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ABSTRACT

Background: Given the central role of the health information system in epidemiological monitoring, and in light of the heavy disease burden that malaria represents in Burundi, this study evaluated the facilitating factors and systemic constraints influencing the quality of the reporting system within the National Health Information System for malaria for the period 2014-2023.

Methods: A mixed-methods study was conducted in four health districts in Burundi focusing on the Health Information Management System (GESIS - *Gestion du Système d'Information Sanitaire)* until 2016 and the District Health Information Software version 2 (DHIS2) between 2016 and 2023. A quantitative component assessed the timeliness, completeness, and representativeness of malaria cases reported through the surveillance system relative to prevalence survey data, logistical stability of human resources and catchment areas of health centers across each district. A qualitative component, based on two individual interviews and nine focus group discussions with DHIS2 system users, explored factors related to the stability, acceptability, and representativeness of the system.

Results: Reporting deadlines and data completeness rates have been met since January 2020 for over 95% of community and health facility reports in the DHIS2 database, reflecting satisfactory data completeness and timeliness. However, representativeness remains partial, as malaria cases recorded are limited to patients who sought care at health facilities. Limitations in terms of acceptability were identified at the first level of the health pyramid, particularly amongst community health workers and health centres. The data entry process is burdensome owing to unstable internet connectivity, insufficient paramedical staff in the

public sector, and an excessive workload. Conversely, data analysis and interpretation of DHIS2 data are carried out at the level of health district and provincial health offices. The case definition has remained stable between 2017 and 2023, ensuring a satisfactory temporal stability of health information collection and management. Data on uncomplicated malaria cases show internal consistency, supported by good familiarity with the variables and rigorous application of case definitions by users.

Conclusions: The DHIS2 system has been functioning relatively well for eight years and continues to improve. However, it faces various operational challenges. Optimising its use for effective response and operational research requires overcoming several structural challenges, foremost among which are stabilising the internet connection, strengthening the computer literacy of healthcare providers, and reducing their workload.

Keywords: surveillance system, performance, malaria programme, evaluation, DHIS2, Burundi.

INTRODUCTION

Globally, the incidence of malaria cases and deaths remains high, with more than 90% of malaria cases and deaths recorded in the World Health Organization (WHO) African Region [1]. In Burundi, malaria remains one of the most significant public health challenges [2]. It constitutes the leading cause of consultations in health facilities and represents the primary cause of death [3]. Despite the implementation of the national malaria control programme, which is based on a strategy combining various malaria interventions, data extracted from the integrated disease surveillance and response system indicate that malaria cases remain elevated in the country with 5,570,418 cases and 795 deaths in 2023, for a population of 12,332,788 inhabitants [4].

Malaria is a notifiable disease in Burundi. Since 2014, every malaria case in Burundi should be reported from the community level up to the national level through the national health information system. To that end, the Health Information Management System (GESIS - *Gestion du Système d'Information Sanitaire*) was used until 2016 and the District Health Information Software version 2 (DHIS2) has been used since then [5]. DHIS2 is an open-source web platform, most commonly used as a health information management system and, in certain cases, as a surveillance system [6]. It is used by 73 low- and middle-income countries [6]. Each country configures their own information system from the generic platform with full ownership of the application and its data. The use of DHIS2 is therefore contextualised and depends on the disease under surveillance in the specific country and on its users [6]. In Burundi, it is used as an integrated surveillance and response tool for malaria and other infectious diseases such as tuberculosis and diarrheal diseases.

Few studies to date have evaluated health information systems for epidemiological malaria surveillance [7-12] and none in Burundi so far.

Given the central role of the health information system in epidemiological monitoring, and in light of the heavy disease burden that malaria represents in the country, an evaluation of this system in Burundi is essential. This study aims to identify the structural and operational bottlenecks specific to the malaria epidemiological surveillance system in Burundi, in order to formulate strategic recommendations to guide future improvements of the health information system.

METHODS

i) Study setting

Burundi is a country in East Africa, organised into hills, communes, districts, and provinces. The health system structure is pyramidal and is organised across four levels: central, intermediate, peripheral, and community. These levels are interconnected through hierarchical functional relationships. In terms of service provision, community health workers (CHWs) operate in the community, within the catchment areas of health centres (HCs) and private clinics. They should refer malaria cases to HC that should refer severe cases to the hospital. HCs are organised around a district hospital (peripheral level). District hospitals refer to regional hospitals (intermediate level) and regional hospitals, in turn, refer to national hospitals [13]. Private structures (HCs and hospitals) are fully integrated into the public health and epidemiological surveillance system.

The integration of the information reporting within the health system is described in **Figure 1**. In the community, CHW collect data on malaria cases seen on paper and then provide this data to the HC. Data on malaria cases in the HC are collected manually on paper from the medical registers. Paper-based data from CHWs, HCs, and private clinics are compiled, entered in the DHIS2 software, and analysed at the HC level. Reports by district and regional hospitals are entered into the DHIS2 and are accessible to districts, provincial health offices, and the central level on a daily basis in real time when possible, and on a monthly basis for validation and analysis [5, 6]. The Directorate of the National Health Information System (DNHIS) organises data review activities and publishes information in the quarterly bulletin [5, 6].

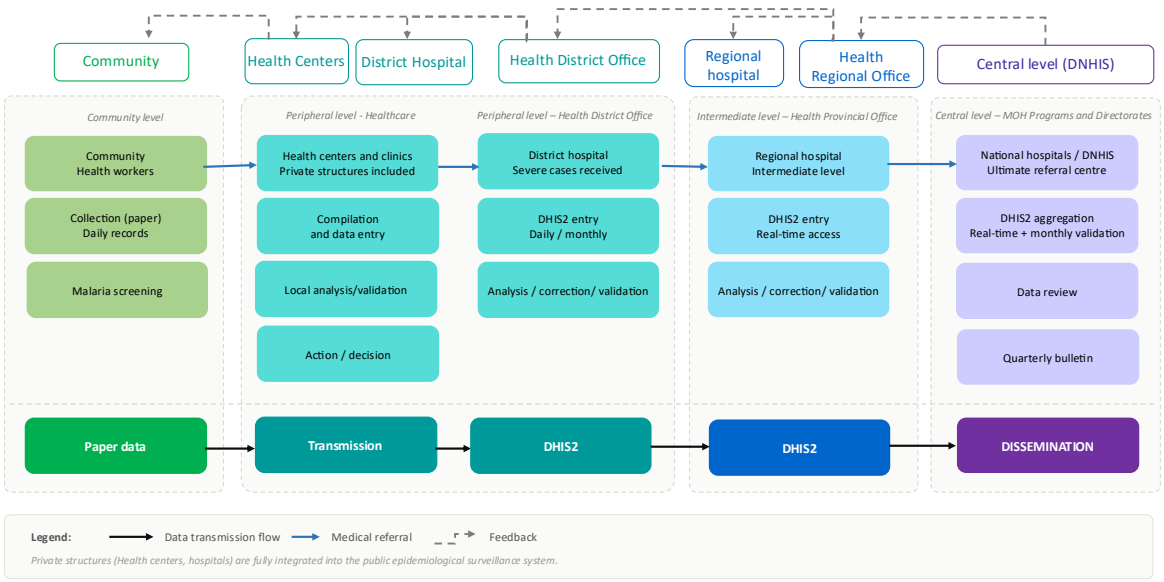


Figure 1: Diagram of the health information transmission flow in Burundi

ii) Study design

A mixed-methods study (quantitative and qualitative) was conducted, with a parallel and convergent design, across four Burundian health districts. The four Burundian health districts

belong to three provinces: Kinyinya (defined through pre-2024 administrative divisions and comprising the current administrative divisions of Kinyinya and Gisuru) belongs to the province of Ruyigi; Gihofi belongs to the province of Rutana; and Ryansoro and Kibuye belong to the province of Gitega.

