Evaluating a scalable model for implementing electronic health records in resource-limited settings

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ABSTRACT

Current models for implementing electronic health records (EHRs) in resource-limited settings may not be scalable because they fail to address human-resource and cost constraints. This paper describes an implementation model which relies on shared responsibility between local sites and an external three-pronged support infrastructure consisting of: (1) a national technical expertise center, (2) an implementer's community, and (3) a developer's community. This model was used to implement an open-source EHR in three Ugandan HIV-clinics. Pre—post time—motion study at one site revealed that Primary Care Providers spent a third less time in direct and indirect care of patients ($p<0.001$) and 40% more time on personal activities ($p=0.09$) after EHRs implementation. Time spent by previously enrolled patients with non-clinician staff fell by half ($p=0.004$) and with pharmacy by 63% ($p<0.001$). Surveyed providers were highly satisfied with the EHRs and its support infrastructure. This model offers a viable approach for broadly implementing EHRs in resource-limited settings.

INTRODUCTION

Electronic health record systems (EHRs) have been implemented and support healthcare delivery in developing countries.[1] Unfortunately, widespread adoption of these systems remains limited by multiple factors, key among them being limited human resources and cost of equipment, software, and personnel.[2] Approaches to overcome these barriers are needed before EHRs can support efficient, large-scale healthcare delivery systems in resource-limited settings.

The emergence of open-source EHRs for use in resource-limited settings has been a step in the right direction. Open-source systems reduce the cost of developing and owning EHRs, thus lowering the threshold for EHR adoption.[3] An example of a widely adopted open-source EHRs is OpenMRS, which has been successfully implemented in a dozen sub-Saharan African countries.[4] However, even with availability of well designed open-source systems, the threshold for implementing EHRs may remain too high for most healthcare systems in resource-poor settings. This is because successful EHR implementation also requires adequate technical support, appropriate infrastructure, and good integration of the EHR system into the local clinical workflow. Models of EHR implementation that address these factors should increase EHR adoption and use.

When one examines current EHR implementations in resource-limited settings, two characteristics become evident. First, most implementation sites employ their own locally-trained information technology (IT) staff; and second, most sites rely heavily on expertise from developed countries. This dependency on foreign expertise is evident in reports of EHRs implementations in Kenya,[5] Rwanda,[6] and Malawi,[7] to name a few. A model of EHR implementation which relies on employing highly trained, full-time personnel at each site or on foreign experts is not scalable—it is too expensive, and the number of qualified individuals, foreign and domestic, is too limited.

In this paper, we describe an alternative and scalable model for implementing EHRs in resource-limited settings. This model directly addresses the human-resource constraints in these settings. Instead of using full-time, highly trained IT personnel at each site or relying on foreign expertise, the model uses a national technical expertise center (TEC), a global developer, and implementer networks to support multiple local implementations.

Implementation model

In traditional implementation models of EHRs in developing countries, almost all aspects of implementation are handled at local practice sites. Our new implementation model shares these responsibilities between the local site and an external resource that supports multiple local implementations (figure 1). The external support resource is comprised of (a) a national TEC, (b) a community of software developers, and (c) a community of EHR implementers. The TEC forms the core of the external support resource, and consists of highly trained IT and informatics personnel from within the country who are familiar with the local healthcare and IT exigencies as well as all technical aspects of implementing and maintaining EHRs. The TEC plays a major role in installing and maintaining the EHR, advising local sites about hardware, software, supplies, and logistics needed to support the system. TEC staff also work closely with each site to configure the EHRs to meet the local needs. As an example, the TEC may help design encounter forms and data entry interfaces, create tools to automatically generate customized reports, and generate clinical summaries that contain the data elements requested by local providers. Once the EHR is implemented, the TEC provides ongoing support as needed. A single TEC that supports multiple local implementations can obviate the need for highly-trained IT personnel at each local site.

