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Improving the management of hypertension and diabetes: An implementation evaluation of an electronic medical record system in Nairobi County, Kenya

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ABSTRACT

Objective: To evaluate the implementation of a novel electronic medical record (EMR) system for management of non-communicable diseases (NCD) (hypertension (HTN) and diabetes mellitus (DM)) in health facilities in informal settlements in Nairobi. Questions of interest were on the use of, perception of the HCWs, and scalability and sustainability of the EMR system.

Method: The study utilised a descriptive and analytical implementation evaluation through a convergent parallel mixed-methods design in 33 health facilities in the informal settlements in Nairobi County, Kenya. We carried out semi-structured interviews with the county and sub-county health management staff (n = 9), facility in-charges (n = 8), healthcare workers (HCW) (n = 35), and project staff (n = 7). Additionally, quantitative analysis, trend analysis, critical evaluation and costing were done. Qualitative data were analysed thematically using NVIVO while quantitative data were analysed using Excel and Stata software.

Results: The EMR system significantly improved data capture and management of HTN and DM patients. The system helped clinicians to adhere to treatment and management guidelines and in clinical decision making. Most HCWs had a positive attitude and perceptions about the EMR system, and it was a good initiative for improving the quality and standardisation of care. The data captured made it easier to generate health facility and clinics reports which were essential for planning and decision-making processes. A critical audit of the EMR system features showed adequate general design features (data elements, structure and organisation, ease of use, accessibility, interfaces, confidentiality, access limitation, accuracy and integrity).

Discussion: Use of the EMR helped in improving patients care. The technology not only enhanced assurance of patients' information safety and availability but also supported in clinical decision making and standardisation of care. Successful implementation of the technology is dependent on positive perception and attitude of the HCWs. While the initial cost of setting and managing the EMR is high, future maintenance cost could be lower, making it sustainable in the long run. However, it is vital for future implementors to source for adequate funds to run it to completion if it is to achieve its objective.

Abbreviations: CVDs, Cardiovascular Diseases; EMR, Electronic Medical Records System; NCDs, Non-Communicable Diseases

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1. Introduction

Electronic medical record (EMR) is a system that helps to create and manage patients' data such as complaints, lab orders, diagnosis, procedures and treatment electronically [1]. It is an enabling technology that allows hospitals to pursue essential quality improvement programs which could lead to healthcare savings, reduction of medical errors, improvement of implementation of care guidelines, and provision of data for decision support [2]. However, adoption of EMRs faces barriers such as high cost of procuring and maintaining the system, inadequate network infrastructure, and difficulty in use among HCWs [3]. Other barriers are difficulties with technology, slow and uncertain financial payoffs, high initial physician time costs, electronic data exchange issues, and physicians' attitudes [2].

Use of EMRs has increasingly been taken up to support healthcare constrained systems in delivering maternal and child health, HIV and tuberculosis (TB) programs [3–7]. Despite the progress in use of EMR, their penetration is still remarkably low [3,8]. Significantly, the use of EMRs in the field of non-communicable diseases (NCDs) is particularly limited in low and middle-income countries (LMICs) [9] despite the increasing burden of the disease in the setting and barriers of institutional surveillance capacities [9,10]. There have been only a few implementations of EMRs for the NCD care in LMICs; nonetheless, those that have been implemented have shown some improvements in health outcomes [11–14].

Kenya is one of the LMICs that face a significant burden of NCDs as they account for 50 % of hospital admissions and 55 % of hospital mortalities [15,16]. Cardiovascular diseases (CVDs) lead NCD mortality due to high prevalence of multiple risk factors such as hypertension (HTN), diabetes (DM), cholesterol, smoking, and obesity [16]. While the proportion of HTN and DM varies across different communities and counties in Kenya [17,18], the overall proportions of HTN in the country is 21.4 % [19] while that of DM is 4.56 % [15]. Consequently, the government of Kenya has developed strategies to encourage use of sustainable EMRs particularly in the public health sector hospitals [20,21] and bridge the gap in NCD management. Additionally, Kenya has developed guidelines to help in managing NCDs [16,22]. Despite there being guidelines, the nationally unified system to record NCDs has been shown as vulnerable, with inadequate testing mechanisms for quality assurance notwithstanding the increasing patient numbers [23]. While other health indicators are collected through the Kenya Health Information System (KHIS), which is a free open source database used for collecting and analysing health information [24], there is a gap in collecting detailed patient information rather than just the aggregate numbers. Therefore, basic health care facilities must be able to collect and release relevant data on NCD either through innovation or by using manually data recording booklets.

