

Bringing malaria surveillance closer to the people through digitally linking the private health sector in Kisumu Kenya: a prospective cross-sectional implementation study

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Abstract

Background:

Malaria is resurging in sub-Saharan Africa due to climate change, emerging drug and diagnostics resistance, new vectors and reduced international funding. These challenges highlight the need to expand access to malaria diagnosis and surveillance beyond the public sector. A large share of care seeking occurs in the private sector. Hence, strengthening connections with private providers has the potential to improve diagnostic coverage and close surveillance gaps. In Kenya ~40% of malaria cases are managed in the private sector, however data regarding the quality of care provided and malaria cases in this context remain largely unlinked to routine public malaria surveillance systems. Here we describe a digital mobile engagement of private community-based providers to expand malaria case detection and improve quality of care and completeness of surveillance data.

Methods:

A cross-sectional study was conducted in Kisumu County, Kenya engaging five private health facilities, 25 private chemists, and 50 community health promoters. Providers were digitally supported to perform and report malaria rapid diagnostic tests using an AI-enabled mobile application that captured photographic images of test outcomes and transmitted them to County surveillance dashboards. Analyses examined malaria positivity by provider type, demographic patterns of infection, and distribution of test outcomes across commonly used malaria test brands. Differences were assessed for statistical significance using chi-square tests.

Results:

Between July 2024 and June 2025, 26,090 malaria tests were recorded through an AI-supported digital surveillance system across private health facilities, private chemists, and community health promoters. Overall, 25,993/26,090 (99.6%) test records were valid; 7,035/25,993 (27.1%) were positive. Malaria positivity differed significantly by provider type: 1,523/3,930 (38.8%) among community health promoters, 3,260/9,364 (34.8%) among chemists, and 2,252/12,699 (17.7%) among private health facilities ($p < 0.001$). Positivity was highest among children. WHO prequalified malaria rapid diagnostic test brands showed significant heterogeneous positivity across provider types (all $p < 0.001$).

Conclusions:

Digitally integrating private and community-based providers into malaria surveillance substantially increases the capture of malaria cases into formal surveillance systems and provides important information for targeted quality improvement of the private sector diagnostic performance.

INTRODUCTION

With an estimated 282 million cases and leading to around 610,000 deaths globally in 2024, malaria remains a leading cause of morbidity and mortality [2]. Approximately 95% of malaria-related deaths occur in sub-Saharan Africa (SSA), and the disease is resurging on the continent due to increasing resistance to malaria treatments and diagnostics, the emergence of new vectors and significantly reduced international funding [1]. Climate change will exacerbate this resurgence, and models indicate that under current control efforts, by 20250 there and could be over 120 million additional malaria cases and over 500,00 additional deaths in SSA. In Kenya, around 70% of the population is at risk of malaria, with an estimated 6.7 million clinical cases reported annually [3].

The World Health Organization (WHO) Test, Treat, Track (T3) strategy provides the foundation for malaria control by emphasizing universal diagnostic confirmation, effective treatment, and comprehensive surveillance [4]. However, persistent gaps in implementation continue to undermine the effectiveness of this strategy in high-transmission settings [5]. Increased coordination between public and private efforts is crucial to address some of these gaps. Evidence in SSA indicates 30%-60% of individuals with suspected malaria seek care in the private sector [6]. Kenya is no exception with ~40% of individuals with suspect malaria accessing the private sector, including private health facilities, chemists, and informal community-based providers [8, 9]. Despite managing a substantial share of malaria cases, most of these private providers do not routinely report diagnostic and treatment data into national health information systems and there is widespread uncertainty about the quality of services delivered [7]. This results in fragmented malaria case management and limited accurate geo- and time-tagged information about malaria burden, particularly in settings where private providers serve as the first point of care.

In Kisumu County, western Kenya, chemists and community health promoters (CHPs) play a central role in the management of febrile illness. Although these providers are highly accessible and trusted within communities, they remain largely excluded from formal disease surveillance systems. Small local chemists are not integrated into Kenya's routine malaria reporting platforms, and limited supervision and lack of access to national treatment guidelines contribute to malaria treatment without confirmatory testing or deviation from recommended protocols. Previous studies have highlighted the importance of engaging private and community-based providers to improve surveillance-completeness and enable early case detection [11, 12, 20].

The Kenya Health Information System (KHIS) is Kenya's implementation of the District Health Information System 2 (DHIS2) [13]. Surveillance reporting through KHIS relies predominantly on data from public health facilities, with limited routine reporting from private providers [11, 14]. Recent interruptions to donor-supported digital health infrastructure have further exposed the fragility of this surveillance system that depends heavily on public-sector reporting alone, underscoring the need for complementary and resilient approaches to malaria surveillance [22, 23].

To address persistent gaps in malaria surveillance, particularly the under-representation of cases that are managed outside the public sector, this study explored an approach that links private and community-based providers to routine reporting systems. A key concern of involving data collection through the private health sector in Africa is lack of quality, completeness and timeliness of such data [11, 14, 23]. With the advent of digital mobile healthcare decision support tools as well as digital data collection and verification tools, this issue can be addressed and (at least partly) quantified.

