioeconomic status, only the travel time to the nearest health facility was retained in the multivariable model.

### Factors associated with confirmatory diagnosis among patients with an acute febrile illness attending a health facility

We excluded patients diagnosed by light microscopy from this analysis due to the inconsistent availability of functional microscopy across PNG.[15] Of the 1573 patients attending health centres or aid posts, 1211 (77%) had a confirmatory mRDT performed (table 3). Confirmatory

**Table 2** Estimated associations between potential risk factors and treatment seeking

| Variables | Categories | N | Per cent seeking treatment | aOR | 95% CI | P value* |
|---|---|---|---|---|---|---|
| Odds of treatment seeking in the reference group† | | | 0.90 | 0.42 to 1.92 | 0.79 | |
| Survey year | 2013/2014 | 385 | 43 | Ref | | 0.17 |
| | 2016/2017 | 264 | 39 | 0.65 | 0.36 to 1.16 | |
| | 2019/2020 | 289 | 36 | 0.64 | 0.38 to 1.10 | |
| Region | Highlands | 204 | 38 | Ref | | 0.31 |
| | Islands | 152 | 48 | 1.60 | 0.80 to 3.20 | |
| | Momase | 345 | 34 | 0.90 | 0.47 to 1.70 | |
| | Southern | 237 | 43 | 1.32 | 0.69 to 2.53 | |
| Age (years) | <5 | 205 | 47 | Ref | | 0.09 |
| | 5–15 | 323 | 38 | 0.81 | 0.53 to 1.24 | |
| | >15 | 410 | 37 | 0.64 | 0.43 to 0.97 | |
| Travel time to the nearest health facility (quartiles) | Shortest | 233 | 43 | Ref | | 0.43 |
| | 2 | 236 | 43 | 1.30 | 0.69 to 2.42 | |
| | 3 | 239 | 34 | 0.78 | 0.41 to 1.51 | |
| | Longest | 230 | 39 | 1.16 | 0.57 to 2.33 | |
| Illness severity | Not severe | 904 | 39 | Ref | | 0.40 |
| | Severe | 34 | 56 | 1.44 | 0.61 to 3.45 | |
| Sex | Male | 469 | 41 | Ref | | 0.92 |
| | Female | 469 | 38 | 1.01 | 0.75 to 1.38 | |
| Total | | 938 | 40 | | | |

*P values for variables with more than two categories were obtained with a likelihood test ratio.
†The reference group refers to participants with non-severe symptoms, <5 years, male, wealth quintile 1, Highlands, 2013/2014 survey year, travel time category 1.
aOR, adjusted OR.

Table 3 Estimated associations between potential risk factors and receiving a confirmatory diagnosis

| Variables | Categories | N | Percentage of confirmatory diagnosis | aOR | 95% CI | P value * |
|---|---|---|---|---|---|---|
| Odds of confirmatory diagnosis in the reference group† | | | | 1.06 | 0.11 to 10.43 | |
| Survey year | 2014 | 443 | 76 | Ref | | 0.16 |
| | 2016 | 585 | 71 | 0.58 | 0.17 to 1.94 | |
| | 2021 | 554 | 84 | 2.13 | 0.34 to 13.48 | |
| Region | Highlands | 256 | 52 | Ref | | < 0.01 |
| | Islands | 391 | 85 | 10.75 | 2.79 to 41.34 | |
| | Momase | 602 | 79 | 4.87 | 1.53 to 15.50 | |
| | Southern | 324 | 81 | 5.19 | 1.47 to 18.29 | |
| Health facility category | Health centre | 834 | 75 | Ref | | 0.93 |
| | Sub-health centre | 381 | 77 | 0.87 | 0.29 to 2.55 | |
| | Urban clinic | 328 | 82 | 1.11 | 0.33 to 3.68 | |
| | Aid post | 30 | 63 | 2.05 | 0.07 to 4.25 | |
| Printed resources | No | 217 | 74 | Ref | | 0.99 |
| | Yes | 1356 | 77 | 1.01 | 0.21 to 4.73 | |
| Trained staff present | No | 586 | 81 | Ref | | 0.98 |
| | Yes | 987 | 74 | 0.98 | 0.25 to 3.87 | |
| Staff trained in 2021 | No | 1363 | 76 | Ref | | 0.87 |
| | Yes | 210 | 80 | 0.85 | 0.12 to 6.04 | |
| Age of patient (years) | <5 | 348 | 69 | Ref | | < 0.01 |
| | 5–15 | 417 | 81 | 1.62 | 1.08 to 2.42 | |
| | >15 | 708 | 79 | 1.69 | 1.19 to 2.42 | |
| Total | | 1573 | 77 | | | |

*P values for variables with more than two categories were obtained with a likelihood test ratio.
†The reference group refers to the 2014 Health Facility Surveys, Highlands region, health centre, absence of printed resources, absence of trained staff, staff not trained in 2021, under 5 years of age.

diagnosis by mRDT was lowest in patients under 5 years of age (69%) and patients from the Highlands region (52%).