Consequently, the government and several partners are playing a role in developing and implementing innovative technologies to help in patient data collection [25,26]. One such partner is the German Ministry for Economic Cooperation and Development, which funded the development of an EMR system that would use innovative technology to improve data capture and management of HTN and DM in Kenya. The system was implemented by Malteser International (MI) through African Institute for Health and Development (AIHD) and IntelliSOFT Consulting Limited in collaboration with Nairobi County Government. The system provided a platform that would digitise DM and HTN patients' data in 45 health facilities in four sub-counties of Nairobi County, namely; Embakasi East, Embakasi West, Westlands and Roysambu / Ruaraka. The ultimate goal was to improve NCD health information; thereby, enhancing the quality of care and also developing tools that could continue to be used by the government in the future. The implementation strategy is shown in Fig. 1.

The project commenced in October 2016 though the actual implementation started in March 2017 when AIHD was identified as the implementer and recruited the system developer in September 2017. The EMR system was developed in January 2018 and piloted in eleven facilities from September 2018 to February 2019. In March 2019 it was expanded to cover 45 facilities and has been operational to date. It aimed at providing high-quality data as a prerequisite for better information and decision-making on NCD. While facility capacity assessment, baseline and midline survey of the projects were conducted, there was need to explore the *acceptability*, sustainability and *uptake* of the EMR.

Therefore, in this study, we present the results of an evaluation of implementation of this novel EMR system for management of HTN and DM in health facilities in informal settlements in Nairobi County. The paper makes contribution to medical informatics by showing: first, the use of the EMR *(uptake and adaptability, acceptability and facilitators, and barriers)* of the EMR system; and second, the software design features and their cost of development and maintenance (*design features*, *scalability* and *sustainability* of the system). The questions are key in addressing successful implementation process of an EMR.

2. Methods

2.1. Study design

We utilised descriptive and analytical implementation evaluation through a convergent parallel mixed-methods design. The qualitative methods were used to explore the perception of the HCWs in using EMR while the quantitative methods were used to answer the questions on use of the EMR, the software design features and the cost of development and maintenance. The findings from both methods were analysed separately, compared or related and then used to interpret findings [27]. We chose the design since findings from each part of the study enhanced understanding of the depth and breadth of the EMR system.

2.2. Study setting

The study was conducted in 33 out of 45 health facilities in the informal settlements of four sub-counties in Nairobi County, namely: Westlands, Ruaraka, Embakasi East and Embakasi West. Despite implementing the EMR system, twelve facilities were excluded from the study due to high turnover of staffs, administrative protocol challenges, late recruitment into the project, and having zero number of patients registered.

2.3. Study population, sampling and sample size

The study population included 52 HCWs from 33 hospitals (12 private/Faith-based organisations and 21 public health centres and dispensaries) (Table 1). The HCWs were either facility in-charges, clinical officers, nursing officers, records officers, sub-county medical officers, or NCD focal persons who were purposively selected based on their experience with the EMR system. Most (46 %) were 24 years and below, 63 % had a diploma level of education, and 60 % had used computers for six years and above (Table 1). Further study respondents were project staff from AIHD, MI, and IntelliSOFT (n = 7). Additionally, we critically evaluated the general design features of the EMR system amongst one HCW in each of 13 purposively selected hospitals out of the 33. Three factors determined the purposive selection of facilities for critical evaluation: the number of patients (volume) that had been recorded in the EMR system in the facility, presence of staff trained on the EMR system, and discussions with the sub-county officials who were managing all the hospitals. The recommended 13 were all high-volume facilities that were within the four sub-counties that had recorded a high number of patients. Only one HCW in each of the 13 facilities, who had been trained about the system and had remained with the facility after training for more than a year, was chosen to respond to the critical evaluation questions. Because of the selection criteria, the 13 were among the 52 overall HCWs respondents.

