Mapping routine malaria incidence at village level for targeted control in Papua New Guinea

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Acknowledgements: The authors would like to thank all patients and communities who agreed to participate in this study. We are grateful to the study nurses who collected data and samples at the sentinel health facilities (Mrs. Naeobo Oren in East Cape, Mr. Paul Basanu in Karimui, Ms. Rhona Sao in Sausi, and Mrs. Lia Pitan in Lemakot), and to the authorities and organizations hosting them. We thank the PNGIMR census field teams, the data managers and data entry staff and acknowledge the support of the National Department of Health through Mr. Leo Makita and his team. We thank Mr. Andreas Weber and Point de Vue for their support and enthusiasm. Their collaboration made the audio-visualization of this paper possible.

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Field Code Changed

Key words: Surveillance, malaria, Papua New Guinea, malaria control, surveillance-response

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Contributions: MWH, JP, IM, LM and PMS conceived of the study. SM, SJM, AT, MWH and JP established and supervised data collection systems and LM facilitated access to the study sites. DRR analysed the data and drafted the manuscript and video concept with inputs from MWH. All authors reviewed and approved the final manuscript and video.

Conflict of interests: The authors declare no conflict of interest.

Funding: Funding for data collection was provided through a Global Fund to Fight AIDS, Tuberculosis and Malaria grant to PNG. DRR was supported by the Forlen Stiftung, Basel, and the R. Geigy Foundation, Basel, Switzerland.

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Video link: https://vimeo.com/327777871; password: 12345Qwert

Abstract

Malaria surveillance and response-systems are essential for identifying the areas most affected by malaria and for targeting resources. This study aimed to assess whether the visualization of routinely collected health facility data linked to village of residence provides ~~useful~~ evidence for targeting control interventions in four sentinel ~~-~~health~~-~~ facilities (SHF) in Papua New Guinea. During the surveillance period a total of 8,173 fever cases ~~within~~from the SHFs catchment areas tested positive for malaria and were mapped by village of residence ~~within the SHFs catchment area~~. Despite limitations, this approach appeared useful in sites with very few remaining cases or with increasingly marked heterogeneity. Villages that could benefit from targeted interventions or investigations were identified.

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Background Section

Variation in the risk of malaria prevalence and incidence between villages in regions with on-going transmission has long been recognized (Bousema et al., 2012; Greenwood, 1989). Such variations become more evident in regions with moderate and low transmission, e.g. after scale-up of malaria control (Bousema et al., 2012). Malaria control efforts in Papua New Guinea (PNG) were re- intensified in 2004. Differences in malaria burden, transmission, and impact of interventions have subsequently been identified even between neighbouring villages (Hetzel et al., 2016, 2014), confirming earlier findings of small-area heterogeneity(Cattani et al., 1986). An analysis of routine health-facility data from seven sentinel sites found that reductions in malaria incidence were associated with LLIN distributions but the effect varied between sites (Rodríguez-Rodríguez et al., 2019). As malaria transmission decreases, and resources remain

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Malaria surveillance and response-systems are essential for identifying the areas or population groups that are most affected by malaria and for targeting resources for maximum impact (World Health Organization, 2018). The Global Technical Strategy for Malaria 2016-2030 proposes the use of a comprehensive approach that includes vector control measures and early diagnosis and treatment, especially at the village level (World Health Organization, 2018, 2015). Identifying villages with on-going transmission and monitoring changes over time is therefore of utmost importance to effectively target interventions. Particularly in settings with weak health systems this information should be generated by simple approaches. Routine data collected at health facilities may provide a viable option if the relevant information is captured and readily analysed. However, research on how to best apply geospatial analyses of simple routine data to identify heterogeneity at village level and support targeting malaria interventions is scarce (Kelly et al., 2012).

This study aimed to assess whether the visualizations of health facility data linked to village of residence of patients provides ~~useful~~ evidence for targeting malaria control interventions. It used malaria incidence data linked to the self-reported village of residence of the patients, collected routinely in four sentinel health facilities (SHF) in PNG. If found to be a valid approach, the operational feasibility of targeting malaria control at district or sub-district level would have to be investigated within the frame of existing capacities and resources of the local health system.

