The OpenMRS Implementers Network

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ABSTRACT

Objective: OpenMRS (www.openmrs.org) is a configurable open source electronic medical record application developed and maintained by a large network of open source developers coordinated by the Regenstrief Institute and Partners in Health and mainly used for HIV patient and treatment information management in Africa. Our objective is to develop an open Implementers Network for OpenMRS to provide regional support for the growing number of OpenMRS implementations in Africa and to include African developers and implementers in the future growth of OpenMRS.

Methods: We have developed the OpenMRS Implementers Network using a dedicated Wiki site and e-mail server. We have also organized annual meetings in South Africa and regional training courses at African locations where OpenMRS is being implemented. An OpenMRS Internship program has been initiated and we have started collaborating with similar networks and projects working in Africa. To evaluate its potential, OpenMRS was implemented initially at one site in South Africa by a single implementer using a downloadable OpenMRS application and only the OpenMRS Implementers Network for support.

Results: The OpenMRS Implementers Network Wiki and list server have grown into effective means of providing implementation support and forums for exchange of implementation experiences. The annual OpenMRS Implementers meeting has been held in South

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Africa for the past three years and is attracting successively larger numbers of participants with almost 200 implementers and developers attending the 2008 meeting in Durban, South Africa. Six African developers are presently registered on the first intake of the OpenMRS Internship program. Successful collaborations have been started with several African developer groups and projects initiated to develop interoperability between OpenMRS and various applications. The South African OpenMRS Implementer group successfully configured, installed and maintained an integrated HIV/TB OpenMRS application without significant programming support. Since then, this model has been replicated in several other African sites. The OpenMRS Implementers Network has contributed substantially to the growth and sustainability of OpenMRS in Africa and has become a useful way of including Africans in the development and implementation of OpenMRS in developing countries. The Network provides valuable support and enables a basic OpenMRS application to be implemented in the absence of onsite programmers.

1. Introduction

Electronic data management and reporting systems are increasingly important for patient and treatment information management. However, in resource-constrained income settings, it is often difficult to justify the relatively high cost of acquiring software systems in the face of other pressing health priorities. One possible solution is to use appropriate free and open source software (FOSS) developed by highly trained health and software development professionals and open source developer networks. FOSS can potentially reduce the costs of acquiring systems and also contribute to in-country capacity and economic development by re-assigning licensing costs to developing local software development and implementation skills. However, in order to realize these benefits, FOSS like all software, needs to be locally relevant, supported and sustainable.

In this paper, we describe an Implementers Network for the FOSS application, OpenMRS, to help support and sustain implementations in Africa and attract inputs from African developers. We also describe the use of the Network to support an implementation of OpenMRS in South Africa.

1.1. Historical development of OpenMRS

OpenMRS (www.openmrs.org) is a highly configurable, scalable and extensible open source electronic medical record (EMR) application currently applied mainly to HIV/AIDS and Tuberculosis patient and treatment information management in developing countries [1]. The initial core application was started as an improvement of the AMPATH Medical Record System (AMRS) originally implemented in Eldoret, Kenya [2–4]. AMRS was extensively redesigned in collaboration with Partners in Health (PIH) and the PIH HIV-EMR system [5], and re-programmed using open source technologies as OpenMRS. The code base is currently developed and maintained by an open source developer community managed by the core group from the Regenstrief Institute and PIH. In 2005, the South African Medical Research Council (SA-MRC) joined the core management team to help develop an OpenMRS Implementers Network in Africa.

1.2. Technical architecture of OpenMRS

The architecture of OpenMRS is shown in Fig. 1. The core OpenMRS application comprises a web application, programmed in Java and JavaScript and a number of open source component applications, maintained by other open source communities, including:

- MySQL—relational database management system (RDBMS);
- Apache Tomcat—servlet application;
- Mozilla Firefox—web browser application, and;
- Hibernate—object to relational mapping and persistence application.

A number of modules can be loaded into the core application to provide additional functionality. Almost all OpenMRS installations use the FormEntry module that allows forms to be developed for data capture and entry to the system. The current version of the FormEntry module uses InfoPath, a core application in the Microsoft Office Professional Suite, to design and implement the forms. Although it is not free or open source, InfoPath was used because (i) it uses XML and follows a very clean model-view-controller (MVC) pattern that allows the data elements being collected to be managed separately from the form's appearance, and; (ii) InfoPath not only renders forms, but also provides a WYSIWYG (what you see is what you get) editor similar to a word processor, bringing form editing within reach of non-programmers. However, several groups and individuals are working on an open source alternative to InfoPath, albeit with lesser functionality.