Malaria data reported in the DHIS2 by HCs (including community health workers) and by district hospitals were evaluated. In addition, data reporting and analysis processes at the district, provincial, and national levels were examined, from January 2014 to December 2023. The study was informed by the surveillance system evaluation guides developed by the CDC and the ECDC [14, 15, 16].

iii) Indicators

The evaluation indicators were selected according to their relevance in relation to the study objectives and agreed upon through consultation between the research and operational teams (Table 1).

Table 1: Summary of the indicator assessed, and methods used to evaluate the indicators

INDICATOR	DEFINITION	METHOD USED
TIMELINESS	Delay in data transmission	Data extracted from DHIS2
REPRESENTATIVENESS	Correspondence between malaria cases recorded in DHIS2 and actual malaria cases observed in the community	Comparison of prevalence surveys with DHIS2 data. Focus-group discussions
ACCEPTABILITY	Willingness and capacity of actors involved to collect, enter, analyse and interpret the data	Focus-group discussions
TEMPORAL AND LOGISTICAL STABILITY	The reliability of surveillance data collection and management methods, as well as the continuous availability of the required data.	Data extracted from ministerial protocols and reports and from the DHIS2
DATA QUALITY	Internal completeness i.e., data completeness and consistency	Data extracted from ministerial protocols and

A) INTERNAL COMPLETENESS	between variables across reporting tools	reports and from the DHIS2.
B) INTERNAL VALIDITY	Internal validity i.e., presence and correct understanding of case definitions among data entry staff	Focus-group discussions

The following indicators were considered in this evaluation:

(a) Timeliness of reporting (= promptness): this refers to the observed delay in data transmission between the different levels of the health pyramid (**Figure 1**) and was extracted from the DHIS2 directly. According to the guidelines of the DNHIS [13, 17], every confirmed malaria case must be reported within 24 hours. Furthermore, for monthly data, community health workers and HCs must enter data no later than the 5th day of the following month. The person in charge of the HC and the hospital medical director validate these data no later than the 10th day of the following month, whilst the district and provincial chief medical officers validate the data on the 25th and 30th days of the following month, respectively. Prior to January 2020, the procedure was slightly different: data were collected by CHWs and health information system officers at the HC and district hospital levels, and transmitted by post on paper to the district for entry no later than the 5th day of the following month. The district chief medical officer would validate the data for onward transmission to the provincial health office, which in turn, together with the provincial health information system officer, would analyse and validate the data for transmission to the central level no later than 35 days after the end of the month.

(b) Representativeness of reported cases: this indicator assesses the correspondence in demographics between malaria cases recorded in DHIS2 and actual malaria cases

(symptomatic and asymptomatic) observed in the community. Demographics of malaria cases identified during community surveys in 2020 and 2021 were compared to demographics of cases entered into the DHIS2 system during those survey periods.

(c) Acceptability: this is defined as the willingness and capacity of the actors involved to collect, enter, analyse, and interpret malaria-related data. Actors involved include CHWs, health information system officers in HCs, districts, provinces, and at the national level. Acceptability was assessed through focus group discussions.

(d) Temporal and logistical stability: this indicator refers to the reliability of surveillance data collection and management methods, as well as the continuous availability of the required data. Stability encompasses a number of sub-indicators: changes in case definitions, changes in the clinical signs and symptoms of the populations tested, changes in diagnostic tests used, the determination of the population-to-paramedical/medical staff ratio, and the frequency of malaria supply stock-outs (such as medicines, tests) over time. This indicator was examined using both quantitative (data extracted from DHIS2) and qualitative data (review of data from ministerial protocols and reports).

(e) Data quality, assessed through **internal completeness** and **internal validity**: internal completeness is measured by both data completeness [18] and the consistency between variables collected in the health information system and those collected in the weekly and monthly reports. Internal validity, for its part, is assessed by the presence of case definitions and by the understanding of these case definitions by the health personnel responsible for data entry. This indicator was also examined using both quantitative (data extracted from

DHIS2) and qualitative data (review of protocols and reports as well as focus group discussions).

iv) Quantitative data collection

Data collected from official DNHIS documents and health districts

The description of the surveillance system was carried out through consultation of official documents and informal discussions with system users. The number, geographical location, and date of creation of each HC (including private clinics) and each hospital in the four districts was collected, as well as the number of CHWs and staff for each health structure from 2014 to 2023. The number of data entry, verification, and analysis officers at the HC hospital, district, provincial, and national levels in 2023 were also mapped out. The case definitions used for malaria surveillance from 2014 to 2023 were extracted from DNHIS and National Malaria Control Program (NMCP) protocols and reports.

Data collected directly from the health information system (at the central level)

For each health facility, monthly reporting delays were extracted directly from the GESIS and DHIS2, where they are calculated automatically by the system (referred to as 'timeliness' within the system). Timeliness is calculated as the percentage of all reports submitted on time. It was extracted for the last version entered by the data officer of the HC, as modifications may be made following feedback from district health information system officers. Monthly data completeness (percentage of unknown or empty values in each report) was extracted directly from the GESIS and DHIS2 in aggregate format, and for the last version entered by the data officer of the HC. Finally, the following data were also extracted: yearly number of suspected, tested, confirmed, and treated cases, weekly number of confirmed

cases, and monthly number of confirmed cases. All data from the central level was collected per HC and for the period 2014-2023.

Quantitative data external to DHIS2 and official documents

Médecin Sans Frontières (MSF) conducted malaria prevalence studies in the general population in August 2020 in Kinyinya, and in June 2021 in Ryansoro [19, 20]. These data were not entered into the DHIS2, and no medication was distributed during these studies. Within these studies, results of the malaria tests were not individually associated with symptoms but overall proportion of fever in the tested population was available. In order to assess representativeness, the results of these malaria screening studies were compared with DHIS2 data for the districts of Kinyinya and Ryansoro for the same catchment areas and survey weeks with an additional two weeks, to account for both the malaria incubation period and delays in accessing care.

v) Qualitative data collection

To gather qualitative data on stability, acceptability, and representativeness, focus group discussions (FGDs) were conducted at each level of the health pyramid. Individual interviews were conducted with key stakeholders who were unable to participate in the FGDs. Study participants held the following positions: CHWs trained in community management of uncomplicated malaria; data officers in HCs, clinics, and hospitals; health information system officers in health districts and provincial health services; data users from the monitoring and evaluation unit of the NMCP and from the epidemiological surveillance unit of the DNHIS. Separate FGDs were organised for each of these four participant groups to minimise power dynamics. Participants were also selected through purposive sampling amongst data officers in HCs, clinics, and hospitals, mixing experienced and newly appointed staff. NMCP and DNHIS

data officers were selected based on their position and informant potential (Head of the monitoring and evaluation Unit, NMCP data officer, Head of the Surveillance Unit, and Statistics Officer).