Sentinel surveillance was established in the health centres of East Cape (Southern Region), Sausi (Momase), Karimui (Highland) and Lemakot (Islands) – one SHF per geographical region of PNG. Surveillance was established as part of the continuous independent evaluation of the National Malaria Control Program (NMCP) (Hetzel et al., 2015, 2014, 2012). Details of the sites are provided elsewhere (Hetzel et al., 2014; Rodríguez-Rodríguez et al., 2019).

All outpatient cases attending the SHF were routinely screened for a history of fever during the previous three days. A study nurse at the facility collected a capillary blood sample from all consenting fever patients for ~~1)~~ diagnosis of malaria by Rapid Diagnostic Test (RDT). Demographic details including village of residence and self-reported mosquito-net use the previous night were recorded on paper case report forms alongside RDT results. Paper forms were then double entered at the PNGIMR. The study team ensured availability of RDTs throughout the surveillance period.

Data was collected from 2010 to 2014 to characterize annual incidence variations between villages in the catchment areas of the SHFs and identify patterns that could guide malaria control efforts. Recently, a paper-based "Malaria Register" has been implemented by the PNG National Department of Health ~~. In addition,~~ and an electronic National Health Information System (eNHIS) is being piloted (Rosewell et al., 2017). The register and eNHIS routinely collects ~~the same~~ malaria indicators ~~variables~~ linked to the village of residence of the patient, which is comparable to ~~used for~~ this analysis, allowing the scale-up of ~~this~~ the ~~method~~ approach if it proves useful.

The ~~size and population~~ delineation of the SHF catchment areas ~~were as~~ was defined by local health authorities ~~and differed between sites~~. A population census conducted by

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Commented [A8]: Introduce abbreviation the PNGIMR in the SHF catchment areas at baseline, during which all houses were identified and each household member was listed, was used as source of village coordinates and population denominator data. The geo-referenced year 2000 National Census database was used to complement the PNGIMR census, particularly to identify villages outside the catchment area. During the surveillance period 25,097 fever cases were tested for malaria across all SHF, 38% (95% CI: 37.6-38.8) were RDT-positive. Table 1 details the number of malaria cases diagnosed at the SHF residing within and outside the SHF catchment area. The analysis includes only the cases within the catchment area. It is important to note that a large number of patients from outside the catchment area were diagnosed and treated in East Cape and Lemakot SHFs. Both HCs are located in areas of constant transit of people.

[Table 1 here]

The maps in this visualization illustrate variations in incidence in space and time. ~~using open source GIS software~~. The video format ~~of the v-communication enabled~~allowed us to visualize the dynamics ~~display over 40 maps in a convenient and~~ in case incidence over time ~~engaging way~~ alongside ~~together with images~~photographs~~-~~ illustrating the context of the data collection ~~that provide insights to of~~in the study sites. ~~and the, often unknown, geographical and cultural diversity of PNG. In addition, t~~The audio-visual format is easily accessible to a ~~great~~ range of stake~~-~~holders ~~and~~ with the potential to ~~could potentially~~ better communicate ~~complex~~ geospatial relationships in an understandable format (Krieger et al., 2012).

Aggregated annual malaria incidence was calculated for every village with at least one malaria case reported by the SHFs. Annual incidence in children under five years of age

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Commented [A11]: Suggesting to move this sentence to after the next one. You may also slightly re-frame the sentence in order to highlight that this is a key aspect of your visualisation was calculated and mapped as a proxy of local transmission since young children are the least immune age group and compared to adults are less likely to travel (Bousema et al., 2012). A census conducted by the PNGIMR in the SHF catchment areas at baseline was used as source of village coordinates and population denominator data. The geo-referenced year 2000 National Census database was used to complement the PNGIMR census, particularly for villages outside the catchment area. Self-reported mosquito-net use by all fever patients during the last year of surveillance (2014) was mapped by village and reported net use by all fever cases was graphed by year as an indicator of trends over time.