The developer and implementer communities complement the TEC by providing the initial EHR

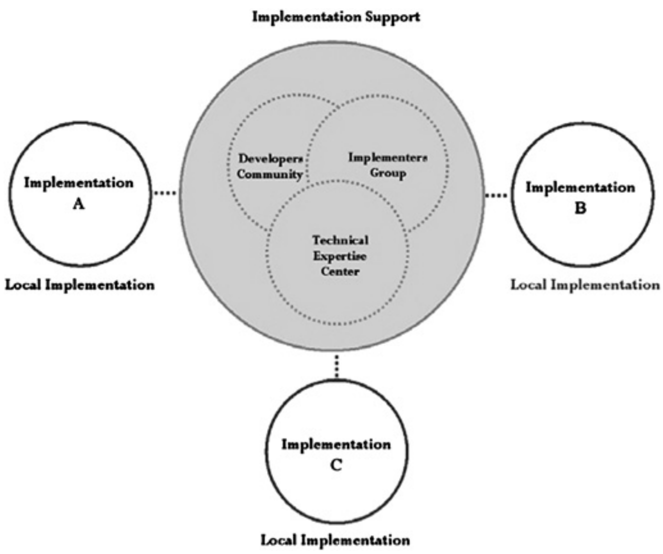

Figure 1 An implementation model for EHRs in resource-limited settings. Support for multiple local implementations is provided by a single external support resource made of a national technical expertise center, the developers' community and the implementers' community.

program(s) and updates, along with suggestions on how to resolve implementation and support issues beyond the TEC's expertise. In the case of systems like OpenMRS, both the developer and implementer communities have active listservers through which members can communicate about problems and solutions. Implementers can also send requests and suggestions to the developers for OpenMRS refinements and enhancements. Questions and answers on the listservers are all incorporated into the OpenMRS website[8] and thus made available to the wider community. Obviously, the developer and implementer communities assume different levels of responsibility depending on how well-established the TEC is in implementing and managing particular EHRs.

The responsibilities of individuals working within this model are shown in table 1. With a robust external support resource, local sites only require data-entry clerks, data managers, and mid-level IT staff to support the EHRs hardware (computers and local area networks). The clerks entering data from encounter forms are overseen by data-managers who also monitor data-quality, and provide data and reports to clinicians, healthcare managers, researchers, and other stakeholders. On-site mid-level IT personnel are responsible for the day-to-day maintenance of the EHRs, guided through close communication with the TEC. All local EHR personnel interact closely with clinicians, site managers, and support staff—who are the end-users of the EHRs and whose needs must be met.

In this paper, we describe the application of this model in three OpenMRS implementations in Uganda, Africa. We assessed the impact of OpenMRS implemented using this model on healthcare delivery with a formal time–motion study of providers and patients at one site. We also surveyed users on their attitudes towards the implemented EHRs and its support infrastructure at all three sites.

METHODS

Electronic medical record

The EHR implemented using the described model was OpenMRS.[4] This open-source system was initially developed through collaboration between Regenstrief Institute, Inc and Partners In Health in the USA, but now has a world-wide community of developers. OpenMRS has a robust patient-centric data model designed after the Regenstrief Medical Record System,[9] and contains a rich Java-based application programming interface. A web-based front-end sits on top of this interface, and all data in the system are transmitted via a standard HL7 messaging format.[10] Most current OpenMRS implementations use the MySQL relational database,[11] with data stored as numeric results or coded concepts to allow for easy retrieval and analysis.[12] Over the past 2 years a strong OpenMRS implementers' community has emerged to serve the needs of the growing number of installations of OpenMRS.[13] Communication in the implementer and developer communities occurs through OpenMRS wiki, Internet Relay Chat, email lists, and regular conference calls.

Because most clinicians in resource-limited settings prefer not to use computers directly during patient-care, OpenMRS offers an option which allows providers to complete paper encounter forms which contain mostly spaces for numeric results and check-boxes for coded answers. Free text is supported but is of limited usefulness for data processing. Data from these encounter forms are entered into the OpenMRS system by data-entry clerks who only need basic computer skills and minimal medical knowledge for this work. The patient-level coded and numeric data stored in OpenMRS can then be used to generate patient-specific clinical abstracts and various reports, and for quality improvement and research activities.

Implementation sites

We used the model described above to support OpenMRS implementation at three sites in Uganda, Africa (figure 2). The model was adopted through consensus between the implementation sites, the Ministry of Health in Uganda, and Indiana University's Regenstrief Institute, Inc.[14] Initially, it had been suggested that Regenstrief Institute, Inc should help with the implementations, but it quickly became evident that support for such multi-site implementations could not be done by a foreign entity from a distance. On the other hand, each of the three individual sites was too small and too resource-constrained to autonomously support its own implementations.