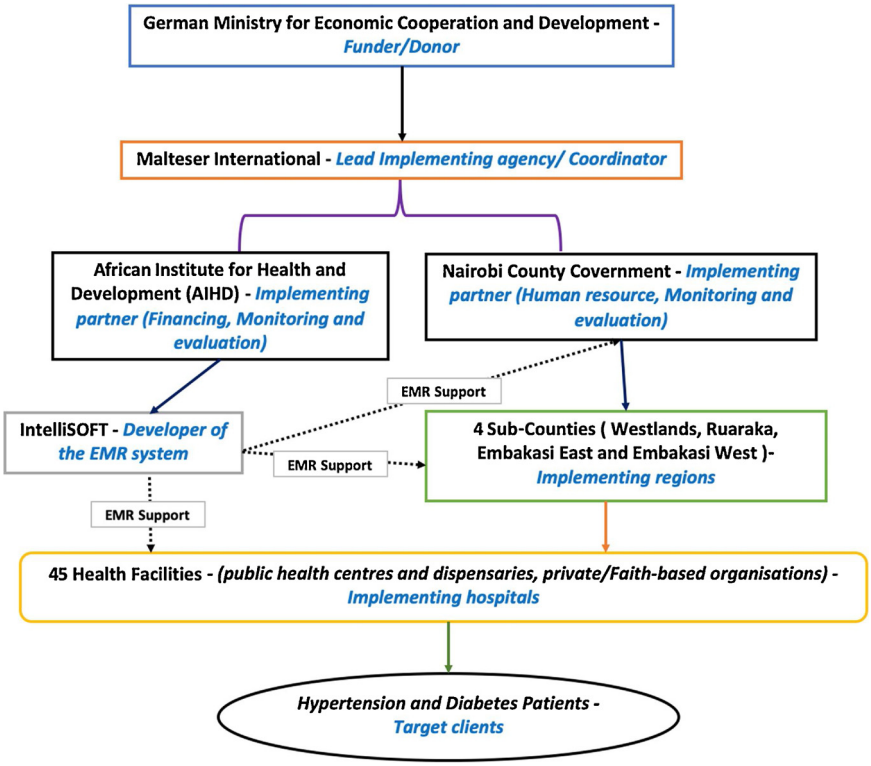

Fig. 1. Implementation of the EMR system.

Table 1
Summary of characteristics of the hospital and respondents from hospitals.

	Characteristics	Frequency	Proportion
Hospital *(n = 33)*	Public health centres and dispensaries	21	64%
	Private/Faith-based organisations	12	36 %
Interviewee designation *(n = 52)*	Facility in-charges	8	15%
	Clinical officers	25	48%
	Nursing officers	5	10%
	Records officers /Data clerks	10	19%
	Laboratory technologists	1	2%
	Sub-county medical officer/ NCD focal persons	3	6%
Age category *(n = 52)*	24 and below	24	46 %
	25 – 35	19	37%
	Above 35	9	17%
Education level *(n = 52)*	Diploma	33	63 %
	Bachelors	18	35%
	Masters	1	2%
Length of computer use *(n = 52)*	5 years and below	10	19%
	6 years and above	31	60 %
	Not specified	11	21%

2.4. Data collection

The study was carried out by five research assistants who were trained for three days on data collection and study tools. The tools were piloted for one day at a non-participating healthcare facility in Nairobi.

2.4.1. Qualitative data

We conducted in-depth interviews using semi-structured questionnaires with Nairobi County and sub-county NCD unit staff who supported the implementation of the EMR system; the facility in-charges and HCWs who interacted with the systems in the hospitals; and the project staff from MI, AIHD, and IntelliSOFT who financed, implemented, and maintained the system respectively.

2.4.2. Quantitative data

There were three main aspect of quantitative data. First, data on characteristics of the patients enrolled in the participating health facilities and trend analysis were extracted from the EMR storage column as provided by the developer using a structured database query. The characteristics of the patients included age, gender, disease specific characteristics, and mode of treatment. The trend data included the cumulative number of DM and HTN patients, number of first visits, new cases and re-visits.

Second, cost data were extracted from source documents such as budget and expenditure reports provided by AIHD. We used a full costing approach [28] to estimate the cost of development and maintenance of the EMR system. All the budget and expenditure information received was entered into an Excel sheet. We then used the VLOOK UP formula in Excel, guided by the dates of expenditures, to categorise and sum up all the monthly costs as either the one-time direct cost of setting up the EMR system or as recurrent costs of managing it. We categorised the one-time direct to include the cost of developing the EMR system and the costs of the equipment such as purchasing mobile phones and laptops. The recurrent cost included the cost of piloting, maintenance of server and backup, SMS costs, and contingency for updates and follow up meetings. The cost was then annuitized by summing up the monthly costs based on the date of expenditures and the rate of consumption of the budget. T To estimate the sustainability and scalability in the short- and long-term, we prorated the annuitized costs based on assumptions of population growth, inflation, and cost allocation on whether the costing item would be applicable in the future of the project or not.