Topics were addressed within designated groups according to participant categories and roles within the health system. Community case management, representativeness of cases in the health information system relative to cases encountered in the community, and material and human resources needed for malaria case detection and reporting were discussed with CHWs. Knowledge of DHIS2, understanding of current case definitions and management of re-presenting cases, acceptability of the system, material and human resources, and utility of the system were talked about with data officers in HCs, clinics, and hospitals. Knowledge of DHIS2 and understanding of current case definitions, acceptability of the system, material and human resources, and utility of the system were explored with data users at district and provincial level. Finally, knowledge of DHIS2, system stability, acceptability of the system, material and human resources, and utility of the system were assessed among data users at the NMCP and the DNHIS.

vi) Quantitative data analysis

The surveillance system was described in terms of the population captured by the system, the case definitions used, any significant changes in case definitions, and the inclusion of new structures since its establishment. Quantitative data were analysed monthly, yearly, by HC and by district. The percentage of agreement between the number of yearly suspected, tested, confirmed, and treated cases per district was calculated, as was the percentage of agreement between the summed weekly number of confirmed cases and the monthly

number of confirmed cases. Each of the following themes were also analysed for all study health districts:

- Comparison of severe versus uncomplicated cases;
- Trends in deaths and comparison of deaths versus malaria cases;
- Comparison of monthly versus weekly cases;
- Comparison of Rapid Diagnostic Tests (RDTs) ordered, consumed, and stock-outs.

The positivity rate for malaria with RDT in the community screening was calculated by age and sex and applied to the population in the district to estimate the number of cases that should appear in the DHIS2 considering that all cases (symptomatic and asymptomatic) come to HC. The number of cases and their age and sex was extracted from the DHIS2 and compared to the estimated "true" number of cases to estimate the representativeness of cases captured by the malaria surveillance system. All quantitative analyses were conducted in Excel version 2402.

vii) Qualitative data analysis

Interviews conducted in Kirundi were recorded, translated, and transcribed into French by Burundian field researchers who had simultaneously participated in a qualitative study in the study districts [21]. All translations were verified and the audio recordings were re-listened by one of the principal investigators for comparison with the translations. Thematic content analysis was carried out iteratively by the co-first authors. Coding initially followed the primary themes developed in the interview guides (Annexes 1A and 1B). It also incorporated emergent themes, such as the heavy workload of health information system officers, causes of system malfunctions including lack of communication means and internet access, means of transport to reach HCs for CHW meetings, and mentoring systems.

viii) Ethical considerations

Approval from the Burundian Ethics Committee was obtained on 13 September 2022 by Decision CNE/29/2022; MSF Ethics Review Board (MSF ERB) approval was obtained on 28 July 2022 under reference number 2247; and Institute of Tropical Medicine Institutional Review Board (ITM IRB) approval was obtained on 17 May 2022 under identification number 1587/22. These approvals were obtained prior to starting qualitative data collection, quantitative data extraction, and the various analyses for this study. The statistical visa in Burundi was obtained under statistical visa number VS2023008CNIS by ministerial decision n°540/95/1184/2023 dated 20/03/2023.

ix) Translation

The translated version of this article in French is available in Annex 2.

RESULTS

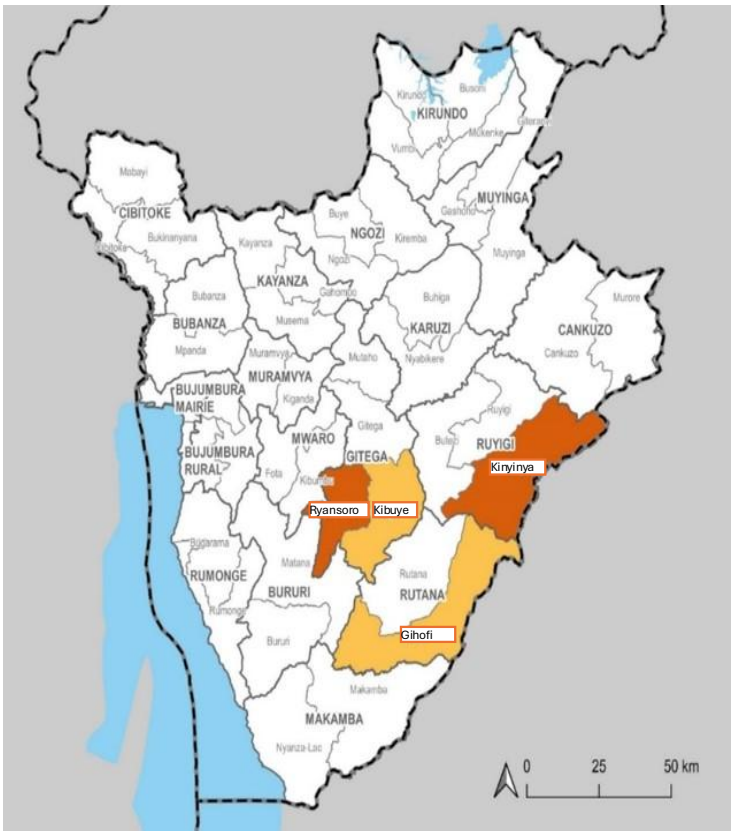
In total, 27 documents dating from 2014 to 2023 were analysed, including malaria case management guidelines, three national strategic plans from 2014, 2018, and 2021, ten statistical yearly reports from 2014 to 2023, two national health information system procedure protocols from 2016 and 2020, and annual NMCP reports from 2014 to 2023. Ten FGDs were conducted, with 74 participants, as well as two individual interviews. More specifically:

- Four FGDs with 32 CHWs trained in community management of malaria (eight participants per district).
- Four FGDs with 28 data officers from HCs, clinics, and hospitals (four to eight participants per district).

- One FGD with the four health information system officers from the health districts and the two health information system officers from the provincial health services.
- One FGD with four participants from the NMCP (two participants) and from the DNHIS (two participants).

Across the four study districts, 81 health structures were present in 2014, and ten new structures were established and became operational between 2014 and 2023. In 2023, 91 health structures (11 to 30 per district) were distributed across the four districts (**Figure 2**).

A)



B)