Table 1 Responsibilities for implementation with new model

Local site personnel	Day-to-day operation of the EHRs
	Data-entry and quality monitoring
	Generation of reports
	Security and routine low-level software updates
	Addressing local clinical provider needs, including determining needed encounter forms and concept dictionary terms
	Working with the external TEC to ensure that EHRs runs smoothly
External implementation support	
TEC	Install and support hardware and high-level software
	Encounter form design and maintenance
	Programming of various reports
	Addressing technical issues beyond the local expertise
	Working closely with the Developer and Implementer communities to address local needs and issues
Developer's community	Forum for developers to share ideas and questions
	Assisting TEC and local implementations to address difficult technical and programming issues
Implementer's community	Forum for implementers to share ideas and implementation tips
	Assisting TEC and local implementations to address questions around implementation

EHR, electronic health record; TEC, technical expertise center.

All implementation sites were HIV/AIDS clinics selected by the Ugandan Ministry of Health (MoH) for this demonstration project and were located in resource-poor urban settings (table 2). The MoH and the administration at each clinic recruited and hired all local staff involved with the EHRs implementation. A clinical champion, usually the in-charge physician at the site, acted as point-person on clinical issues related to the EHRs. There was also active engagement of providers at each site during evaluation of the clinic's workflow and in the creation of concept dictionary terms and encounter forms for each clinic.

All sites relied on a single TEC for their EHRs implementation: the Faculty for Computing and Information Technology at Makerere University in Kampala,[15] located 130–240 km from the sites (see map in figure 2). Two of the sites, Masaka and Mbale, each had only one local data manager who also provided local IT support. Masaka hired three data-entry clerks while Mbale had one. The third and largest site, Mbarara, had one data manager, one mid-level IT person, and seven data-entry clerks.

The three sites relied heavily on the national TEC for initial installation, training, and continued implementation support. The TEC at Makerere University had two full-time employees and a third part time employee (25%) to support all three implementations. The first employee had a bachelor's degree in computer science and 3 years of both IT support and computer-programming experience. The second employee had 5 years of IT support experience, 7 years of programming experience, but no university degree. The part time TEC employee had a bachelor's degree in computer science, 1 year IT support experience and 2 years of programming experience.

The most concerted engagement of the TEC staff occurred on the ground at each site during the initial EHR's installation. With one TEC serving three sites, implementations were staggered between January 2007 and January 2008—these initial implementations also involved developing encounter forms,

Figure 2 Implementation sites: 1—Mbarara, 2—Masaka; and 3—Mbale. The national technical expertise center serving all three implementation sites was in Kampala.

terms for the concept dictionary, and standard reports in concert with clinician-leaders and data managers from all three sites. The final content and format of the encounter forms were different between the sites, serving local needs and interests.

Evaluation

To assess the impact of the EHR implemented using the TEC model, we conducted formal time–motion studies at the Masaka Healthcare Centre clinic. The time–motion studies were not conducted in Mbarara because this site had previously used an electronic database to store data abstracts from paper charts for research purposes[16] and implemented a simpler encounter form for a subset of its patients prior to the OpenMRS implementation. We did not conduct time motion studies at Mbale because of its small size, and the fact that its HIV clinic was convened only once a week. Post-implementation, providers at all three implementation sites were surveyed on their attitudes towards OpenMRS and its support infrastructure. The study was approved by the Institutional Review Boards of Indiana University-Purdue University at Indianapolis, University of California San Francisco School of Medicine, and the Institutional Review and Ethics Committee responsible for Masaka, Mbale, and Mbarara.