Patients aged between 5 and 15 and over 15 years were more likely to be tested by mRDT than patients in the youngest age group (aOR 1.62 (1.08 to 2.42) and 1.69 (1.19 to 2.42), respectively). Patients in the Highlands region were less likely to have an mRDT than those in other regions. There was a tendency for more patients to be tested in the last survey round, though this was not statistically significant.

There was no evidence of an association between health facility category, presence of trained staff or access to printed resources and receiving a confirmatory diagnosis.

## DISCUSSION

The timely administration of a curative dose of an efficacious antimalarial medicine is essential to reduce malaria morbidity and mortality, and a pre-requisite to eventually achieving malaria elimination. While findings of reduced efficacy of antimalarial drugs receive increasing attention[25–27] and antimalarials achieving less than 90% cure rates are recommended by WHO to be replaced,[28] less attention seems to be paid to the fact that access barriers continue to prevent many patients from being appropriately treated.[4 5]

This study provides estimates of the coverage of effective case management for symptomatic malaria patients according to guidelines of the PNG Department of Health. Our findings indicate that in PNG, low frequency of seeking treatment for febrile illness episodes is the primary obstacle to achieving effective malaria case management through the formal health sector. Only 40% (95% CI: 37% to 46%) of individuals with a febrile illness indicative of malaria sought care in a formal health facility. Aggravated by shortfalls in subsequent steps along the continuum of care, this study estimated that overall, only 19% (95% CI: 15% to 23%) of symptomatic malaria cases across PNG are effectively treated at a formal health facility. This value lies in the range of estimates from sub-Saharan African countries which span from less than 1% in Chad and South Sudan to 60% in Botswana.[4]

Treatment seeking is influenced by different factors including the various dimensions of access to healthcare,[16 29] sociocultural factors, the perceptions of illness severity and treatment.[30–33] In this study, however, none of the variables included to represent these factors reached statistical significance. This can be due to non-identified confounders. Nevertheless, among respondents in the surveys included in this analysis, the most frequently cited reasons for not seeking care included a perception that the illness was not serious, that the patients got better or they would wait for the condition to get more serious before attending a health facility, and a long distance to the nearest health facility often in combination with a lack of money for transport or medication.[34] An analysis of data from household surveys in malaria endemic countries found that education level, government health expenditure and Gross Domestic Product growth were important predictors for treatment-seeking.[20] Children from households with the highest socioeconomic status were less likely to be delayed in seeking care than those from households with the lowest socioeconomic status.[35] Previous studies have shown a decrease in accessing treatment with increasing distance to a health facility in malaria endemic countries.[36–38] A recent geospatial analysis found that access to health facilities is a challenge in many rural parts of PNG. While populations in the National Capital District, East New Britain, New Ireland and Bougainville have easy access to health facilities, >30% of the population living in Gulf, Western, Madang, East Sepik and Sandaun provinces have a travel time to the nearest health facility exceeding 2 hours.[22] A prior survey in PNG[39] suggested that, besides the distance, cultural factors and prior episodes of malaria were also important predictors of treatment-seeking to consider. A limitation of our analysis was that the functionality or patient's perception of the nearest health facility could not be considered in the analysis alongside the travel time to the facility. Overall, a low proportion of people seeking treatment may suggest suboptimal resource allocation and utilisation, and reflect the population's perception regarding the severity of the illness or the overall quality of malaria care.[4]

Symptomatic cases from the Highlands region were less likely to receive a malaria test in comparison with cases from other regions, contributing significantly to the decay in overall treatment coverage. Young children were least likely to be tested by mRDT, which was surprising given the national guideline's emphasis on appropriate case management among this most vulnerable group. There was no evidence of an association between the presence of staff trained in the current NMTP and compliance with confirmatory diagnosis. The finding needs to be interpreted with caution as formal 'classroom' training sessions were organised immediately before and a few years after the initial roll-out of mRDTs and Artemisinin-based Combination Therapy (ACT) in 2012. In recent years, that is, in years preceding the 2021 HFS, 'on-the-job' training on the NMTP was provided to health workers by Provincial Malaria Supervisors or Regional Malaria Coordinators during supportive supervision visits. These visits were likely not recorded as 'training' in the HFS, as reflected in the significant decline in healthcare providers reporting attendance of formal training in the current NMTP between the 2011 HFS (84%) and the 2021 HFS (25%). It appeared in the descriptive results of the last HFS that very few staff had undergone 'training' but this is most probably because they did not report the 'on-the-job' training as formal training.[40] The type of health facility attended was also not statistically significantly associated with testing compliance; however, the number of patients who attended aid posts was low, the percentage tested in aid posts was lower and previous surveys found aid posts to be more frequently out of mRDT stock than health centres—even though this situation had improved in recent years.[13] As patients attending facilities without mRDT in stock were excluded from this analysis, the finding regarding the relevance of the health facility type for compliance with diagnostic testing procedures should be interpreted with caution.