In this article, we report an intervention in Kisumu County, Kenya. The 'Connected Diagnostics' (ConnDx) project facilitated the routine capture of malaria diagnostic data from private health facilities, private chemists, and community health promoters (CHPs). Malaria rapid diagnostic test (mRDT) results were digitized through mobile phone-based photographic capture using a customized App (HealthPulse) and transmitted to County-level dashboards directly accessible to tablets and mobile phone of the Department of Health (DoH) [10, 19]. HealthPulse supported offline data capture on low-end mobile phones to accommodate low-connectivity settings, allowing results to be synchronized once connectivity is restored. By facilitating routine reporting from providers who are frequently the first point of care for febrile illness, this approach aimed to expand the connectivity and visibility of malaria testing results beyond formal (public) health facilities and closer to communities where transmission occurs

A consequence of engaging private-sector providers is that a broader range of different malaria rapid diagnostic test (mRDT) brands is used than typically seen in the public sector, where diagnostics are procured centrally. In such pluralistic private diagnostics markets [18], there is the potential for heterogeneity in test outcomes and lot-to-lot performance, with implications for the accuracy and comparability of surveillance data [17]. This study examines the pros and cons, surveillance gains and quality challenges associated with digital private-sector engagement in malaria testing to inform malaria surveillance strategies. We assess malaria testing volume, result validity, and positivity patterns across different private provider types, patient profiles, and commonly used mRDT brands.

METHODS

Study setting and design

This cross-sectional implementation study was conducted in Kisumu County, western Kenya, between May 2024 and June 2025, with active malaria testing and digital reporting from July 2024 to June 2025. A total of five private health facilities, 25 chemists, and 50 community health promoters (CHPs) from five Community Health Units (CHUs) participated. A hubs-and-spokes model was applied, with private health facilities serving as hubs and chemists and CHPs acting as community-level spokes. The study was implemented across four sub counties - Kisumu East, Nyando, Nyakach, and Kisumu West - representing both peri-urban and rural settings.

Site selection and phased implementation

Sites were selected in consultation with the Kisumu County DoH. Selection criteria for private health facilities included facility level, ownership type, patient volume, and geographic location. Chemists were selected based on routine provision of malaria-related services, accessibility, and willingness to participate in digital reporting. CHPs were selected from CHUs affiliated with the participating private health facilities. Ownership of a mobile phone was required for participation.

The study was implemented in two phases. Phase I (May-November 2024; active data collection July-November 2024) included two private health facilities, 10 chemists, and 20 CHPs. Phase II (November 2024-June 2025) expanded participation to a total of five private health facilities, 25 chemists, and 50 CHPs. Phasing of this study was related to experiments in digital incentivization of participation, as described elsewhere [29].

Intervention and digital surveillance linkage

The intervention consisted of digitally linking malaria testing conducted by private and community-based providers to routine surveillance systems using the ConnDx approach. Providers recorded malaria test results using the HealthPulse mobile application, creating a complementary reporting layer to the KHIS and enabling routine capture of malaria diagnostic data in real time from providers not typically represented in national surveillance.

Three-monthly review meetings were held with the Kisumu County DoH to compare ConnDx data with KHIS reports, identify discrepancies, enhance data quality and guide supportive supervision.

Data Collection Tool: HealthPulse App

Malaria testing and reporting were conducted using the HealthPulse mobile application (Fig. 1), which was configured with step-by-step instructions to guide providers through the diagnostic process. At the start of each consultation, the provider entered basic patient information (age, sex, pregnancy status) and then selected the mRDT brand they would use to conduct a malaria test. The app then displayed test-specific instructions, as well as a timer, tailored to the brand of mRDT in use, ensuring adherence to manufacturer guidance. A unique 4-digit code was generated to write down on the mRDT cassette to ensure a unique test ID and prevent mRDT reuse.

After completing the mRDT procedure, the provider used the app to capture a standardized photograph of the test cassette, where test results were displayed. The app's built-in quality controls ensured that the full test strip was visible, properly lit, and aligned before accepting the image. The image was then uploaded for back-end quality control classification as positive, negative, invalid, or uninterpretable, using AI. The provider had no access to this back-

end classification. After photographing the mRDT, the provider entered their own interpretation of the test result in the app. This interpretation was used as the standard for patient care, in accordance with Kenyan national malaria guidelines.

The HealthPulse app stored patient metadata, provider interpretations, and back-end quality control outputs in a secure, cloud-based system. Results were automatically fed into real-time Power BI dashboards accessible by the Kisumu County DoH and research teams, allowing monitoring of test volumes, positivity rates, and demographic patterns by provider type and mRDT brand. This standardized digital workflow ensured that each malaria test was accompanied by verified metadata and harmonized reporting, strengthening the reliability of surveillance data.

The HealthPulse app was specifically designed to fit into the malaria care pathway, supporting frontline healthcare providers (Fig. 2). When a patient presenting with fever sought care at a participating health facility, chemist, or through a CHP (Step 1), the provider recorded basic demographic details in the app, creating a traceable digital record for each suspected malaria case. The provider then performed an mRDT, guided step by step by the app and captured an image of the test result. Digital testing instructions were available for eight WHO pre-qualified mRDT brands commonly used in Kenya.