Third, a critical evaluation of the EMR system was conducted in two phases. Phase one was done using an EMR audit tool [29] administered to the developer to evaluate the EMR system against a standard EMR. The purpose was to evaluate the general design features (data elements, structure and organisation, ease of use, accessibility, interfaces, training, confidentiality, access limitation, accuracy and integrity);

HCWs features (record management, case management and administration reports generation); and patient-specific features (reminders, access to information and educational resources) [29,30]. Phase two was done using an evaluation tool adapted from the EMR audit tool and the Kenya national strategy for the prevention and control of non-communicable diseases 2015–2020 [16,29]. The phase was useful to evaluate the decision-support structure around the national guidelines and was targeted to one HCW in each of the 13 facilities as described in the sampling section. It appraised whether, by using the EMR system, HCWs were adhering to the national guidelines, and were supported to make the right clinical judgements.

2.5. Data analysis

2.5.1. Qualitative data

The interviews were recorded and transcribed then exported to NVIVO 11 software (QSR International, Australia) for coding and analysis. The participants were identified using a participant identifier and code. We then conducted a thematic analysis of emerging themes using both inductive and deductive approaches. Arising comparisons in perceptions and concepts were documented within and among the facilities.

2.5.2. Quantitative data

Patients characteristics and trend data were cleaned and analysed using Stata 15.0 (Stata Corporation, College Station, Texas, USA). Costing data was filtered and analysed using Excel software. Descriptive analysis was conducted using frequency distributions, and measures of central tendency and dispersion. Critical evaluation data was entered into excel and analysed using descriptive analysis.

2.6. Ethics consideration

We obtained ethics clearance from the AMREF Ethics Review Board (Ref no. AMREF-ESRC-P695/2019), and authorisation from Nairobi County health services (Ref no. CMO/NRB/OPR/Vol 1–2/2019/121). All interviewees provided written consent, and we obtained permission from the hospitals to engage them.

3. Results

3.1. The use of the EMR

3.1.1. Uptake and adaptability of EMR

A trend analysis of the data captured in the EMR showed that the number of patients captured in the system during implementation consistently increased. It was also noted that; the cumulative number of HTN patients in care was more than the cumulative number of DM patients in care throughout the entire implementation duration of the system (Fig. 2) as also indicated by the HCWs: *"…from the project initiation up to now you can see that the reporting rates have increased…the clients out there are getting captured and they are being managed"* (*Clinician 023)*.

The EMR system allowed clinicians to capture important aspects of care such as biodata, risk factors, diagnosis, treatment provided, follow up of patients and referrals as shown in Table 2 that were previously not captured in the KHIS. For instance, we were able to tell from the daily register that could be extracted from the system that the cumulative number of patients enrolled in the EMR system from 1st September 2018 to 31st July 2019 was 2,449. 18.8 % had DM, 44.8 % had HTN, and 16.2 % had a co-morbidity of DM and HTN diagnosis. Slightly more than half (57.5 %) of the patients were aged between 36 − 60 years, while 70.6 % were female. 14 % had a normal BMI of between 18.5–24.9, and 17.6 % had blood pressure (BP) of above 140/90. There were 214 newly diagnosed HTN and 103 DM patients (Table 2). However, while it was crucial that the such data was captured, there was still some patients missing crucial data; for instance, 20.2 % of the patients had a missing disease category, 49.7 % had missing BMI information, and 2.7 % missing BP records.

3.1.2. The acceptability and facilitators of the EMR system

Several clinicians shared that before the EMR system was introduced, reporting, specifically for NCDs, was poor: *"Initially reporting was poor…they [sub-county] did not have a clear picture of how many patients are on treatment for non-communicable diseases, but today they can be able to access that."* (*Clinician 031)*. Before the EMR, HCWs were spending much time to access patient files, especially in busy facilities with many clients. Often, they had to arrive early at work to ensure the files were ready before the clinic began, but with the system, the patient information is readily accessible. One HCWs noted that follow-up information documenting the progress of patients was equally easy to access: *"…it makes it easy to access the data from the patient from the history depending on the number of visits the patient has come so you can easily access the visit and see the medical history…" (Clinician 022)*. In fact, the HCWs and the sub-subcounty officials noted that by capturing data electronically through the EMR system, facilities had real-time data and they were able to generate and share monthly reports timely. The real time data entry, they noted, averted inconveniences and inaccuracies that come with entering the data retrospectively as one health records and information officer shared: *"…we conduct real-time data entry at once so that we can have everything updated instead of backdating because backdating at times can be a challenge." (Sub-county HRIO 001)*. Equally, the system was easy to use, improved work efficiency and hence, efficiency in work management in hospitals: *"The system has added value because we have been able to work faster and we have many clients, so all of them are in the system, so when a client comes, it is just putting in the identification number then you see that client, other than sitting with all the tools and taking a long time." (Sub-county NCD focal person, SC 001)*.