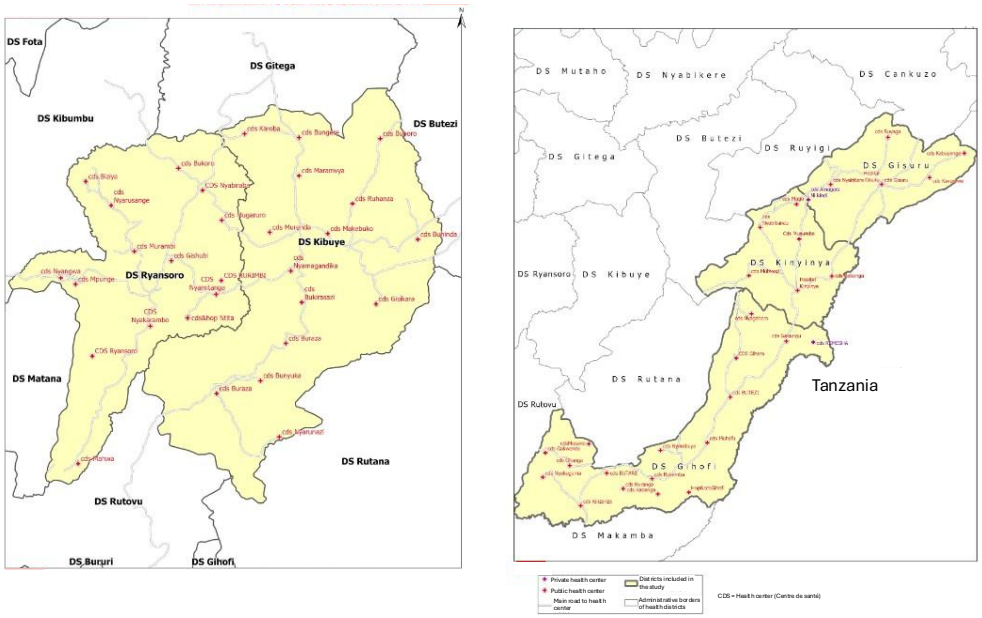
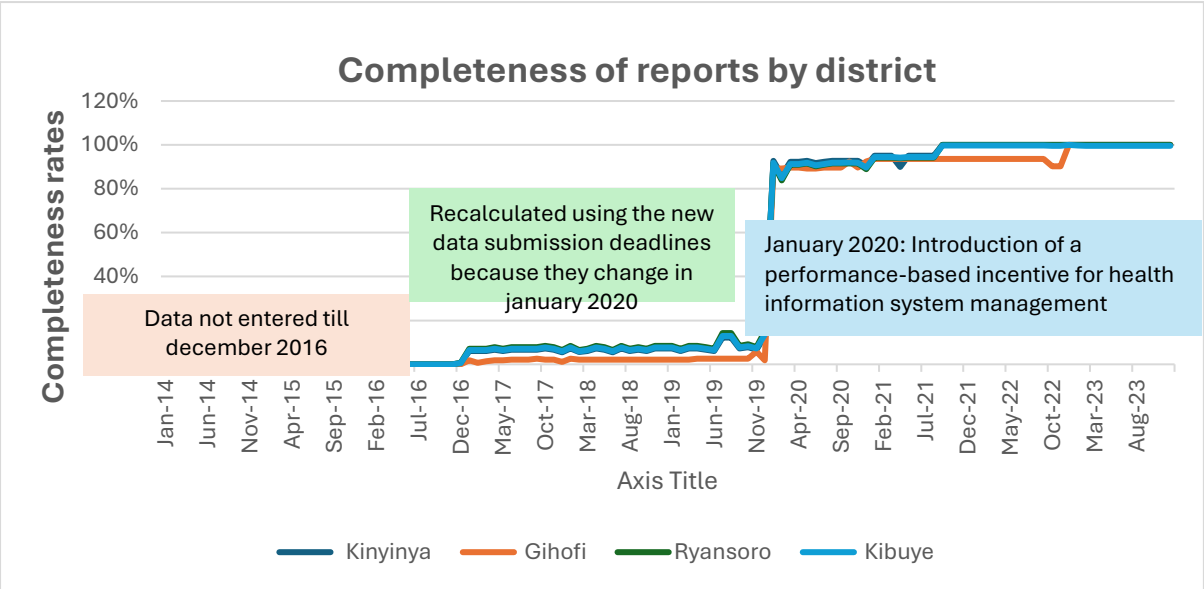


Figure 2 – Map of the four study districts in Burundi (A) and the health centers present in the four study districts in 2023 (B).

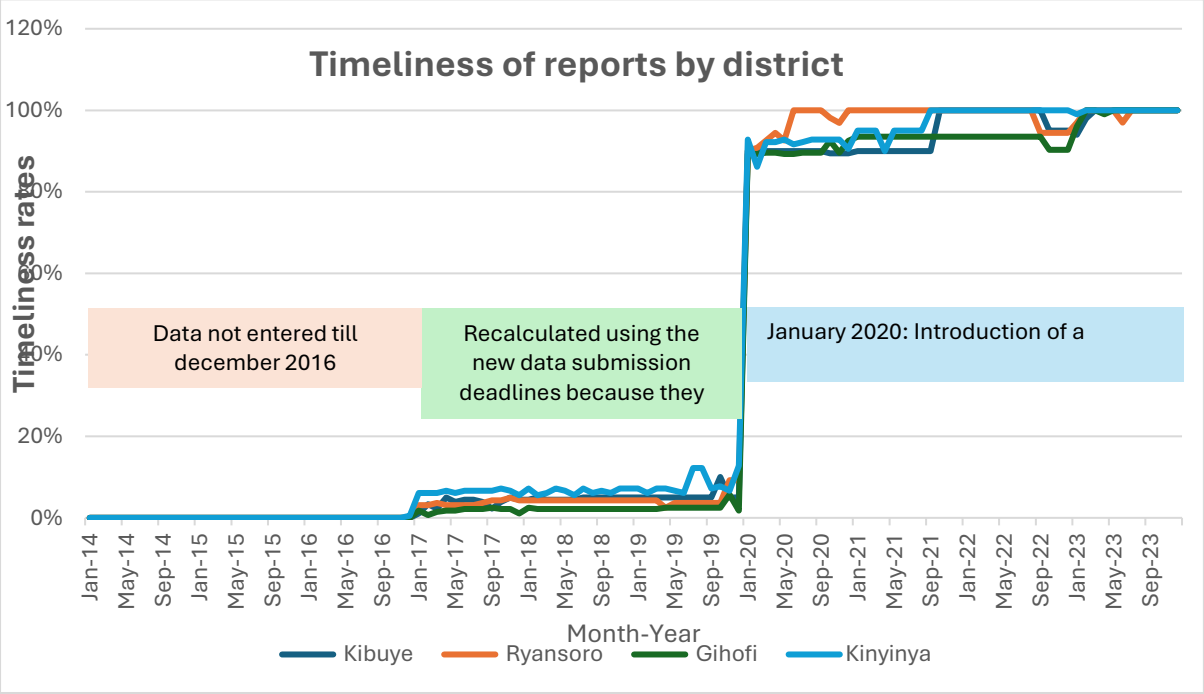
The remainder of the results are organised by indicators.

(a) Timeliness of reporting

From 2014 to 2016, in Burundi, the health information system management used another software called "GESIS" (Health Information Management System - *Gestion du Système d'Information Sanitaire).* The DHIS2 software was introduced in 2017. Subsequently, in December 2019, it underwent a reconfiguration aimed at revising the system, integrating new indicators, and adjusting the timelines for data transmission at each level of the health system pyramid. Since January 2020, 95% of reports have been submitted on time across the four health districts included in this study (**Figure 3**).



361



362

363 **Figure 3. Trends in timeliness and completeness rates of reports from 2014 to 2023 in the**

364 **four districts.**

365 This improvement was driven by the introduction of a performance-based incentive for health

366 structures that submitted their reports on time. It should be noted that reporting deadlines

367 themselves changed between 2014 and 2023, becoming progressively shorter.

368 **(b) Representativeness**

Comparing the proportion of positive malaria cases detected during mass testing with the number of cases reported in the DHIS2, 12% of the estimated number of positive malaria cases in the community were captured in the DHIS2 in Kinyinya and 35% in Ryansoro (**Table 2**). Note that both asymptomatic and symptomatic malaria cases were detected in the community.