Time–motion study

To evaluate the impact of the implemented EHR on provider and patient time management, we conducted a formal time motion study at the Masaka Healthcare Centre before and after implementing OpenMRS using methods we had previously employed in the USA[17] and in rural Kenya.[18] Before implementation, chart notes, log-books, and Ministry of Health registries were handwritten by clinicians and staff who had little if any access to prior visit data, and reports were generated manually. After implementation, visit data were recorded by clinicians onto paper-based, clinician-defined encounter forms that contained numeric fields and check boxes for specific diagnoses and other patient characteristics (see Appendix 1, available as an online data supplement at http://jamia.bmj.com). A patient summary was generated from data in the EHR and printed at the beginning of each clinic visit. This abstract was viewed by all clinicians, pharmacists, and staff who saw the patient during the visit (see Appendix 2, available online at http://jamia.bmj.com). In addition to individual patient summaries, OpenMRS also generated reports for the Ministry of Health and international funding agencies, thus replacing the log-books and registries.

Both before and after implementing OpenMRS, we planned to follow 100 established adult HIV-positive patients and 20 newly-diagnosed adult HIV-positive patients from the time they presented to the registration clerk at the Masaka Healthcare Centre. Pediatric patients were excluded because Masaka had a very small pediatric HIV clinic. We also excluded adults who came only for HIV testing. Patient observations began as soon as they presented to the registration desk and ended when the patient left the clinic grounds. Observations for clinicians started at the moment they arrived in their offices to begin their workdays. All clinicians—physicians, clinical officers, and nurse practitioners (NPs)—who were scheduled to work regular shifts during the study period were eligible for observation, and all agreed to be observed for three full workdays in both phases of the study.

In consultation with the clinical staff at the site, two investigators (MCW and JS) came up with a list of provider tasks and patient activities to be used for the study. These tasks and activities were programmed into Personal Digital Assistants (PDAs) using the HanDBase software (DDH Software, Inc,

Table 2 Characteristics of implementation sites*

Clinic	Masaka	Mbale	Mbarara
Primary affiliation(s)	Masaka RRH and Uganda CARES†	Mbale RRH	MUST
Documentation of patient visits	Free-text hand-written notes	Free-text hand-written notes	Paper-based encounter forms with coded answers
Distance from Kampala	130 km	200 km	240 km
Registered HIV+ patients	7600	1900	11500
Patients on ARVs	4000	940	4900
Number of physicians	2	4	4
Number of COs	1	3	0
Number of clinical NPs	3	0	0
OpenMRS implementation date	Jan 2008	Nov 2007	Jan 2007

*All numbers are based on figures from November, 2008.
†Uganda CARES is a partnership between Uganda Ministry of Health and the USA-based AIDS Healthcare Foundation. ARVs, antiretroviral (HIV) medication; COs, clinical officers; MUST, Mbarara University of Science and Technology; NPs, nurse practitioners; RRH, regional referral hospital.

Wellington, Florida) (see Appendix 3, available online at http://jamia.bmj.com). These PDAs were used by trained Ugandan observers to record provider and patient activities. An observer first contacted a subject (either a patient presenting for a visit or a provider beginning his or her workday) and then opened a visit record in the PDA. When the subject initiated the first observed activity (such as talking), the observer recorded the activity in the PDA which assigned it a beginning time. Once it became clear to the observer what the activity was, he or she picked the specific action from the pre-established list in a structured menu. When the next activity began, the observer recorded a new observation into the PDA which assigned an ending time to the previous activity and a beginning time to the next activity. 'Down time' or inactivity was recorded as 'waiting'. No conversation was allowed between the person being observed and the observer. At the end of each observation day, the data were transferred to a Microsoft Access 2003 (V.11.5) database.

Survey

To assess end-user attitudes towards the EHR implemented using the TEC model, we gave an anonymous self-administered survey to a convenience sample of 45 clinical providers who were scheduled to work during the period of the survey administration. These providers consisted of eight from Mbale, 15 from Masaka, and 22 from Mbarara. The providers included the clinicians who were part of the time—motion study as well as others (registration officers, pharmacy staff, and triage nurses) who interacted directly with patients. All respondents were asked to rate the reliability of OpenMRS and its support infrastructure, its impact on productivity and quality of care, the quality of training received, and overall satisfaction with OpenMRS implementation. Responses were on a 7-point scale with ratings of 1 (never) to 7 (always). Providers also gave information about their gender, job title, and prior computer experience (see Appendix 4, available online at http://jamia.bmj.com).