Integration of ConnDx into the malaria care pathway

Clinical decision-making regarding malaria treatment was based exclusively on provider visual interpretation, in line with national guidelines (Step 2). Providers were guided to treat or refer patients as appropriate, and CHPs tested but did not treat pregnant women.

Verified test results and associated patient information were uploaded in real time to a secure digital database, which triggered digital incentives to support routine testing and reporting (Step 3). At the same time, aggregated data were visualized through dashboards accessible to the Kisumu County DoH (Step 4). County teams used these dashboards to monitor malaria trends, plan supportive supervision and retraining, reinforce appropriate testing and treatment practices, and support timely public health responses (Step 5).

Training, supervision, and implementation support

Participating providers received standardized training on malaria case management and use of the HealthPulse app. Malaria case management training was delivered by the Kisumu County DoH and focused on appropriate testing, result interpretation, and referral in accordance with national guidelines. Training also covered digital reporting, standardized image capture and data entry. Training was adapted to provider roles and delivered in formats designed to minimize disruption to routine service delivery. Periodic supportive supervision was provided throughout the project period.

To support routine testing and reporting during implementation, modest digital incentives were provided. During Phase I, providers received mobile data bundles (50 MB per correctly uploaded test), supplemented by a monthly 500 MB data provision to enable routine data synchronization. During Phase II, a small per-test monetary reimbursement (15 Kenyan Shillings per correctly uploaded test) was introduced in addition to the data bundles. These incentives were implemented to offset reporting costs and encourage confirmatory testing before treatment and consistent submission of test results. Incentives were independent of test outcomes and were not evaluated as primary outcomes in this analysis. Findings related to these interventions are elaborated elsewhere [29]. At the start of each phase, each provider was supplied with two free boxes of mRDTs (Paracheck) to facilitate commencement of malaria testing and data reporting.

Data management and analysis

Malaria testing data was aggregated by provider type, mRDT brand, and patient demographics. Analyses were structured to address the study objectives. Diagnostic yield when testing was delivered closer to communities was assessed by comparing malaria positivity proportions across provider types using chi-square tests of independence. Variability in test outcomes across mRDT brands was examined using chi-square tests, stratified by provider type, with invalid test results included to assess operational reliability. Brands with very small testing volumes (< 10) were excluded from interpretive comparisons to avoid unstable estimates.

Demographic distribution of malaria positivity was analyzed by age group (0–4, 5–17, 18–39, 40–59, and 60+ years), sex and pregnancy status. These age categories were defined to reflect standard malaria risk and transmission strata [1], including young children (0–4 years), school-aged children (5–17 years), reproductive-age adults (18–39 years), and older adult groups (40–59 and ≥ 60 years). Statistical significance was assessed at the 95% confidence level ($p < 0.05$). Analyses were conducted using R software.

RESULTS

Malaria testing volume and validity by provider type

Between July 2024 and June 2025, a total of 26,090 malaria tests were recorded across private health facilities, chemists, and CHPs (Table 1). Overall, 25,993/26,090 (99.6%) test records yielded valid results, while 97/26,090 (0.4%) were classified as invalid by the tester.

Testing activity was monitored through county-accessible dashboards displaying cumulative test volumes, positivity patterns, and the geographic distribution of reporting provider units across Kisumu County (Figure. 3).

Private health facilities contributed 12,750/26,090 (48.9%) of all tests, followed by chemists with 9,380/26,090 (36.0%) and CHPs with 3,960/26,090 (15.2%). Validity (and thus invalidity) differed slightly but significantly across provider types (Pearson $\chi^2 = 26.4$, $df = 2$, $p < 0.001$) exceeding 99% across all settings.

(Table 1). Correspondingly, invalid results ranged from 16/9,380 (0.2%) among chemists to 30/3,960 (0.8%) among CHPs.

Among valid tests, overall malaria positivity was 7,035/25,993 (27.1%), with provider-specific positivity of 1,523/3,930 (38.8%) among CHPs, 3,260/9,364 (34.8%) among chemists, and 2,252/12,699 (17.7%) among private health facilities (Table 1). Differences in positivity across provider types were statistically significant (Pearson $\chi^2 = 1117$, $df = 2$, $p < 0.001$).

Table 1
Malaria testing volume, validity, and positivity by provider type

Provider type	Valid tests n/N (%)	Invalid tests n/N (%)	Positive tests n/N (%)
CHPs	3,930/3,960 (99.2)	30/3,960 (0.8)	1,523/3,930 (38.8)
Chemists	9,364/9,380 (99.8)	16/9,380 (0.2)	3,260/9,364 (34.8)
Private health facilities	12,699/12,750 (99.6)	51/12,750 (0.4)	2,252/12,699 (17.7)
Total	25,993/26,090 (99.6)	97/26,090 (0.4)	7,035/25,993 (27.1)

Demographic profiles of individuals tested for malaria by provider type

Demographic profiles of individuals tested differed significantly across provider types (Table 2). Gender distribution varied slightly, but significantly by provider type (Pearson $\chi^2 = 47.7$, $df = 4$, $p < 0.001$). Female clients more frequently tested for malaria at formal private health facilities 6,790/13,714 (49.5%), compared with chemists 4,825/13,714 (35.2%) and CHPs 2,099/13,714 (15.3%). Male clients tested at private health facilities 5,948/12,337 (48.2%), followed by chemists 4,548/12,337 (36.9%) and CHPs 1,841/12,337 (14.9%). Unknown gender was rare ($n = 39$; $<0.2\%$) and was therefore not included in comparative interpretation across provider types.