The evaluation showed that the EMR system through its interfaces, was making it easier for the HCWs to quickly and easily generate reports, unlike before when reporting was cumbersome and took much time. Health records and information officers (HRIOs) often had to mine data from different hardcopy documents in order to compile a comprehensive report. One clinician said: *"reports are just one click away, you just press one button and you have all your reports there, yeah, compared to the previous one where we used to count all of them, a lot of adding" (Clinician 016)*. Additionally, the EMR system simplified generation of reports over a specified time due to the flexibility of the system: *"…so I just go to the dashboard, click on reports and then insert dates 1*st *maybe to 31*st *then I run the report, the system generates the reports for me…"* (*Data Clerk 042)*.

Through the EMR system data elements, it was possible for the HCWs to capture detailed history of patients which then made it much easier to obtain a comprehensive medical history for a particular patient. As one clinician noted: "… *at times you would forget other systems [of the body] that you need to tackle, but with the tool, it is systematic. You know after the biodata you have to do this and do this …" (Clinician 023)*. Equally, the presence of an EMR also aided in capturing more details of the patients no matter the workload by the HCWs as one clinician noted:*"… in public facilities sometimes, you get overwhelmed, but when you are using the tool, it takes you through almost every detail of a patient, it is hard to miss a thing in a patient." (Clinician 016)*.

The system was characterised with improved quality management of care. Keeping the electronic records on the characteristics was enabling the HCWs to track the progress of the disease across a continuum of care, as reported: *"We are able to keep records and the data, and it is easy for us …to know the history of the patient. If you have not been here, your colleague has been seeing the patient previously; you are able to retrieve and see how the patient has been progressing" (Clinician 002)*. Aside from the data, there are built-in functions that automatically calculate specific parameters of a patient such as BMI given the height and weight

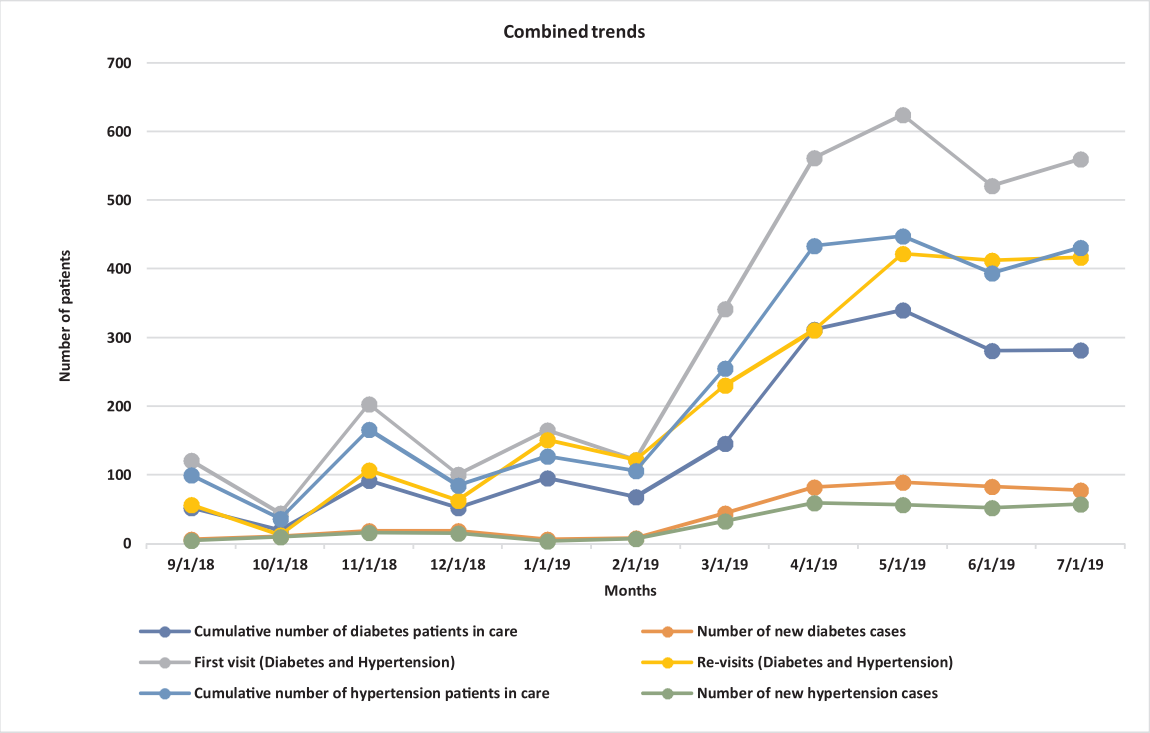

Fig. 2. EMR Data Trend analysis.