Data analysis

The mean number of patients who visited each clinic per day was computed from data contained in the EHRs. Data from the time—motion study were analyzed using SAS V.9.1. The unit of analysis for patients was the clinic visit, which we recorded from the time the patient was registered for the day's visit to the time he or she left the clinic. We excluded from analysis all times before formal clinic registration because some patients arrived several hours before the clinic's doors opened. (Because the clinic did not have a formal scheduling system, patients were served in the order in which they presented to the clinic.) The duration of an activity was calculated as the difference between its start and end time. We calculated the mean length of each visit by subtracting the start time of the first observation from the end time of the last observation for that visit. We did not control the analyses for provider because each patient was seen by multiple providers, and because patient and provider identifiers were not recorded to assure patient and provider anonymity.

For clinicians, we computed the mean length of their workday and the mean number of patients seen each day they were observed. Providers worked variable numbers of hours per day, so instead of presenting data in terms of minutes or hours, we calculated the percentage of workday each provider spent in each major task category before and after the EHR implementation. In addition, we compared the mean amount of time providers spent in direct and indirect care per each patient-encounter. Direct care included talking to, counseling, examining, or performing a procedure on patient. Indirect care included reading from or writing to a patient's chart or encounter form, prescribing medications, or discussing care with other staff. We used either unpaired t test (UT) or Kruskal—Wallis (KW) test to compare relevant continuous measures, depending on the scale of sample size—all tests were two-sided. Descriptive statistics were computed for the survey.

RESULTS

Implementations of OpenMRS

The national TEC at Makerere played an active role in each implementation. TEC staff received initial training at an OpenMRS Developers Conference held by Indiana University in Eldoret, Kenya in April 2006 and in subsequent Developers Conferences in Cape Town, South Africa in 2007 and 2008. TEC staff also participated actively in the online OpenMRS Implementer and Developer communities.

Once the TEC staff was capable of implementing and sustaining the EHR, they worked collaboratively with local sites to implement OpenMRS. The TEC performed the following functions for each local site: installing the LAN and client computers; programming the encounter form data entry interfaces; building site-specific patient summaries using Business Intelligence and Reporting Tools (BIRT) and Eclipse's Rich Client Platform technology (Eclipse Foundation, Inc, Portland, Oregon, USA); programming reports for clinical management, President's Emergency Plan For AIDS Relief,[19] and the Uganda Ministry of Health; working with sites to update all the above functions; and helping trouble-shooting problems arising after the initial implementation.

Mbarara went live with OpenMRS first, in January of 2007. As of June 2009, over 5.4 million clinical observations for more than 107 000 clinic visits had been recorded for approximately 11 500 active patients. In Mbale, the system was implemented in November 2007. By June 2009, the smaller Mbale clinic has entered only 230 000 observations from 3100 clinic visits for 1900 unique patients. Masaka was last to implement OpenMRS, going live in January of 2008. By June 2009, more than 1.3 million observations from 51 000 clinic visits for 7600 unique patients had been entered into OpenMRS. All sites continued active use of OpenMRS since their implementation dates, with on-site TEC help only needed once every few months at any particular site.

Masaka time–motion study

The pre-implementation time motion study was performed in January and February of 2007 and the post-implementation in July and August 2008.

Clinicians

All physicians, NPs, and clinical officers working as full-time providers during the study period participated in the study. We observed three physicians in the pre-implementation phase compared to two in the post-implementation phase. We also observed two NPs and one clinical officer in each phase of the study. During a total of 916 h of observation, 1406 separate clinician activities were recorded in the pre-implementation phase and 2062 activities were recorded in the post-implementation phase.

The mean time spent in clinic by providers in the pre-implementation phase was 5.6 h per day versus 7.0 h in the post-implementation phase (p=0.06). In the pre-implementation phase, these providers cared for a mean of 28±8 (SD) patients each day (range 16–48 patients per day and 3–9 patients per hour) while in the post-implementation phase they saw a mean of 40±18 patients each day (range 18–72 per day and 3–9 per hour) (p=0.07).