Table 2. Comparison of prevalence surveys and DHIS2, 2020-2021, Burundi

District, age and sex		Total tests performed in survey	Positive tests in the survey (positivity rate)	Total district population	Estimated number of malaria cases in district according to survey positivity rate	Number of cases reported in DHIS2	Representativity[1]
Kinyinya		**3 415**	**564 (16.5%)**	**311 858**	**51 457**	**6 086**	**11.8%**
Sex	Female	1 973	294 (14.9%)	158 223	23 575	3 145	13.3%
	Male	1 442	270 (18.7%)	153 635	28 760	2 941	10.2%
Age	< 5 years	694	112 (16.1%)	49 220	7 939	3 801	47.9%
	≥ 5 years	2 721	452 (16.6%)	262 638	**43 624**	2 285	5.2%
Ryansoro		**2 356**	**265 (11.2%)**	**202 775**	**22 711**	**7 962**	**35.1%**
Sex	Female	1 388	142 (10.2%)	107 422	10 989	4 264	38.8%
	Male	968	123 (12.7%)	95 353	12 119	3 698	30.5%
Age	< 5 years	587	55 (9.4%)	24 833	2 327	6 093	261.9%
	≥ 5 years	1 869	210 (11.2%)	177 942	20 000	1 869	9.3%

[1]*Number of cases captured in DHIS2 in district/ Estimated number of cases (symptomatic and asymptomatic) in the same district*

In the MSF survey, in Kinyinya, 34.5% of children less than 5 years-old had had fever in the past 2 weeks while in Ryansoro, 29.7% of children less than 5 years-old had had fever.

Comparison of the demographic profiles of malaria-positive cases detected in the community in 2020 with cases reported in the DHIS2 (**Table 2**), revealed a higher proportion of cases

among women than among men in the DHIS2, but a higher prevalence among men. There was a clear over-representation of children under 5 years of age in the DHIS2 in Ryansoro, and an adequate representation of age groups in Kinyinya. This under-representativeness of consulting cases relative to actual community cases, as well as the differences by sex and age, were confirmed by qualitative interviews, and several reasons were identified. According to health information system officers, some individuals prefer to go directly to pharmacies or consult prayer houses or traditional healers when they are poor or cannot afford healthcare or due to socio-cultural representations. The following quotations from a FGD with data officers illustrate this:

> *"It depends on the period. // Patients who refuse? // Interviewer: I mean people who fall ill but do not seek care at health facilities? // Yes, that exists. I can give an example from our area. In previous years, before MSF's intervention, many people fell ill but instead of going to be treated at a health facility, they went to the pharmacy to buy medicine. They might buy two tablets depending on how much money they had, and would prefer to buy those two tablets to see if there was an improvement. If there was improvement, they would not buy more. But it is because of poverty. They would calculate the cost of the thick blood smear, other tests, and medicine, which adds up to a lot of money, which is why they prefer to buy medicine at the pharmacy. There are also traditional medicines that people drink and that cure malaria. I think they prefer these medicines because of poverty or because they live far from health facilities. Those who live close to a health facility go to the pharmacy because they want to avoid the long queues at the health facility. // I can add a little, because as the saying goes 'each swamp has its own crocodile', there are those who consult charlatans instead of going to health facilities when they have headaches or other symptoms because they think they have been poisoned. But the CHWs and health promotion technicians continue to raise awareness among the people so that they consult health facilities when they fall ill, and we can observe the change." (FGD with data officers from provincial health services and health districts)*

Furthermore, the inaccessibility of health centres, staff shortages at health centres, long waiting times, and poor quality of reception push individuals to consult traditional healers or to resort to self-medication, which may lead to late presentations. This is captured in the following exchange:

"Yes, there are those who refuse to seek care due to a lack of means or religious beliefs, and there are others who choose to consult traditional healers. // Another thing: they refuse to come to the HC due to staff shortages there. For example, there are men who self-medicate or go to the pharmacy because they do not want to waste time at the HC given these staff shortages." (FGD with HC data officers)

Consultations also depend on other financial priorities. For instance, patients wait for market day to seek care, using money from their sales. Mothers are generally better followed up at HCs, as it is they who bring children for vaccination and other healthcare reasons.

(c) Acceptability

The workload was particularly heavy for CHWs as well as for health information system officers at HCs and hospitals. It was mentioned by almost all health information system officers and CHWs. These individuals are in high demand, with full and busy days, and, in some cases, working into the night owing to continuous activities (morning, midday, evening, and night) for community malaria case management. It was also noted that CHWs must collect a considerable volume of data, whilst health information system officers at health structures must, in addition to their specific health information system tasks, provide routine patient care. Participants described this directly:

"Clearly, none of us is a civil servant. We are all farmers, and those who are not must find an occupation to provide for their families. What I see in our area is that they come in good numbers every morning, just as at the health centre. So when you think you are done, you go off to your other activities to be available at midday, as they often come at three times, morning, midday, and evening, so you have to make sure you are available at those times. // Another thing: we spend a great deal of time because after treatment, we have to carefully complete the register to facilitate reporting. One would think we do nothing at home." (FGD with community health workers)

"The difficulties are mostly connectivity. You see, here in Burundi, the connection is unstable. It is true that there is a work connection, but it does not often work, so we resort to our personal connection using our own credit." (FGD with DNHIS and NMCP Senior Staff)

CHWs reported receiving an insufficient allowance to cover their communication needs (telephony and internet). As for health information system officers, they reported receiving a salary equivalent to that of other nurses who were only providing patient care, whilst also reporting a lack of funding for communication and internet connectivity. Health information system officers are responsible for patient care and are additionally tasked with data compilation on paper templates, data entry, adherence to deadlines, and online data analysis, all of which require communication resources. This comes through clearly in the participants' own words:

> *"The Ministry of Public Health has supported us. Previously we said we had no means of transportation, but that was resolved, and we were also given a telephone for communication. The only thing we owe in return is to be courageous, unless the Ministry of Health gives us even more. The problem we have is communication costs; even though we have phones, honestly, communication costs are a problem for us." (FGD with community health workers)*

> *"The data and credit allowances are not sufficient. Sometimes I manage on my own. For some, they are insufficient. I have a problem with headphones, and certain tools are lacking, such as data allowances. // Thank you very much. I wanted to start with the question about whether we are proud of our work. Everyone who has an occupation that helps them to survive is proud of that work. Health information system work is an extremely demanding job, as we have already said. If you do it for many years, your health can deteriorate. We already have testimonies, and I too have contracted several illnesses since I started this job. Our work is very demanding because we are always under pressure, always being asked questions and having to produce reports. We have no time to rest. As for the salary, as others have said, it is difficult to live on a civil service salary when prices keep rising, it is a disaster. (Laughter.) As for the data allowances we are given, I live in a place where I can use an unlimited connection, even if it is slow, and I can do my work. But when I travel to a place where only 3G is available, I stop working because I cannot use the unlimited connection. It requires using data allowances rather than an unlimited connection. We have an unlimited package because we are given little money for data allowances. Thank you." (FGD with data officers from provincial health services and health districts)*

Most health information system officers and CHWs nonetheless consider that, despite these constraints, they have established strategies to ensure the continuity of their activities.