Age distribution differed substantially across provider types (Pearson $\chi^2 = 2275.5$, $df = 8$, $p < 0.001$). CHPs contributed a disproportionately high share of tests among children aged 0–4 years 1,138/3,442 (33.1%) relative to chemists 657/3,442 (19.1%), while private health facilities contributed 1,647/3,442 (47.9%). For school-aged children (5–17 years), private health facilities contributed 3,443/7,533 (45.7%), chemists 2,403/7,533 (31.9%), and CHPs 1,687/7,533 (22.4%). In contrast, private health facilities accounted for many tests among older adults aged ≥ 60 years 1,071/1,678 (63.8%), compared with chemists 510/1,678 (30.4%) and CHPs 97/1,678 (5.8%).

Pregnancy status among female clients also differed markedly by provider type (Pearson $\chi^2 = 798.5$, $df = 2$, $p < 0.001$). Among tests from pregnant women, private health facilities contributed 1,244/1,481 (84.0%), compared with chemists 200/1,481 (13.5%) and CHPs 37/1,481 (2.5%). Among tests from non-pregnant women, private health facilities contributed 5,546/12,233 (45.3%), chemists 4,625/12,233 (37.8%), and CHPs 2,062/12,233 (16.9%).

Table 2
Demographic profiles of individuals tested for malaria by provider type

Characteristic	Chemists n/N (%)	CHPs n/N (%)	Health Facilities n/N (%)
Sex			
Female	4,825/13,714 (35.2)	2,099/13,714 (15.3)	6,790/13,714 (49.5)
Male	4,548/12,337 (36.9)	1,841/12,337 (14.9)	5,948/12,337 (48.2)
Age			
0–4	657/3,442 (19.1)	1,138/3,442 (33.1)	1,647/3,442 (47.9)
5–17	2,403/7,533 (31.9)	1,687/7,533 (22.4)	3,443/7,533 (45.7)
18–39	4,438/9,791 (45.3)	789/9,791 (8.1)	4,564/9,791 (46.6)
40–59	1,372/3,646 (37.6)	249/3,646 (6.8)	2,025/3,646 (55.5)
≥ 60	510/1,678 (30.4)	97/1,678 (5.8)	1,071/1,678 (63.8)
Pregnancy			
Yes	200/1,481 (13.5)	37/1,481 (2.5)	1,244/1,481 (84.0)
No	4,625/12,233 (37.8)	2,062/12,233 (16.9)	5,546/12,233 (45.3)
Total	9,380/26,090 (36.0)	3,960/26,090 (15.2)	12,750/26,090 (48.9)

Malaria test outcomes by mRDT brand and provider type

Abbott/SD Bioline, First Response, Meriscreen, and Paracheck were the most recorded mRDT brands across provider types (Table 3). Across all provider types, malaria positivity varied substantially by brand. Among CHPs, positivity ranged from 152/551 (27.6%) with Meriscreen to 184/418 (44.0%) with Abbott/SD Bioline, while Paracheck accounted for the largest testing volume (2,511 tests) with 1,035/2,497 (41.4%) positivity. Among chemists, positivity ranged from 1,113/3,646 (30.5%) with First Response to 183/474 (38.6%) with Abbott/SD Bioline, while First Response contributed the largest testing volume (3,651 tests) with 1,113/3,646 (30.5%) positivity. Positivity in formal health facilities was consistently lower across all brands, ranging from 168/1,480

(11.4%) with Meriscreen to 291/1,065 (27.3%) with Abbott/SD Bioline, despite high testing volumes for First Response (6,883 tests; 1,068/6,841 (15.6%) positivity).

Within each brand, malaria positivity differed across provider types (Abbott/SD Bioline: $\chi^2 = 44.5$, $df = 2$, $p < 0.001$; First Response: $\chi^2 = 350.0$, $df = 2$, $p < 0.001$; Meriscreen: $\chi^2 = 218.0$, $df = 2$, $p < 0.001$; Paracheck: $\chi^2 = 239.0$, $df = 2$, $p < 0.001$). Invalid results ranged from 0.0% to 1.7% across brand provider strata (Fig. 4).

Table 3
Malaria test outcomes by mostly used mRDT brands and provider type.

mRDT brand	CHPs Positive n/N (%)	Chemists Positive n/N (%)	Private facilities Positive n/N (%)
Abbott/SD Bioline	184/418 (44.0)	183/474 (38.6)	291/1,065 (27.3)
First Response	131/397 (33.0)	1,113/3,646 (30.5)	1,068/6,841 (15.6)
Meriscreen	152/551 (27.6)	272/715 (38.0)	168/1,480 (11.4)
Paracheck	1,035/2,497 (41.4)	520/1,489 (34.9)	689/3,075 (22.4)
Total	1,502/3,863 (38.9)	2,088/6,324 (33.0)	2,216/12,461 (17.8)

DISCUSSION

This study demonstrates that routine digital capture of mRDT results from private health facilities, chemists, and CHPs in SSA can generate data that are complementary to public sector efforts. This facilitated improved and more complete monitoring and surveillance, which provides the best-possible information to health policy makers and managers to make decisions on targeting actions to improve quality of malaria care.