Following a general declining trend, clear differences in incidence between villages were found in some sites. Mapping of village-level incidence appeared most useful in settings with very few malaria cases (Karimui and Sausi) or with pronounced spatial clustering of cases (Lemakot). In such settings, villages that could benefit from targeted interventions could be identified. However, further investigations in some of the identified local foci are required to understand local heterogeneity. Unequal access to health facilities, availability of other health care providers and treatment seeking behaviour may confound village-level incidence particularly if data is only originating from one facility. In addition, in some communities, village, hamlet and ward names may be used inconsistently by both patients and health workers. It is possible that cases in small communities are attributed to larger nearby villages. Furthermore, case-reporting becomes inaccurate in areas with constant transit of people. Uniform surveillance across all health facilities and a harmonized use of village names could optimize the current approach. Villages have been used as operational units for household-level net distributions in PNG. Villages may also be the smallest feasible unit to target interventions making village level data highly relevant.

Since effective management of malaria programmes requires geo-spatial components to inform response-systems a next step could devise a simple standardized approach to generate spatial data on malaria risk that can be easily translated into response action can complement universal coverage campaigns in a meaningful way. Since 2015, eNHIS has been piloted in 184 health facilities in PNG. The platform includes a geo-referenc~~ed~~ing feature for mapping malaria cases ~~in~~at a village level and automated data analysis, reporting and identification of outbreaks (Rosewell et al., 2017). If proven successful eNHIS could considerably strengthen malaria surveillance in PNG. A similar Spatial Decision Support System building upon and extending existing data collection systems and exploiting current geo-spatial tools has been validated in nearby Vanuatu and Solomon Islands in areas of very low transmission (Kelly et al., 2012). Areas in PNG that have reached a low level of transmission with clear foci may benefit from a similar approach. However, local (sub-national) capacity to further investigate local foci and implement targeted response action would be required as much as sufficient and sustained funding for these activities.

"Outlook"

- Age-specific malaria data collected routinely at health facilities and linked to the village of residence of patients may direct programmes to local foci of transmission.
- This approach appears most useful in settings with few cases or marked heterogeneity, where it may direct further investigations or (complementary) interventions.

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- A Malaria Register introduced in health facilities in PNG and the eNHIS currently piloted in selected provinces that record~~s~~ the village of residence of ~~test-confirmed~~ malaria cases ~~is~~ are ~~an~~ opportunit~~y~~ies to validate this approach at larger scale.
- A simple tool for calculating and mapping malaria case incidence at district or sub-district level, as is currently included in the eNHIS, is required to operationalize the approach, along with the capacity, policies, and mechanisms required to implement targeted response action at the respective operational level.

Box 1 ~~o~~Overall aim

To asses weather the ~~simple~~ visualization of health information (malaria incidence, net use and residence of patients) extracted from a routinely implemented surveillance system can inform local malaria control programs to better target interventions.

Malaria surveillance systems are crucial for identifying the areas that are most affected by malaria. The proposed approach adds a geospatial component to health facility data in order to understand differences in malaria burden between villages and identify communities that would benefit from targeted interventions.

Box 2 Software used

Maps were generated using the open-source software QGIS (version 3.0 Girona). The video was edited using Adobe Premier Pro CC (version 13.0.2, Adobe Systems Incorporated, San Jose, CA, USA)

References

Bousema, T., Griffin, J.T., Sauerwein, R.W., Smith, D.L., Churcher, T.S., Takken, W., Ghani, A., Drakeley, C., Gosling, R., 2012. Hitting hotspots: Spatial targeting of malaria for control and elimination. PLoS Medicine 9, 1–7.

Cattani, J.A., Moir, J.S., Gibson, F.D., Ginny, M., Paino, J., Davidson, W., Alpers, M.P., 1986. Small-Area Variations in the Epidemiology of Malaria in Madang Province. PNG Med J 29, 11–17.