Health information system officers explained that they use their own financial resources to purchase communication credit, borrow equipment (staplers, correction fluid, paper), work from home, and have documents printed at public secretariats. These strategies are employed in order to submit reports on time to health district offices. CHWs mentioned cancelling other income-generating activities or carrying out activities close to home so as to remain flexible and available for clients, and accepting the need to travel to compile reports at the HC, as reported in the following exchanges:

> *"Nothing! We are not given any money. Everyone digs into their own pocket for communication credit." (FGD with community health workers)*

> *"In other words, what I would like to add is the situation where you are on your way to the health facility and you realise you have no rain jacket or umbrella. With regard to what you are saying, we have always said that we need phones, whether small or large, so that when you are in the community, you can call the provider at the health facility to ask for advice. So there are times when you realise there is no credit on your husband's or your child's phone, and you find that difficult. What do you do? You wait for them to come and get credit, and then you realise it is too late, there is too much complications, that too is one of the obstacles." (FGD with community health workers)*

> *"Yes, we have many constraints as HC CHWs in carrying out our activities. We have groups… incentive payments that are given to us but do not reach us on time. We organise ourselves by creating savings association groups (VISLA) where we continue our work because we use our own funds, money meant for the family, because we carry out the activity as if it were our own, for the general interest of the community." (FGD with community health workers)*

> *"As here there are no routers or wifi, I adapt by using my phone to share the connection. // I borrow it from another office. In general, the health information system officer has no fixed office because they work both at the office and at home. Even if you work somewhere with wifi, we always need data allowances for our phones and a router to use at home. I was given a router to use at home. I requested it because I work even during the night. It was DNHIS that distributed the routers and modems. I was asked to choose between a router and a modem, and I chose the router because the USB modem was like sharing the connection through the phone. The router helps a great deal, but you have to top it up yourself because we are not given data allowances for routers. They only give us allowances for phones. The problem is that we use our own money to*

keep the work going by topping the routers up." (FGD with data officers from provincial health services and health districts)

(d) Temporal and logistical stability

No remarkable change in the national malaria case definition has been observed since 2012. The NMCP, in collaboration with the DNHIS, has consistently defined a confirmed case of uncomplicated malaria as any person with fever or a history of fever within the past 24 hours, with laboratory confirmation by RDT or thick blood smear. Similarly, a confirmed case of severe malaria has always been defined as any patient with laboratory-confirmed *Plasmodium falciparum* parasitaemia with signs and symptoms of the severe form of the disease (vital organ dysfunction) [22, 23, 24]. This stability is maintained by a regular and sufficient supply of malaria diagnostic and treatment commodities, with a dramatic reduction in stock-outs from 2018 onwards, according to the DHIS2 data, as shown in figure 4.

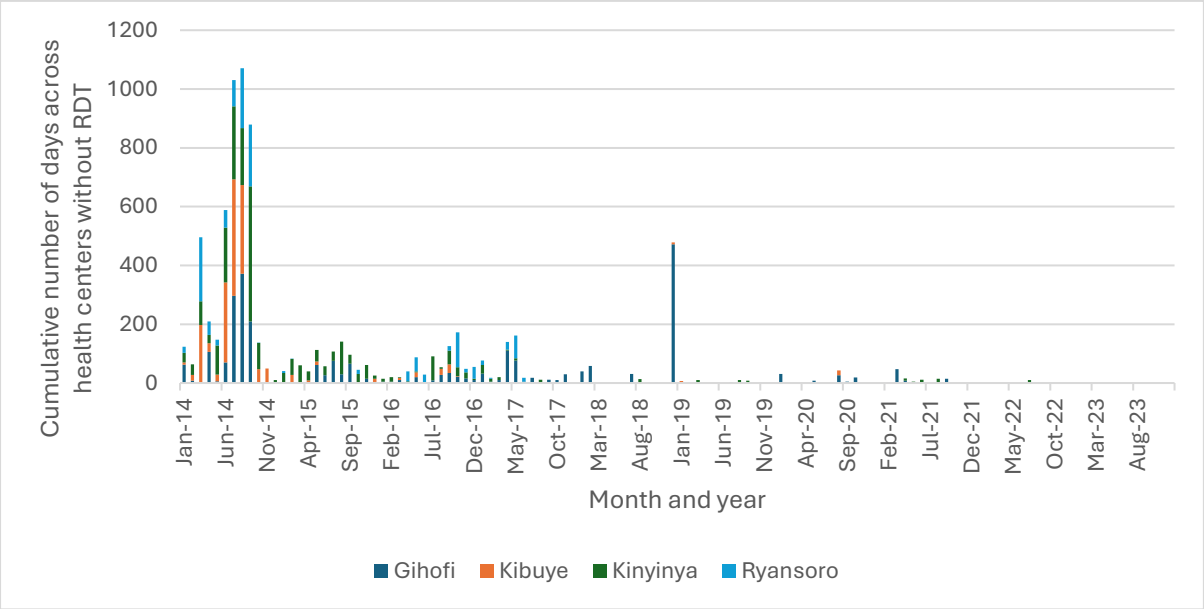


Figure 4. Trends in monthly stock-out days from 2014 to 2023 in the four districts. Stock-out days are calculated by adding the number of days without malaria RDT in each of the health facilities in each district.

The ratio of population to paramedical staff and to physicians in 2023 is presented in **Table 3**.

Table 3: Number of CHWs, healthcare staff, and physicians in each district, Burundi, 2023.

District	*Kinyinya*	*Gihofi*	*Ryansoro*	*Kibuye*
Population	331 816	280 637	215 753	310 285
Number of HC	18	32	19	23
Paramedical staff per HC	6	9	7	5
Persons per paramedical staff	3 072	974	1 622	2 698
Persons per physician	32 165	65 000	44 000	27 000
Persons per HC	18 434	8 769	11 355	13 490
Number of catchment areas	17	23	14	17
Number of CHWs per catchment area	16	9	9	16
Number of hospitals	2	2	2	3

(*HC = Health Facility; CHW = Community Health Worker)*

The population-to-paramedical staff ratio is below the WHO standard of 5,000 per nurse, whilst the population-to-physician ratio is substantially above the WHO standard of 10,000 per physician. There is therefore sufficient paramedical staff but a significant shortage of trained physicians.

(e) Data quality

Report completeness was low until 2020 and has been at 95% since January 2020. This is primarily attributable to the change in data entry and transmission deadlines, as well as the update of all online database indicators in January 2020 at the national level, including the

study districts. There was very good consistency between treated and diagnosed cases, explained by the approach of testing and treating all those who test positive (Figure 5).