We recorded marked differences in malaria case finding rates, dependent on private provider type, with a remarkably higher positive case finding rate in informal community-proximate channels as compared to formal private health facilities [9, 14, 21]. This can be explained by differences in types of clients and how and when they seek care across community-based, retail, and clinic settings [8, 9, 20]. Indeed, we demonstrated that the demographic distribution of individuals tested differed significantly across provider channels. CHPs contributed a disproportionately high share of malaria testing among children and adolescents, whereas private health facilities accounted for most testing among older adults and pregnant women. Clearly community-proximate providers serve as important and complementary access points for populations who are less routinely present in clinics. This highlights the surveillance value of integrating chemists and CHPs, as they extend malaria case detection closer to transmission reservoirs that are often underrepresented in facility-based reporting [12, 14, 21, 25]. Malaria case management in the private sector is shaped by pricing, access, provider behavior, and client preferences, all of which influence testing uptake and the case mix presenting at different points of care [8, 9, 20]. Community and retail testing channels capture symptomatic individuals earlier or those less likely to attend clinics, contributing to detection of infections outside formal facilities [12, 26].

An additional explanation of the marked differences in malaria positivity rates with various types of private providers could be differences in quality of their diagnostic services. In the study setting, as expected with more fragmented supply chains [9, 18], we observed a high diversity of mRDT brands used and significant differences of malaria test results across provider types. This is a remarkable finding, because all mRDTs used in private facilities complied with WHO prequalification standards. Differences in positivity across brands and significant within-brand differences by provider type indicated significant diagnostic heterogeneity. This could be due to a multitude of factors, including storage conditions, surpassed expiry dates, lot-to-lot reagent variability [17], incorrect or suboptimal performance of the mRDT test by providers. However, the numbers of invalid mRDT outcomes in our setting were relatively low (0.4%), not directly indicating a general failure to correctly perform the tests.

This study provided evidence that digital mobile approaches can complement public sector efforts by strengthening routine reporting of malaria test outcomes and improving visibility of care through private facilities that are closer to the population. Importantly, the increased transparency of malaria collected have the potential to be used to rapidly improve the performance of the private sector. The information generated can, for example, be used by Kisumu DoH for the targeted training of private providers that demonstrate aberrant results.

Strengths and limitations

This study has several notable strengths. To our knowledge, this is the first study in Kenya to prospectively and systematically integrate private health facilities, private chemists, and community health promoters into a single, unified digital malaria surveillance system, generating real-time linked data across all three provider types simultaneously. The study is further strengthened by its robust data collection approach. The HealthPulse mobile application ensured standardized data capture through photographic mRDT verification, built-in quality controls, and automated transmission to county-level dashboards, minimizing the risk of data loss or transcription errors that typically affect paper-based surveillance systems. The large sample size of 26,090 tests recorded over a 12-month period across peri-urban and rural sub-counties provides a substantial and representative dataset for examining malaria positivity patterns and diagnostic heterogeneity in the private sector. Finally, the real-time linkage of private sector data to County DoH dashboards represent a replicable model for strengthening malaria surveillance beyond the public sector in resource-limited settings.

The findings have several limitations. First, they rely on routine digital records rather than a controlled study design, and testing volumes and case mix, likely differed across provider types due to variation in care seeking behavior, access, and provider practices, which may influence observed positivity patterns [8, 9, 20, 26]. Second, the dataset captures diagnostic outcomes but includes limited clinical detail, preventing assessment of symptom severity, prior treatment, referral completion, or treatment outcomes, all of which are relevant for interpreting differences in diagnostic yield across settings or test seeking behaviors

[4, 9]. Third, multiple mRDT brands were used through routine private-sector supply chains, and differences in product characteristics, lot variability, storage conditions, and handling had unquantified contributions to variation in observed positivity across provider type and brand strata [17, 18]. Finally, although invalid results were rare, routine reporting may still be subject to data entry error and misclassification, and findings should be interpreted as reflecting operational surveillance performance and diagnostic yield rather than definitive estimates of infection prevalence in the underlying population [14, 21, 25].

CONCLUSION

Routine digital capture of mRDT outcomes from private health facilities, chemists, and CHPs can provide valuable insights in quality, timeliness and completeness of test results and enables complementary monitoring of malaria positivity patterns outside routine public facility reporting. In addition, by involving the private sector closer-to-home, other client profiles are covered that are normally underrepresented in formal public sector facilities. All in all, digitalization of mRDT through mobile photography allows for ‘looking over the shoulder’ of private providers who previously created unknown results. We identified marked differences in malaria prevalence data between different mRDT brands used in different private settings, identifying quality issues that are actionable. Digital point-of-care malaria monitoring allows for linking previously unconnected private malaria care providers, while generating invaluable real-time data that allow for targeted quality improvement.