Table 3 shows activities by clinicians as a percentage of the workday during the pre-implementation and post-implementation phases. Direct and indirect patient care accounted for 60% of clinicians' workday before the system's implementation, and only 43% after the EHRs was implementation (p<0.001). This reduction in time spent on indirect patient care during the post-implementation phase was largely explained by less time spent reading charts (3.5% vs 1.7%, p=0.006) and writing orders and prescriptions (15% vs 6.7%, p=0.01). In the post-implementation phase, clinicians spent 40% more time on personal activities (p=0.09) and 57% more time on miscellaneous work-related activities (p=0.06). During more than 1000 observed patient encounters, clinicians spent a third less time in direct patient care (p<0.0001) and a third less time in indirect patient care (p<0.0001) when the EHR was in use (table 4). This resulted in saving 2.5 min a visit (p<0.001) and 99 min a day if averaged for the 40 patients seen per clinician per day in the post-implementation period.

Patients

During the pre-implementation period, an average of 119 patients (SD 34, range 71–197) visited the Masaka clinic each day compared to 135 (SD 61, range 62–310, p=0.19) in the post-implementation phase. We observed 21 new patients and 90 returning patients in the pre-implementation and 20 new patients and 96 returning patients in the post-implementation phase, for a total of 349 h of patient observations. The mean visit duration for new patients did not change significantly between the pre-implementation and the post-implementation phase (99±41 vs 109±50 min, p=0.57). For returning patients, visit lengths increased by 24 min (32%) in the post-implementation phase compared to the pre-implementation phase (102±33 vs 77±32 min, p<0.001).

Time spent with clinicians other than pharmacists did not change significantly for either new (p=0.18) or returning patients (p=0.72) with implementation of EHR (table 5). Returning patients spent significantly less time interacting with the pharmacists and with other staff members with the EHR in use. For returning patients the time spent waiting for clinicians did not change significantly, but time waiting for other staff increased by 24 min (216%, p<0.0001) in the post-implementation phase. For new patients, there were no significant pre/post-implementation differences except for the time waiting for the pharmacy, which was 10 min longer (59%, p=0.01) in the post-implementation phase (table 5).

Table 3 Provider activities (% of workday) at Masaka before and after implementation of OpenMRS

Activity (% of workday)	Paper medical record system (n=16)*	Electronic medical record system (n=15)	p Value‡‡
Indirect patient care†	32	21	0.001
Writing orders or prescriptions	15	6.7	0.01
Writing chart notes	12	12	0.78
Reading patient's chart	3.6	1.7	0.006
Reading medical reference	0.91	0.91	0.53
Patient-related phone call	0.42	0.16	0.42
Writing other	0.18	0.051	0.16
Direct patient care‡	29	22	0.02
Personal§	18	25	0.09
Administrative¶	15	23	0.009
Waiting**	4.2	6.2	0.18
Miscellaneous††	4.3	2.6	0.06

*n=number of PCP observations.
†**Indirect patient care**: These tasks include reading or writing on patient's chart or encounter form, prescribing medications, discussing patient's care on phone or with other providers.
‡**Direct patient care**: These tasks include talking and listening to patient, counseling patient(s), and examining or doing a procedure on patient.
§**Personal**: These tasks include provider's personal activities for example breaks, conversations, email, and reading.
¶**Administrative**: These tasks include all non-patient-centered work activities like filing of records, using computers for work actiivitivies, and other staff interactions.
****Waiting**: These tasks include waiting for patients, records, or other staff.
††**Miscellaneous**: Examples include 'Provider leaving facility' or walking within facility. Also includes activities not in our other categories.
‡‡Kruskal–Wallis test.

Table 4 Mean minutes per patient-encounter spent by providers in direct and indirect care

Activity (mins/encounter)	Paper medical record system (n=453)*	Electronic medical record system (n=601)	p Value*
Direct patient care	3.35	2.33	<0.0001
Indirect patient care	3.70	2.29	<0.0001
Direct+indirect patient care	7.05	4.62	<0.0001

*Unpaired t test.

Survey results

Thirty-one of 45 healthcare providers surveyed (69%) at the three implementation sites returned completed surveys. Respondents included 10 medical doctors, seven nurses, four clinical officers, three pharmacists, and two each of counselors, nurse aides, and records clerks. Only six providers reported being regular computer users, while four had never used a computer before. Overall satisfaction with the implemented EHRs and the support infrastructure in place was high (5.4±1.5), as were reports of the positive questions in the survey (figure 3). Providers were generally happy with the support system in place (5.5±1.7), with only two reporting dissatisfaction (rating less than 4) with the support-infrastructure. Respondents expressed an interest in further training on the EMR (5.5±1.8).