measurements and also indicate the whether they are within the normal ranges of specific parameters such as BP: *"Yes because for example when you key in weight and height it automatically calculates the BMI and it brings an alert where there are colour codes, blue, red and so between red tells you whether it is bad or good that is just an alert." (Clinician 025)*. The function, the noted, helped to improve data completeness and eliminated errors through manual calculations. Some of the errors that the HCWs cited were flags when there was wrong combination of drugs is given, hence helping HCWs make right decisions and prescriptions.

The clinicians also reported that the patient's data in the EMR systems also ensured a systematic and standardised way of managing NCD patients and a reminder of good clinical practice: *"…at least now we have a very systematic and standardised way of managing NCDs…" (Clinician 023)*. Besides the standardisation, the HCWs reported that the EMR system was a mirror reflection of the national guidelines on the management of DM and HTN. The patient's data together with the standard operating procedures (SOPs) and charts that it contained, acted as a reference point for better clinical decisions and care of HTN and DM patients: *"When I say it is working, I mean the system has enabled us to see the patient faster, manage this patient correctly, and also the drugs that are required are in the system, and we are able to pick the right medication. So, it is giving us that aspect, and also we are able to generate our reports." (Sub-county NCD focal person, SC 001)*.

Equally, all patient information collected on the EMR system was securely stored in password-protected servers which ensured that data was confidential and always available as needed. It consequentially prevented issues of misplaced or missing patient information that often had been accumulated over a long period: *"…if you enter your data correctly, that data will forever be there whenever you need it you will get it, and I have never seen…there has not been loss of data" (Clinician 016)*. Over the course of their practice, clinicians reported that they had had situations where hard-copy patient files went missing: *"…initially we used to use just the files …you could find that most of the patient files were missing…" (Clinician 016)*. However, since the introduction of the EMR system, there are always a backup of the patient information.

3.1.3. Barriers of the EMR system

However, the system was associated with increasing workload of HCW because they have to document patients care in both MOH Paper-based reporting tools and the EMR system. As a result, some preferred using the paper-based system of managing patients: *"…we are supposed to use this system yet we are still being given this paper..this is like double work..whatever is in the system is what is copied on the paper. So, when you fill in that you must go back to the system again to key in those patients" (Clinician 025)*. Besides, some respondents also felt that health system-related deficiencies such as staff shortage and inadequate supply of basic medication had affected compliance to national guidelines: *"Adherence to national…that's…it's been a bit tricky to tie that to the system because primarily because of workload and staff shortage. So, in that sense, we cannot monitor in real-time, and the tool ends up being more for collecting the data than really monitoring the adherence of it… " (Program Officer 002 IntelliSOFT)*.

However, despite the positive trends, further analysis showed that, while the system was developed to help update patient's data on the KHIS, there was a variance in the number of patients captured in the EMR system and the KHIS. For instance, the cumulative number of DM patients reported from November 2018 to July 2019 was higher in the KHIS as compared to the system. In July, the number of patients reported in KHIS was 564, while only 282 patients were recorded in the system (Fig. 3).

3.2. Design features, scalability and sustainability of the system

This section present findings of the critical evaluation of the software design features of the EMR and its cost of development and maintenance for sustainability. The findings show that the EMR system is particularly useful in general design features (data elements, structure and organisation, ease of use, accessibility, interfaces, training, confidentiality, access limitation, accuracy and integrity). In terms of HCWs features (record management, case management and administration reports generation), the system was reasonably supportive of NCD case management compared to other EMR systems. On patient-

Table 2
Characteristics of the DM and HTN patients registered in the EMR system for HTN and DM.