ABBREVIATIONS

Abbreviation	Definition
AI	Artificial Intelligence
CHPs	Community Health Promoters
CHUs	Community Health Units
ConnDx	Connected Diagnostics
D2A	Data to Action (an approach that emphasizes using surveillance and research data to guide programmatic decisions)
DoH	Department of Health
HMIS	Health Management Information System (the routine national system for collecting, analyzing, and reporting health service data)
KHIS	Kenya Health Information System
MIS	Malaria Indicator Survey (a nationally representative household survey used to measure malaria burden and intervention coverage)
mRDTs	Malaria Rapid Diagnostic Tests
NMCP	National Malaria Control Program (the government program responsible for malaria prevention, diagnosis, treatment, and surveillance)
OTSS	Onsite Training and Supportive Supervision (a quality assurance approach where supervisors provide hands-on training and mentorship at h
SBC	Social and Behavior Change (strategies to influence community knowledge, attitudes, and practices around malaria prevention and treatme
T3	Test, Treat, Track
VC	Vector Control (interventions targeting malaria-transmitting mosquitoes, such as insecticide-treated nets and indoor residual spraying)
WHO	World Health Organization

DECLARATIONS

Ethics approval and consent to participate

Ethical approval was obtained from the Maseno University Scientific and Ethics Review Committee (MUSERC/01375/2024). Given that the study was embedded within standard malaria care and did not involve the collection of identifiable personal data, individual patient consent was waived. All participating providers gave informed consent prior to inclusion.

Consent for publication

Not applicable. This manuscript does not contain any individually identifiable data, images, personal details, or videos of any individual person.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

NO: Conceptualization, project implementation, data curation, formal analysis, writing original draft, and writing review and editing. FB: Methodology, ethics approval, and writing review and editing. KOO: writing review and editing. LS: Conceptualization, funding acquisition, and writing review and editing. CK: Software (dashboard development and database integration). NH: Project administration GPG: Conceptualization and writing review and editing. AK: Data collection and investigation. SK: Supervision and review. PI: Software development and methodology. CP: Writing review and editing. LD and GG: Project administration partners. JR and JMC: Supervision, funding acquisition, and writing review and editing. TFRdW: Conceptualization, supervision, funding acquisition, writing review and editing.

All authors read and approved of the final manuscript.

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Data Availability

The datasets generated and analyzed during this study is available from the Kisumu County Department of Health upon reasonable request. Data is locally hosted and owned.

Availability of data and materials

Aggregated study data supporting the findings of this study are available from the Kisumu County Department of Health upon reasonable request. Data is locally hosted and owned. Facility-level data remain protected due to privacy considerations and ethical approvals.

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Figures

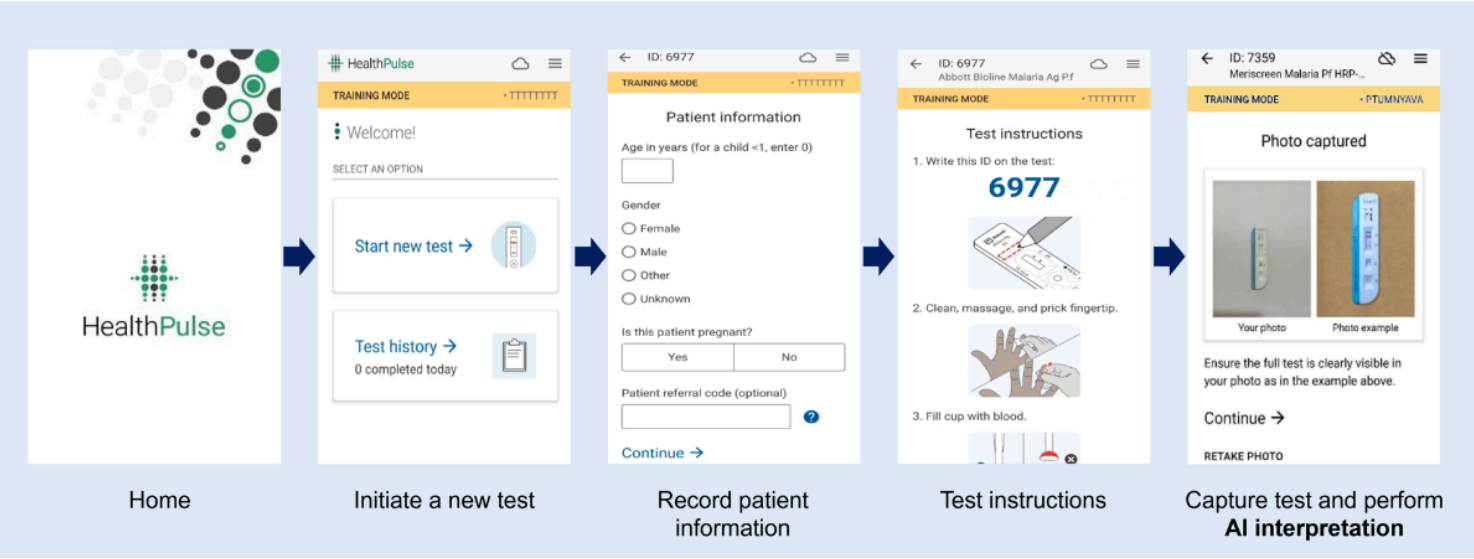
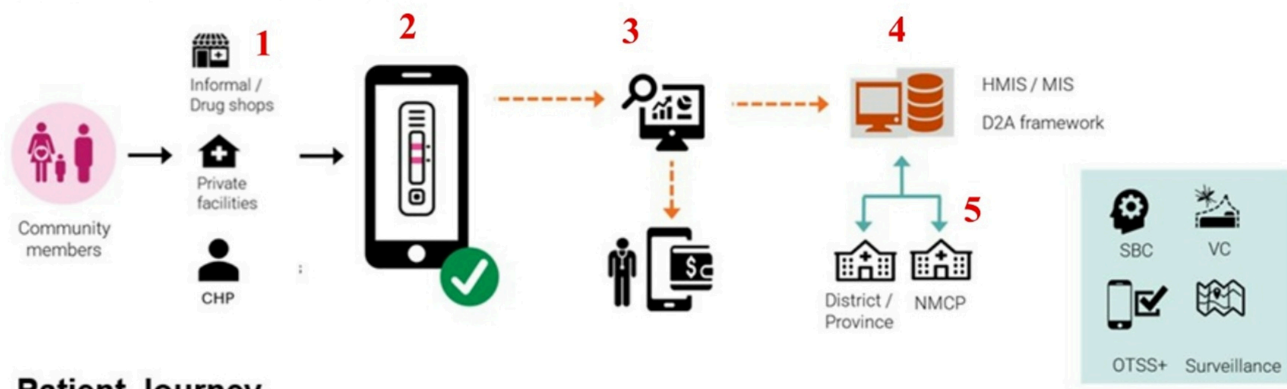