DISCUSSION

A model providing external support with a TEC connected to global developer and implementer groups successfully implemented an open-source EHR in three geographically separated and programmatically different HIV/AIDS clinics in Uganda. With support of the TEC, all three sites have had fully functional EHRs since the initial installation, and end-users have reported general satisfaction with the implemented system. Our model directly addresses the shortage of highly-trained IT personnel and the prohibitive cost associated with supporting EHRs in resource-limited settings. By using a shared external support-infrastructure provided by an academic TEC, each implementation site was spared from having to compete for, hire, and maintain its own highly-trained and expensive high-level EHR implementers. Furthermore, the local sites did not need to rely on foreign EHR developers for on-site implementation support.

Such an implementation-model could serve as the key to enable and sustain broad-based EHR implementation in resource-limited settings. It is also a model that can be easily adopted by developing countries' ministries of health or by international healthcare funding agencies—such as PEPFAR—which support many clinics. In the developed world, there is also an increasing interest in similar models for broadly implementing EHRs. An example of this can be found in the USA, where the Office of the National Coordinator of Health Information Technology intends to support Regional Centers which will "furnish assistance, defined as education, outreach, and technical assistance, to help providers in their geographic service areas select, successfully implement, and meaningfully use certified EHR technology to improve the quality and value of healthcare".[20]

The three OpenMRS implementations in Uganda demonstrate that it only takes a small number of IT support technicians at the TEC to support several implementations. By staggering the dates for initial implementations at the three sites, TEC personnel were able to focus more energy on one site at a time. It was a bonus to have strong implementer and developer communities for OpenMRS, but this does not reduce the central support-role played by the national TEC. For EHRs without well-developed implementer and developer communities, a well-organized TEC could assume most responsibilities for the external support resource. Such a TEC would need to provideIT support and informatics support, including concept dictionary maintenance and clinical data management, for the implementations.

Through the time–motion study and surveys, we observed that EHRs implemented using an external support resource could be well-received by end-users, and that such systems could improve the efficiency of providers. Almost all providers had a positive attitude towards the EHR, and they found the support infrastructure adequate for their needs. The concern that an EHR would slow clinicians down was not demonstrated—in fact, clinicians spent less time per patient-encounter on both direct and indirect patient care and had relatively more time for both personal and other work-related activities after the EHR implementation. It is likely that without OpenMRS, the clinicians would have had difficulty increasing their number of patients per day from 28 to 40.

However, the apparent benefits in increased efficiency for physicians were balanced by more waiting time spent per visit by returning patients post-implementation of OpenMRS. This was possibly due to providers' inexperience with computers, especially among non-clinician staff. However, it is also possible that the increased waiting time was due to bottlenecks caused by increased clinic volume post-implementation. Confounding by changes in the healthcare environment is a well-recognized limitation of historical cohort (before-and-after) studies such as ours. However, in almost all cases, once the patient finally saw a provider, the time spent in taking care of the patient was lower in the post-implementation phase for all types of providers.

In addition to problems with confounding of prospective cohort studies, several other limitations of our study deserve mention. We could not adhere to a strict random selection of patients to observe, given the unpredictable nature of their visits and lack of clinic scheduling. Also, observing the providers and patients may have changed their behavior (Hawthorne effect). The EHR was implemented at three sites, and time–motion studies performed only at one site and this could limit generalizability of these findings. Our survey was not psychometrically tested, and the results may also not have been representative of the whole group. Finally, our model of using an external support resource and TEC may not easily translate to institutions that use proprietary EHRs with their own end-user support.