Variable	Category	Frequency (n = 2449)	Percentage
Age categories	0 – 5 years	4	0.2%
	6 – 18 years	16	0.7%
	19 – 35 years	345	14.1%
	36 – 60 years	1407	57.5 %
	> 60 years	677	27.6%
Gender	Male	721	29.4%
	Female	1728	70.6 %
Disease category[1]	Diabetes only	461	18.8 %
	Hypertension only	1097	44.8 %
	Both diabetes and Hypertension	397	16.2 %
	Missing disease category	494	20.2 %
BMI	< =18	19	0.8%
	18.5 – 24.9	344	14.0%
	25 – 29.9	463	18.9%
	> = 30	406	16.6%
	Missing BMI information	1217	49.7 %
BP	Bp > 140/90	432	17.6 %
	Normal BP	1951	79.7%
	Missing BP record	66	2.7 %
Type of Visit	First	1125	45.9%
	Revisit	452	18.5%
	Missing type of visit	872	35.6%
Modes of treatment	Diet and physical activity	167	6.8%
	Oral glucose-lowering agents	375	15.3%
	Insulin	86	3.5%
	Anti-hypertensives	800	32.7 %
	Other	36	1.5%
	None	985	40.2 %
Newly diagnosed[2] (n = 317)	Diabetes	103	32.5%
	Hypertension	214	67.5%

[1] Diabetes was categorised as Type 1 Diabetes Mellitus, Type 2 Diabetes Mellitus, Gestational Diabetes Mellitus, and Diabetes Secondary to other sources while Hypertension was categorised as Hypertension and Pre-Eclampsia.

[2] Number of newly diagnosed cases was 317.

specific features (reminders, access to information and educational resources), the EMR system was reasonably good as it was sending out reminders to patients who missed clinic appointments (*Appendix 1*).

The evaluation of the EMR system in the management of DM and HTN showed that HCWs knowledge about the EMR and what information it could capture varied across the health facilities. For instance, while EMR system captured risk factors, classified HTN based on blood pressure, and supported clinicians in drug prescription, some clinicians were not aware of these inbuilt features and thought the EMR system content is not in line with the national guidelines (*Appendix 2*).

In terms of cost, the overall cost of implementing the EMR system, both direct and indirect costs incurred by the implementer at the roll out to all 45 facilities, was € 165,621 cumulatively (*One Euro € = 112 Kenya Shillings (KES)*). It is postulated to cost the implementers € 11,553 in 2020 and € 11, 322 by 2024 attributable to both the direct and indirect cost of maintaining the system post the project life, including the cost of SMSs, server and back up. This would may be sustainable in the long run for the implementer due to the lower future maintenance costs compared to the initial costs associated with its development, pilot and roll out.

4. Discussion

The study set out to evaluate the implementation of this novel EMR system for management of HTN and DM in health facilities in informal settlements in Nairobi County. Particularly it addressed the elements of the use and uptake of the EMR, perception of the HCWs in using EMR and design and sustainability issues. The findings illuminated several crucial factors that would potentially affect the sustainability of the EMR implementation.

Our findings showed that the EMR system was crucial in steering the management plan for patients in the right direction. By capturing detailed patient information, the EMR can act a tool for enhancing of continuity (follow up) and consistent delivery of high quality of care. Other studies have showed that in-built resources in an EMR improve care, standardises health services [29,30], and improve physician performance and patient outcomes [12]. As our results have shown, implementation of EMR systems could potentially lead to healthcare savings, reduce medical errors, improve implementation of care guidelines, and provide data for decision making; thus, improved health [2]. One of the major hindrances to ensuring consistency in patient management is segmented and incomplete documentation of a patient's

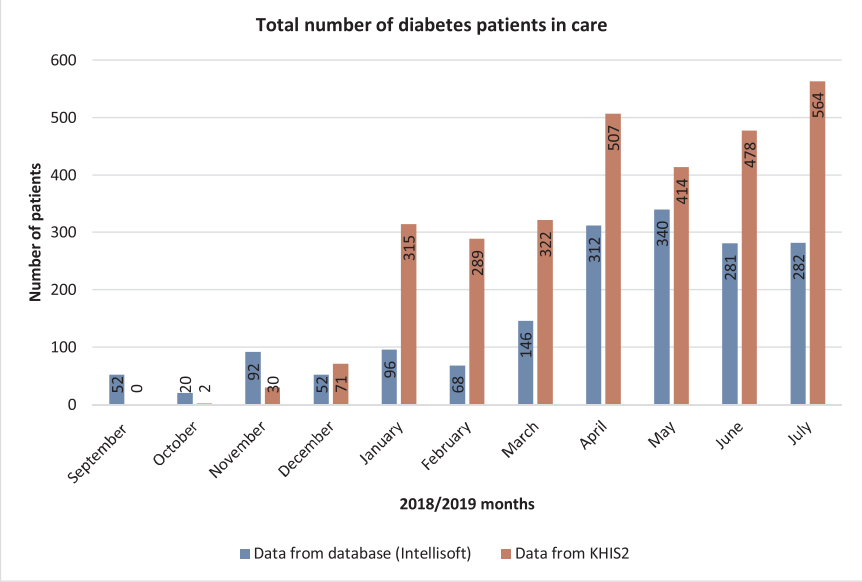

Fig. 3. Total number of DM patients in care KHIS2 against the EMR system.

medical history and the management plan [20]. An incomplete history may detour the correct course of management and eventually worsen the patient's condition, especially for chronic diseases that are managed over a long period. The lack of necessary patient information management of patients [31]. In resource-constrained settings, complete and comprehensive medical history for HTN and DM is often hard to achieve thus EMRs can play a critical role [13].