Figure 1

HealthPulse App. This figure depicts from left to right the steps followed by the provider when using the app to conduct a mRDT. Fourth figure from the left shows the unique identifier number (here 6977) that providers must write on the mRDT before the result is captured to ensure unique test ID and prevent multiple usage.

Health System & Data Flow



Patient Journey

- 1 Treatment-seeking, private sector focus
- 2 Confirmation of RDT completion and result, with AI interpretation
- 3 Push to ConnDx, confirmed RDT result triggers digital subsidy to provider
- 4 Increased data optics, oversight for the County DoH
- 5 Informed and targeted response by supervisors or government partners

5

Figure 2

ConnDx Health System and Data flow

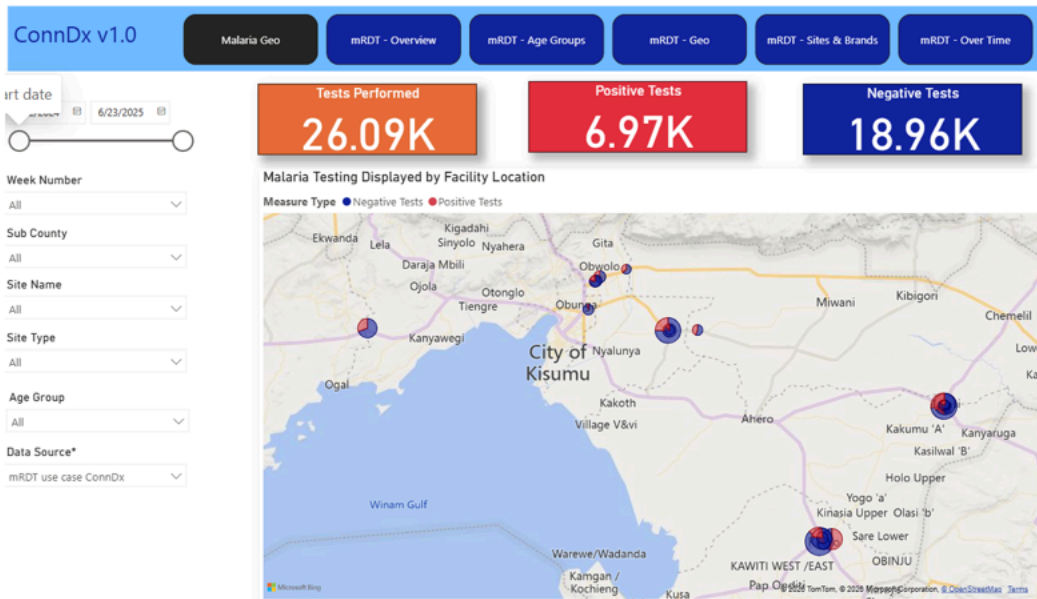


Figure 3a

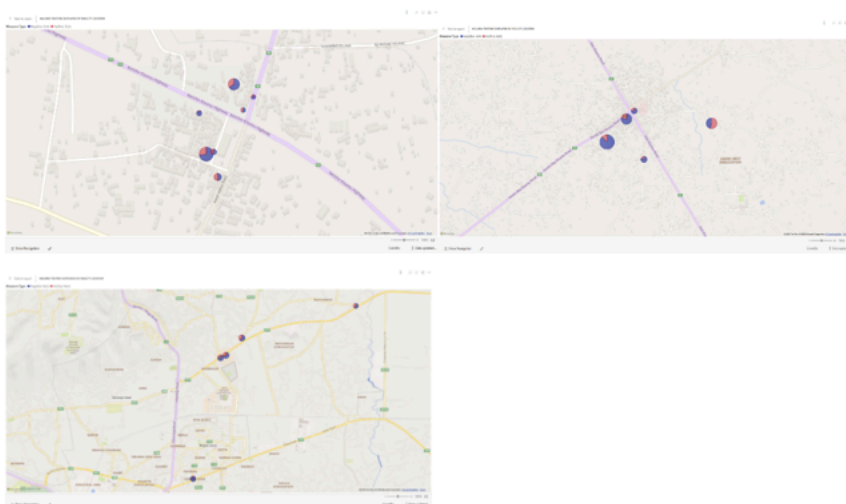


Figure 3b

Figure 3

3a. ConnDx malaria surveillance dashboard. Showing cumulative malaria testing volumes and geographic distribution of reported results across Kisumu County, July 2024-June 2025. Invalid tests are not shown due to small numbers.