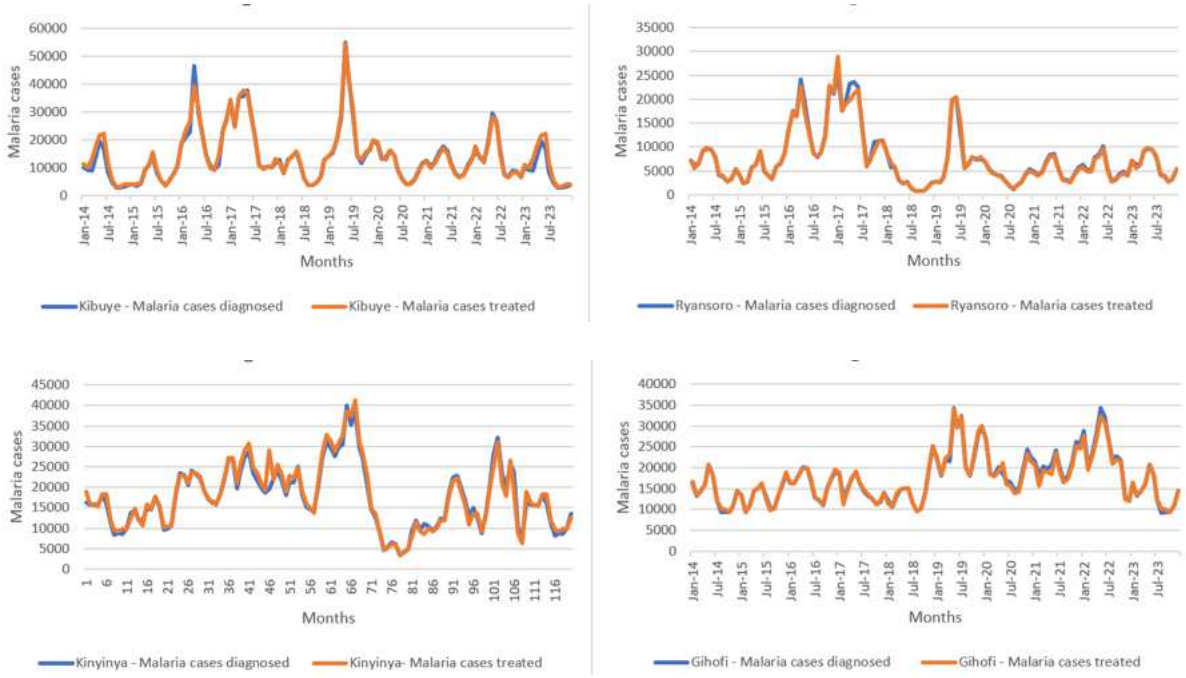
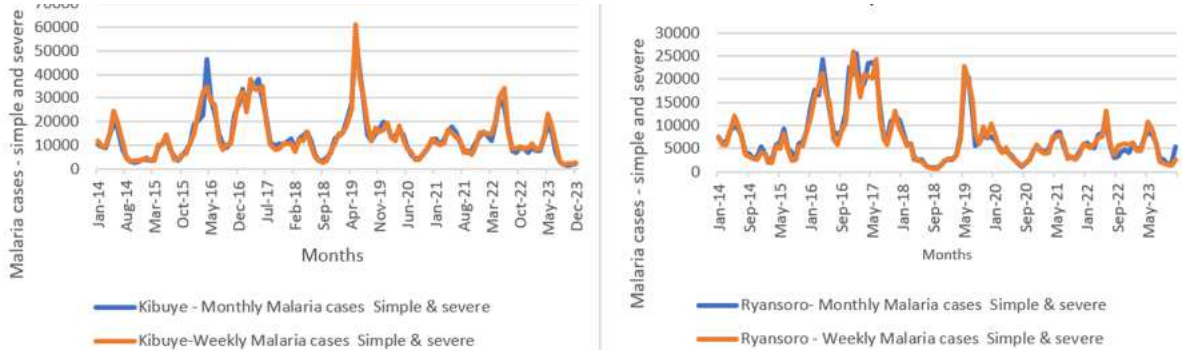


Figure 5. Trends of malaria cases diagnosed and treated from 2014 to 2023 in the four districts.

There was also good consistency between the number of cases reported monthly and the number of cases reported weekly for the health districts of Kinyinya, Ryansoro, and Kibuye. This was not the case for Gihofi, where large discrepancies were observed (Figure 6).



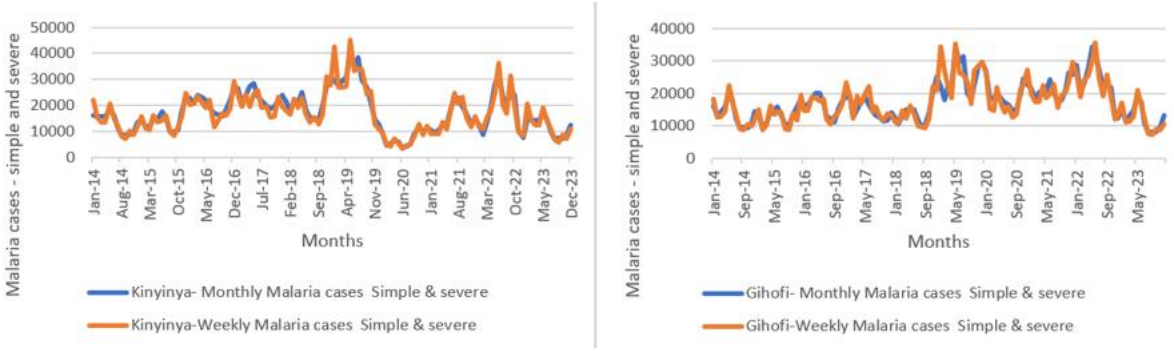


Figure 6. Trends in monthly and weekly of malaria cases 2014 to 2023 in the four districts.

All interviewees seemed familiar with the clinical case definitions defined in the DHIS2. However, in practice, other clinical signs are also used. For example, unspecified signs indicating renal dysfunction were cited by participants as precursors of a severe malaria case.

> *"Renal failure or other symptoms. In general, there are symptoms that cannot be treated with medication: signs of anaemia or signs showing that the kidneys are not functioning properly. In that case, this person has signs that are added to those of uncomplicated malaria, which means that one can say it is severe malaria." (FGD with Health Information System officers, Ryansoro)*

Some FGD participants amongst health information system officers differentiate uncomplicated from severe malaria based on the parasite density found on thick blood smear.

> *"What I can add relates to the laboratory test. Results are obtained according to the number of parasites found; the results help define uncomplicated and severe malaria. If many parasites are found, it is considered severe malaria, in order to facilitate patient monitoring so that malaria does not progress to a complicated form." (FGD with Health Information System officers, Ryansoro)*

Several CHWs across the majority of FGDs cited multiple signs in favour of clinical malaria, including fever, headache, arthralgia, and myalgia, as well as a bitter taste.

> *"What I can add is that when you find severe malaria with signs of severity and when malaria is confirmed, it is in that case that you administer the tablet rectally and transfer them to the health centre for follow-up. Secondly, we conduct a home visit to the malaria patient on the second day after confirmation of malaria to assess their health status; if there is no improvement, you transfer them to the health centre; if you*

find that there is improvement, you tell them to continue taking the medicine to complete the treatment course." (FGD with community health workers in Kibuye)

DISCUSSION

This study constitutes the first in-depth evaluation of the Burundian national health information system for malaria. It is a system that has continued to evolve and adapt in response to local contexts. Major adaptations were implemented with the introduction of the DHIS2 in 2016, the creation of new indicators, and new data collection templates [17]. The malaria surveillance system in Burundi is a relatively stable system, both temporally and logistically, with satisfactory internal validity. Reporting timeliness and data completeness have been high since 2020 after a performance-based incentive for health structures that submitted their reports on time was introduced in January of that year.

. Data are generally consistent. Data analysis and interpretation at the district and provincial levels are carried out regularly and are considered straightforward by health information system officers. However, representativeness was overall low, mostly due to factors influencing healthcare access and use, and the resources in place for a number of indicators remain insufficient, particularly with regard to internet connectivity and communication, especially at the lower levels of the health pyramid. Another evaluation study of the DHIS2 system in Burundi for tuberculosis had identified similar strengths and challenges, including a clear surveillance data flow and case definition implementation, but general under-detection of TB [25]. To the authors' knowledge, there hasn't been an evaluation for other diseases in Burundi.

606 Overall, the timeliness and completeness rates drawn directly from the DHIS2 are difficult to
607 interpret. These indicators were not automatically collected prior to 2017. After 2017, these
608 variables were calculated directly by the system, but they provide only a rough estimate of
609 actual timeliness and completeness. Indeed, timeliness is calculated from the last version of
610 DHIS2 data extracted. If, for example, a report is submitted by an HC before the deadline, but
611 modifications are subsequently requested by the district health office upon verification,
612 timeliness is recalculated from the version containing the modifications (which in most cases
613 is re-submitted after the deadline). Furthermore, completeness represents the percentage of
614 reports submitted in complete form, such that a half-completed report is considered entirely
615 incomplete. Completeness for specific variables could not be retrieved, and it can be assumed
616 that incomplete reports are primarily related to more administrative variables, such as the
617 number of tests ordered, rather than to the number of cases. It is possible that between 2017
618 and 2019, providers had less training in basic computing (particularly in Excel and Word), and
619 in data management via DHIS2. It was noted that they had limited experience with online
620 health information, resulting in lower completeness and timeliness rates. From 2020
621 onwards, providers were accustomed to the system and motivated by the performance-based
622 approach, enabling improved completeness and timeliness, although it is difficult to interpret
623 the exact percentages. National evaluations conducted in Kenya, Senegal, and Tanzania have
624 demonstrated marked improvements in data completeness and reporting timeliness
625 following DHIS2 deployment, enabling the use of data for programme monitoring and
626 planning [7, 8, 9, 10, 11]. However, these studies also highlighted persistent limitations in data
627 quality, including missing values, difficulties in distinguishing ‘zero’ from ‘not reported’,
628 under-representation of data from the private sector, and inconsistencies that require local
629 verification prior to analytical use [9, 11, 12].