Future work needs to demonstrate the effects of EHRs on provider productivity as a justification for their implementation

Table 5 Activities (mean minutes per visit) by patients before and after implementation of the EHRs

	Paper medical record system	Electronic medical record system	p Value*
Returning patients	**90 Patients**	**96 Patients**	
Waiting	51	85	<0.001
Waiting for clinician	23	23	0.74
Waiting for other provider	11	36	<0.0001
Waiting for pharmacy	16	27	<0.0001
Time with other staff	11	4.8	0.004
Miscellaneous	5.9	3.9	0.026
Time with clinician	7.4	6.8	0.72
Time with pharmacy	2.7	1.0	<0.0001
Total visit length	77	102	<0.001
Activities for new patients	**21 Patients**	**20 Patients**	
Waiting	77	84	0.72
Waiting for clinician	41	26	0.26
Waiting for other provider	18	30	0.14
Waiting for pharmacy	17	28	0.010
Time with other staff	9.9	14	0.28
Miscellaneous	5.2	3.3	0.10
Time with clinician	5.5	6.7	0.18
Time with pharmacy	1.9	1.3	0.18
Total visit length	99	109	0.57

*Kruskal–Wallis test.

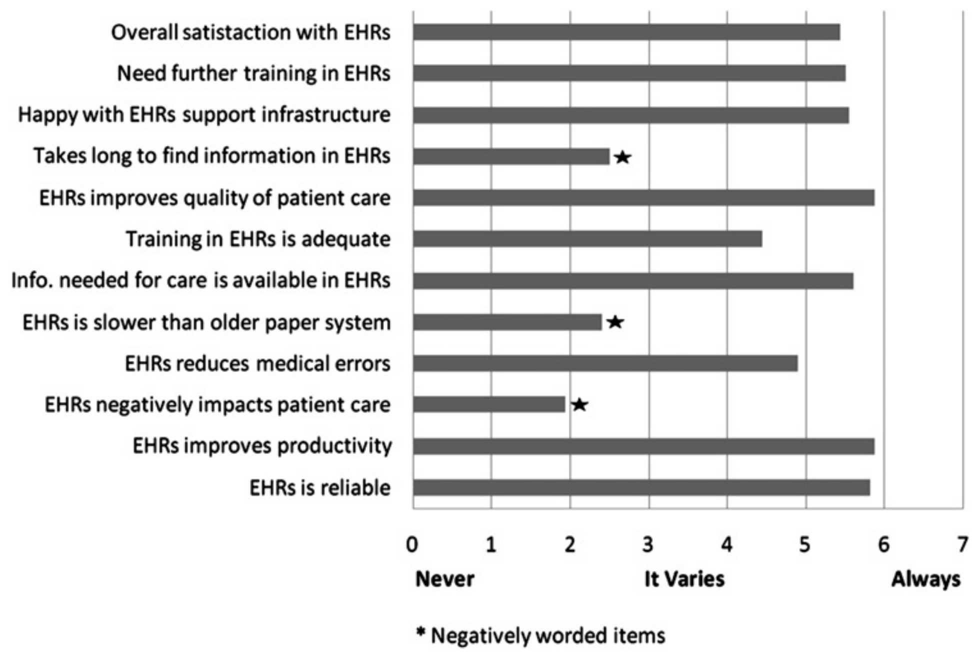

Figure 3 User satisfaction with the electronic health records (EHRs) and the support infrastructure in place at the three implementation sites.

and management costs. Studies on the financial impact of using an external support resource centered on a national TEC, satisfaction with quality and efficiency of service offered by this model, and the cost-benefit of using this model are also needed. We also need to formally evaluate attitudes by the TEC staff, developers, and implementers towards this model. In the short term, it will most likely take a national TEC supported by a community of developers and implementers to ensure that local EHR implementations evolve gracefully—so that the greatest value is obtained from healthcare information. In the long term, there is need to enhance the informatics capacity of the TEC, especially through academic and public–private partnerships.[21] Further, the number of TECs specializing in EHRs implementations needs to be increased, and mechanisms put in place to ensure that implementers feel confident turning to them for implementation needs. This will ensure that TECs emerge as self-reliant centers of excellence that can also support broad-based EMRs implementations.

CONCLUSION

An external support resource centered on a national technical expertise center supported by global developer and implementer groups can be effective in successfully implementing and maintaining EHRs at multiple sites in resource-limited settings. This implementation model addresses both the human-resource and cost constraints of implementing EHRs, lowers the general threshold for implementation, and offers a viable option for scaling up EHRs in resource-limited settings which, in this case, had salutary effects on provider productivity.

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