3b. Zoomed-in views of the ConnDx malaria surveillance dashboard showing private chemists enrolled in the project across Kisumu County

Unit-level malaria positivity by provider type and mRDT brand (4 brands)

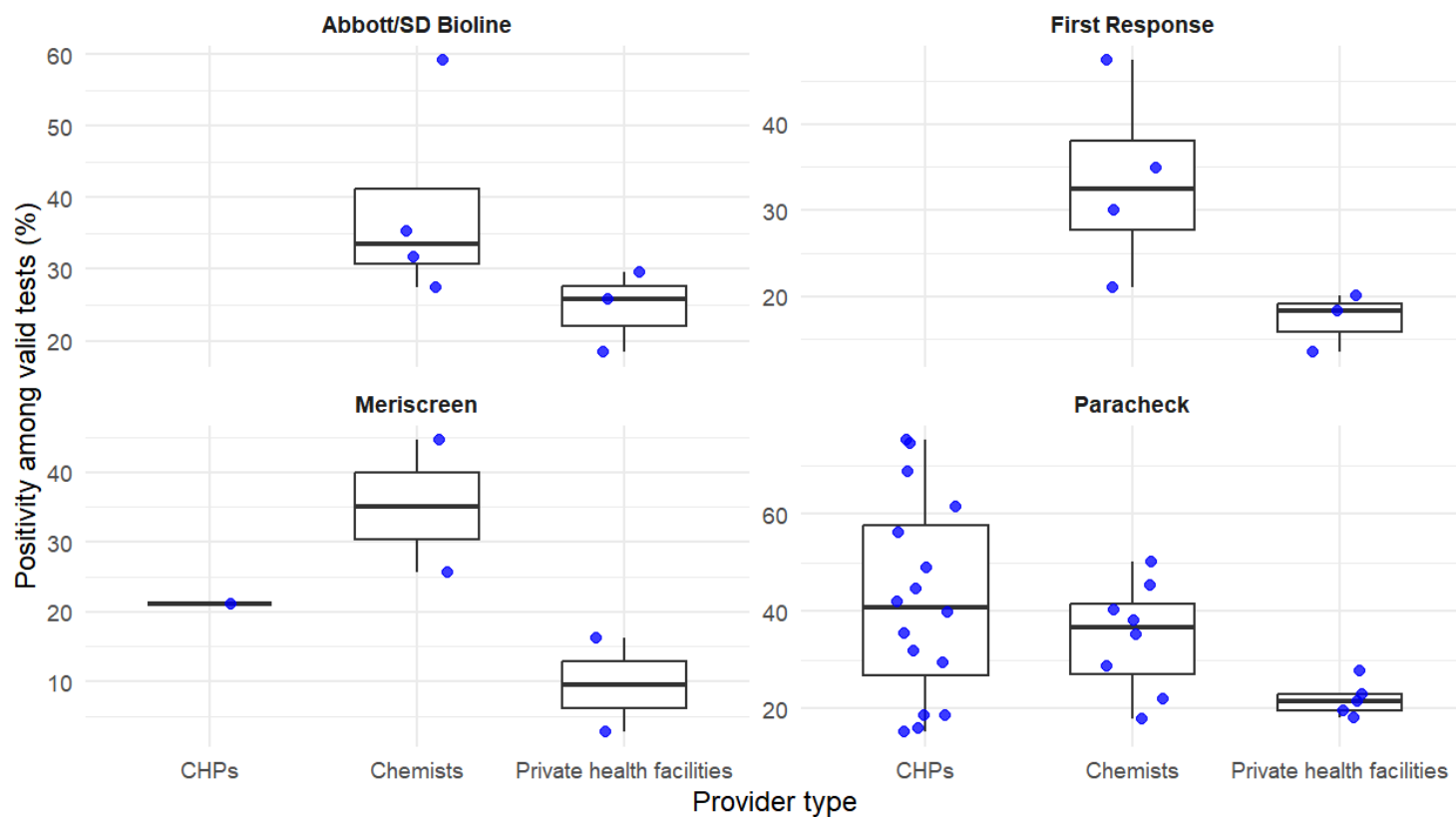


Figure 4

Unit-level malaria positivity among valid tests by provider type and mRDT brand. Boxplots show the distribution of positivity (%) across anonymised provider units within each provider type. Points represent provider units meeting the stability threshold (≥ 50 valid tests per unit within brand). The central line represents the median unit-level positivity, and the box indicates the interquartile range. Points represent individual provider units, illustrating variability and outlier units with disproportionately high positivity within specific brand-provider strata.