The compliance of health workers with case management guidelines, particularly the test and treat protocol, would benefit from further enhancement in PNG. To foster even better compliance, emphasis should be placed on ensuring consistent and adequate supply of commodities and implementing regular supportive supervision, as is currently carried out through the programme. Additionally, other initiatives contributing to sustained compliance, such as comprehensive training modules integrated into routine health worker trainings, could be considered.

The lower rates of testing in children under 5 years old raise concerns. It is imperative to ensure appropriate treatment for this vulnerable demographic group, either with an antimalarial if a malaria infection is confirmed, or with alternative treatment, as appropriate, if the test results are negative. Notably, health workers in PNG can rely on the accuracy of mRDTs, as these are routinely quality checked through procedures facilitated by WHO (personal communication, Dr Rashid, WHO PNG) and withholding antimalarials from mRDT-negative children was shown to be safe.[41] Thus, maintaining the quality assurance of diagnostic tools and reinforcing training programmes should contribute to sustaining the effectiveness of the test and treat protocol. A previous analysis of HFS data found that improving compliance with a strictly test-based administration of antimalarial drugs may in fact delay treatment-seeking if treatment of malaria test-negative patients is not addressed. Patients may perceive treatment quality as poor if non-malarial febrile illness cases do not receive equivalent care as malaria-positive patients.[42]

Our analysis is a simplification of the complexities underlying malaria treatment effectiveness. Limitations of the analyses include the definition of the cascade steps—which was based on earlier publications but may

not capture all relevant aspects of effective coverage—and the data that was available to quantify these steps. For the treatment adherence step, we had to refer to a meta-analysis carried out on data from other endemic countries,[23] because no local data was available. However, in the cascade, the impact of the adherence factor on overall effective coverage is comparably small. Furthermore, with the cascade approach, all steps are quantified independently, while in real life they are inter-related and there may be different pathways leading to effective treatment.[43] The cross-sectional surveys are only snapshots, though the pooling of several surveys should have provided more reliable estimates. Self-reported data may be subject to recall and social desirability biases. Further in-depth investigations may help to corroborate the study's findings. In both MIS and HFS, there are still limited data to quantify the quality of malaria care along a treatment cascade. Indeed, malaria surveys still do not comprehensively capture several relevant aspects, such as information about patient adherence to the treatment, especially for *P. vivax* infections that require a 14-day primaquine regimen in addition to an ACT. The analysis of provider compliance only included ACT and did not consider the underlying malaria species. Furthermore, it is crucial to acknowledge that the efficacy of treatments is established based on therapeutic efficacy studies employing quality-assured medicines.[24] However, there is no guarantee that all medicines used in practice are quality assured. Historical instances of substandard antimalarials being identified in the public health facility supply chain in PNG underscore the need for continued vigilance in ensuring medication quality.[44]

Recent findings have suggested that artemisinin resistance markers have emerged in PNG, raising concerns about treatment efficacy of the first-line antimalarial treatment.[24 45] There is no doubt that close monitoring of treatment efficacy is warranted. Yet, based on the findings from this study, the real current obstacles to effectively treating malaria patients are health system factors, first and foremost treatment seeking and performing a diagnostic test. An initiative to upgrade health facilities and provide village-level primary healthcare services through community health workers may improve access and increase treatment seeking as long as these healthcare providers are adequately supplied, well supported and incentivised. Providing additional training and support to health workers could improve their knowledge and skills related to the test and treat protocol and address additional barriers to health worker compliance, such as a lack of confidence in mRDT results and a lack of time to provide adequate counselling to patients.[14 36 46–49] From a patient perspective, our study highlights the need for promoting treatment-seeking from a healthcare provider after the recognition of the first symptoms, which presupposes the availability of a functional provider. A better understanding of the reasons underlying low treatment-seeking is essential in this context. For this purpose, qualitative studies might be required.

In conclusion, effective malaria case management in PNG is influenced by a range of factors at different levels of the health system. Addressing the determinants of effective malaria treatment coverage identified in this study along the cascade of care is essential to reduce morbidity and mortality from malaria and to progress towards the goal of malaria elimination in PNG.

**Author affiliations**
[1]Swiss Tropical and Public Health Institute, Allschwil, Switzerland
[2]University of Basel, Basel, Switzerland
[3]Papua New Guinea Institute of Medical Research, Goroka, Papua New Guinea
[4]National Department of Health, Port Moresby, Papua New Guinea

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**ORCID iDs**
Vincent Minconetti http://orcid.org/0009-0000-5380-4545
Manuel W Hetzel http://orcid.org/0000-0002-5285-3254

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