Implementation of EMR system requires the participation, satisfaction and proper attitude of the HCWs [32,33]. Our results have shown that the HCWs perceived positively the EMR based on it supporting the achievement of national guidelines for management of HTN and DM, supporting in reporting, ensuring completeness, timeliness and safety of data. This finding is consistent with Bonner et al.'s work which showed EMR improves accessibility of data [34]. However, there was an equally different perception that the EMR was increasing the workload and slowing the pace of work of the HCWs. These results congruent to that of a study in an emergency department of a teaching hospital, which showed that EMRs had increased documentation by four to five-fold [35]. Equally, another study heighted the dearth of comfort in using EMR by HCWs as being a significant challenge [3]. This finding could likely explain why there was a difference in the number of records in KHIS and the EMR as HCWs may have been feeling seeing it as duplication of work. The non-direct integration of the EMR system to KHIS hindered automatic submission of that in the system and affected the timeliness and quality of NCD data. Other studies have shown that data verification in EMRs and clinical decision support could help improve care [4]. Also, improved data capture had enabled sub-county and facility in-charges to plan better on the needed resources to manage NCDs, including DM and HTN as was supported by the finding of a systematic review of other studies [36].

The cost analysis of the EMR system showed the initial cost of setting up the EMR was significantly high. However, the system would be sustainable in the long run if the other high-cost EMR implementation activities such as EMR system development and pilot are not carried out again. Other studies have shown that barriers to adoption of EMRs are high procurement and maintenance costs and inadequate network infrastructure [3] which in our study was a significant contributor to high initial cost. Besides, the high initial financial costs, difficulties with technology, unpredictable financial payoffs, immense initial physician time costs, electronic data exchange issues, and physicians' attitudes [2] are some of the factors that could hinder feasibility of roll out of EMR system. Further research on cost-effectiveness analysis would be paramount to ascertain the level of cost-effectiveness of the EMR. Also, the study showed intrinsic EMR system inefficiencies that are consistent with other literature on EMRs. For instance, server instability (downtime periods, UI frame and root errors) during report generation and data submission have been shown in other parts of Kenya [37]. The challenges would hinder proper implementation.

5. Limitation of the study

Generalising the results of critical evaluation from the 13 purposefully selected high-volume facilities is not warranted because the findings may not translate to lower volume facilities because of systemic differences. In assessing the patient's clinical data, we encountered missing information which could point to systemic challenges of implementations; hence, the results should be interpreted with caution. Our data limitations prevented us from comparing characteristics of patients by condition (DM, HTN, and DM + HTN); this represents a topic for future evaluation.

6. Conclusion

The evaluation of the implementation of this novel EMR system for management of HTN and DM showed that use of innovative technology likely to improve patients' care. The technology not only enhances assurance of information safety and availability, but also support in clinical decision making and standardisation of care. Successful implementation of the technology is dependent on positive perception and attitude of the HCWs. While the cost of setting and managing the EMR could hinder its sustainability, it is important for future implementors to source for adequate funds to run it to completion if it is to achieve its objective. Overall, the EMR was useful in the treatment and management of HTN and DM patients.

Authors contribution

Study concept and design: BO, SM, WK, CN; *Analysis and interpretation of data:* BO, SM; *Drafting of the manuscript:* BO, SM; *Critical revision of the manuscript for valuable intellectual content:* WK, CN, MS, VK, MC, SG, SW, MS; *Statistical analysis:* BO, SM; *Study supervision:* BO, SM.

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Summary table

1 The implementation of the EMR system has improved the clinical data capture for patients with diabetes and hypertension.
2 The system enhanced the patient's follow-up, eased record-keeping for tracking medical history and supported in the standardisation of care.
3 Successful implementation of the EMR is dependent on positive perception and attitude of the health care workers.
4 The cost of setting up and managing the EMR could hinder its sustainability; therefore,it is important for future implementors to plan for adequate long-term funding to maintain the system if it is to achieve its objective.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijmedinf.2020.104220.

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