Greenwood, B.M., 1989. The microepidemiology of malaria and its importance to malaria control. Trans R Soc Trop Med Hyg 83, 25–29.

Hetzel, M.W., Gideon, G., Lote, N., Makita, L., Siba, P.M., Mueller, I., 2012. Ownership and usage of mosquito nets after four years of large-scale free distribution in Papua New Guinea. Malar J 11, 192.

Hetzel, M.W., Morris, H., Tarongka, N., Barnadas, C., Pulford, J., Makita, L., Siba, P.M., Mueller, I., 2015. Prevalence of malaria across Papua New Guinea after initial roll-out of insecticide-treated mosquito nets. Trop Med Int Health 20, 1745–1755.

Hetzel, M.W., Pulford, J., Maraga, S., Barnadas, C., Reimer, L.J., Tavul, L., Jamea-Maiasa, S., Tandrapah, T., Maalsen, A., Makita, L., Siba, P.M., Mueller, I., 2014. Evaluation of the Global Fund-supported National Malaria Control Program in Papua New Guinea, 2009-2014. PNG Med J 57, 7–29.

Hetzel, M.W., Reimer, L.J., Gideon, G., Koimbu, G., Barnadas, C., Makita, L., Siba, P.M., Mueller, I., 2016. Changes in malaria burden and transmission in sentinel sites after the roll-out of long-lasting insecticidal nets in Papua New Guinea. Parasites and Vectors 9, 340.

Kelly, G.C., Tanner, M., Vallely, A., Clements, A.C.A., 2012. Malaria elimination: Moving forward with spatial decision support systems. Trends Parasitol 28, 297–304.

Krieger, G.R., Bouchard, M.A., de Sa, I.M., Paris, I., Balge, Z., Williams, D., Singer, B.H., Winkler, M.S., Utzinger, J., 2012. Enhancing impact: Visualization of an integrated impact assessment strategy. Geospatial Health 6, 303–306.

Mendis, K., Rietveld, A., Warsame, M., Bosman, A., Greenwood, B.M., Wernsdorfer, W.H., 2009. From malaria control to eradication: The WHO perspective. Trop Med Int Health 14, 802–809.

Rodríguez-Rodríguez, D., Marga, S., Lorry, L., Robinson, L.J., Siba, P.M., Mueller, I., Pulford, J., Ross, A., Hetzel, M.W., 2019. (Submitted) Repeated mosquito net distributions, improved treatment, and trends in malaria cases in sentinel health facilities in Papua New Guinea. Malar J.

Rosewell, A., Makita, L., Muscatello, D., John, L.N., Bieb, S., Hutton, R., Ramamurthy, S., Shearman, P., 2017. Health information system strengthening and malaria elimination in Papua New Guinea. Malaria Journal 16, 1–10.

World Health Organization, 2018. World Malaria Report 2018. Geneva.

World Health Organization, 2015. Global Technical Strategy for Malaria 2016-2030. Geneva.

Table

Table 1 Total n~~N~~umber of malaria cases (all ages) and malaria cases in children under five years of age residing within and outside the catchment area

	Malaria cases residing in the catchment area	Malaria cases residing outside the catchment area	
Site	N (%)	N (%)	Total N (%)
East Cape			
Total cases (all ages)	3,265 (93)	250 (7)	3,515 (100)
Cases in c~~C~~hildren <5 years	1,076 (93)	82 (7)	1,158 (100)
Sausi			
Total	1,532 (99)	13 (1)	1,545 (100)
Children <5 years	305 (98)	6 (2)	311 (100)
Karimui			
Total	545 (99)	8 (1)	553 (100)
Children <5 years	260 (98)	5 (2)	265 (100)
Lemakot			
Total	2,831 (71)	1,142 (29)	3,973 (100)
Children <5 years	818 (73)	299 (27)	1,117 (100)
Total cases	**8,173 (85)**	**1,413 (15)**	**9,586 (100)**

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Total cases in children <5 years	**2,459 (86)**	**392 (14)**	**2,851 (100)**

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