A number of logistical solutions have been implemented in Burundi over time, notably in 2020, including the introduction of performance-based incentives for completeness, timeliness, and other indicators, which are positively reflected in the data. Thorough documentation of indicators has enabled stability of case definitions and adherence to data collection standards [22, 24]. Strong pressure to improve supply chain management of commodities and other medical products has reduced the number of stock-outs; since 2018, the number of RDT stock-out events is now almost nil each month [26]. Despite these improvements, several logistical challenges persist, notably the lack of computer training for users and the need for a highly stable internet connection together with the material and financial resources to maintain it. Evaluations of DHIS2 as a surveillance system in other countries in Africa and the Pacific have similarly identified comparable strengths and weaknesses, including good data management and flexibility of the application, alongside operational challenges related to lack of funding and shortages of trained workforce [27, 28]. A study conducted in the Solomon Islands evaluated the availability, completeness, timeliness, and reliability of several malaria indicators collected in DHIS2, covering report dates, numbers of malaria cases, laboratory results, and case treatment. These characteristics varied considerably between provinces and were generally poor [28]. According to the same study, improving the timeliness, completeness, and reliability of reports is dependent upon ongoing on-site support, supervision, and feedback, as well as further system improvements such as higher-performance computers [28].

In our study, additional logistical difficulties were identified relating to the workload of providers owing to staff shortages and lack of standard material requirements necessary for effective reporting. The poor quality of reception and long waiting times in HC services,

mentioned in the interviews, might be in part attributable to the lack of HCs and physicians per inhabitant. Whilst the number of nurses and HCs has increased in recent years and the nurse-to-population ratio, ranging from 1,158 to 2,136 inhabitants per nurse, remains below the WHO maximum standard of 5,000 inhabitants per nurse, patients must often wait several hours before receiving care [29]. In absence of physicians, nurses and other paramedical staff likely take over more tasks than expected. Moreover, in addition to patient care duties, all administrative tasks fall to the staff, including completion of data registers which are then transferred to paper DHIS2 entry templates. These combined pressures result in a surveillance system that, in its current form, is difficult for CHWs and health information system officers in HCs to adopt, due to limited communication resources, inadequate remuneration, and a heavy workload. Studies in Africa and the Pacific previously also underscore the persistence of logistical challenges associated with the use of the health information system, notably the lack of adequately qualified human resources with computer literacy, unstable internet connectivity, and deficiencies in data analysis and supervision [7, 8, 9, 10, 11, 12, 28]. They highlight that, unfortunately, investments and changes to DHIS2 frequently emphasise the technological development of the platform rather than data collection and utilisation [7].

Whilst the population captured through the malaria health information system over the past ten years is stable, clinical cases are still under-represented at HCs. Our study reveals a very low proportion of cases reaching the HC (35% in the health district of Ryansoro in 2021 and 12% in the health district of Kinyinya in 2020). This substantial under-representation could potentially be explained by a large proportion of asymptomatic or subclinical cases, particularly in a district with a high transmission rate such as Kinyinya, but is also attributable to sociocultural and demographic constraints, such as recourse to prayer houses, traditional

678 healers, and medicinal plants; lack of financial means; distance from HCs; and/or poor quality
679 of reception in HC services [30, 31]. There was also an under-representation of men consulting
680 for malaria at HCs, which may partly be explained by the fact that women consult more
681 frequently on behalf of their children or family members and are therefore more likely to be
682 diagnosed themselves, a phenomenon observed in multiple settings and often associated
683 with women's role as managers of family health [32, 33]. The over-representation of cases
684 among children under 5 years of age is due to the clinical severity of malaria in this age group,
685 which leads parents to bring the child for consultation [34]. Together, these factors result in
686 a surveillance bias, such that the health information system likely captures cases that are,
687 overall, more severe or from more affluent families. This is further evidenced by the finding
688 that severe cases and deaths accounted for less than 2% of uncomplicated cases, whereas the
689 literature indicates rates of severe cases ranging from 5% to 20% [19, 20, 34]. It is possible
690 that severe cases and deaths are under-reported or recorded as uncomplicated cases, given
691 that all severe cases must be transferred to hospital and that declaring a death at an HC is
692 considered an offence. In MSF-supported districts, it is additionally possible that improved
693 malaria management has reduced the proportion of severe cases [34].
694

695 Our study has a number of limitations. It is difficult to find an appropriate community-level
696 comparison to estimate the representativeness of malaria cases captured by the DHIS2
697 system. No screening study was conducted in the districts of Gihofi and Kibuye, and the results
698 of any other mass screening study conducted by the NMCP are entered into DHIS2 and could
699 therefore not serve as an external source of comparison. The study was conducted in four
700 districts, and there may be substantial inter-district variation such that the findings may not

be generalisable to the country as a whole. Finally, social desirability bias cannot be excluded, as interview participants may not have felt comfortable criticising the system or their working conditions. To minimise power dynamics, FGDs were organised in separate groups by hierarchical level and participants were assured of the confidentiality of their responses; however, some reluctance to express criticism may nonetheless have persisted, particularly among civil servants commenting on a national programme.

CONCLUSION

The health information system for malaria surveillance in Burundi has been functioning relatively well for eight years and continues to improve. However, it is still faced with various operational challenges, including the need for a stable internet connection, a lack of computer training amongst users, and an excessive workload for system users. These constraints give rise to disruptions in data quality control and data analysis, with thorough verification carried out only on a monthly basis. These factors prevent the system from operating optimally for the rapid detection of malaria outbreaks. Despite all these challenges, the existence of an online data collection and management system facilitates the rapid transmission of data, swift feedback, and timely error detection at each level. An increase in human and financial resources is key to enabling the system to achieve optimal functioning and to meet its objectives. Addressing persistent gaps in internet connectivity, computer literacy, and the remuneration and workload of community health workers and data officers will be essential for the system to reach its full potential. As the first in-depth evaluation of the DHIS2-based malaria surveillance system in Burundi, this study provides a baseline for monitoring future improvements and can inform targeted digitalisation strategies both nationally and in comparable settings.

Author contributions

RN, TN, YN, VH, PS, CM, JM, and SC designed the protocol; ANA, ON, WVB, and MM reviewed the protocol; ANA and ON extracted the quantitative data; RN collected the qualitative data; RN, TN, MM, and SC analysed the qualitative data; RN and SC analysed the quantitative data; RN, TN, MM, and SC wrote the manuscript, and all authors reviewed the manuscript.

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ANNEX 1A - Interview Guide for Community Health Workers

ANNEX 1B – Interview Guide for Health Information Officers

ANNEX 2 – French Translation of the Article

Supplementary Files

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