OpenMRS implements several standards to support its functioning as a client server and distributed application and to improve interoperability with other systems. Data and forms are represented in the Extensible Markup Language (XML) and the XForms (XML Forms) standards, respectively and data is communicated between the FormEntry module and the application layer packaged as Health Level Seven (HL7; www.hl7.org) messages. The RDBMS stores data according to an open relational model and can be manipulated and queried using standard Structured Query Language (SQL).
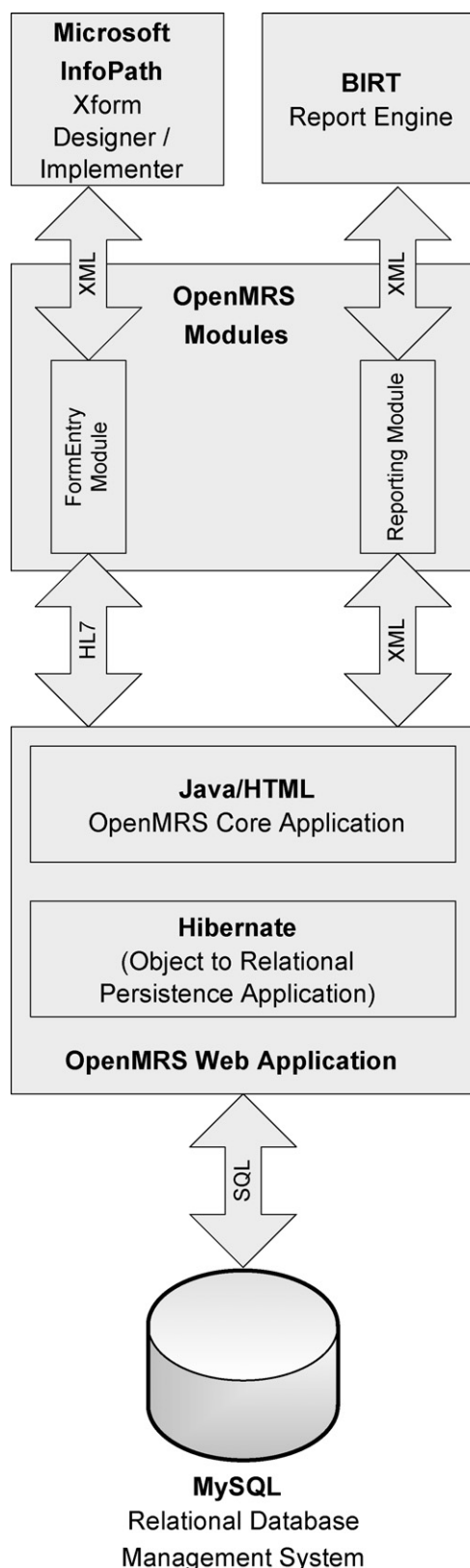
Fig. 1 – OpenMRS technical architecture.

1.3.   OpenMRS implementations

The first production implementations of OpenMRS for HIV and TB patient management took place in 2006 in Kenya [2,3], followed later by implementations in Rwanda [6,7] and South Africa [8]. Since then, OpenMRS has been implemented in many other countries, notably in Malawi (http://www.baobabhealth.org/), Mozambique, Lesotho, Tanzania, Uganda and Haiti. The Millennium Villages Project (http://www.milleniumvillages.org) has expanded the scope of OpenMRS via the Millennium Global Village-Network to include primary health care and plans to implement OpenMRS in eleven African countries [9].

The OpenMRS data model has also been used and incorporated, in whole or part, into other applications and implemented, in part, in other languages including Ruby on Rails and Microsoft Dot Net. The World Health Organization (WHO) has developed a version of OpenMRS (OpenMRS Express) preconfigured with the forms accompanying the WHO-recommended HIV patient treatment and monitoring guidelines.

The first two implementations of OpenMRS in Kenya and Rwanda were applied to HIV/AIDS patient and treatment information management and carried out by teams that included professional software developers from the USA who were simultaneously involved both in developing and implementing the application. Although OpenMRS had been designed as a general purpose EMR application to be configured and implemented by Implementers without necessarily writing code, at this time there was little or no experience to support this notion.

In this context, an Implementer is defined as a health information systems professional who focuses on installing and configuring software and systems to meet the needs of a particular health information system requirement with little or no programming of the actual software application. The appropriateness of a general-purpose EMR in a developing country context is greatly enhanced by its ability to be implemented and maintained without programming support as skilled programmers with the necessary expertise are scarce in developing countries and are usually attracted away by high-paying jobs in the commercial sector.

It was recognized from the outset that extension of OpenMRS to the Implementer community carries with it a greater support burden. Implementers, by definition, are not able to solve implementation problems programmatically and are dependent on rapid responses from developers or other technical support staff in remote locations to assist them when they encounter difficulties in a particular implementation. In commercial settings, this function is typically provided by company resources but open source applications have to rely on open source communities of volunteers to help them.

Around the time of the first OpenMRS implementations, it was decided to start an OpenMRS Implementers Network to meet this requirement. The OpenMRS Implementers Network would implement collaboration tools to provide support for implementers in developing countries and to reduce the burden on developers. It would also organize regular Implementer meetings and training courses and, in order to contribute to African professional development, it would

also provide opportunities for African developers to join the network. Lastly, it would seek economies of scale and collaboration with other appropriate open source developer and implementer networks working in Africa and develop interoperability between applications.

2. Methods

2.1. OpenMRS collaborative web-based tools

A dedicated Implementers Wiki (www.openmrs.org/implementers) was implemented by the core OpenMRS developer group within the OpenMRS Wiki (MediaWiki) and hosted at the Regenstrief Institute in Indianapolis, USA. A dedicated list server was also implemented at the Regenstrief Institute (implementers@openmrs.org). Members of the OpenMRS community were encouraged to direct email appropriately to either the developers or implementer list server.

2.2. OpenMRS Implementer Network meetings

Funding for the OpenMRS Implementers Network was obtained by way of research grants from the Information and Communication Technologies for Development (ICT4D) program of the International Development Research Centre (IDRC; www.idrc.ca), the Knowledge Management and Sharing Department of the WHO and, recently, from the Rockefeller Foundation.

2.3. OpenMRS Internship Program

The OpenMRS Internship Program (OIP; http://openmrs.org/wiki/OIP) is modeled on the successful Google Summer of Code (GSoC) project (http://code.google.com/soc/) in which OpenMRS is an active participant. The OIP was initiated at the end of 2007 to provide African open source developers with an opportunity to work on OpenMRS. Projects are posted to the OpenMRS Wiki and African implementers are invited to submit proposals. Applicants may also suggest self-initiated proposals. Projects are selected on a competitive basis and applicants are offered a stipend to protect their time for about three months so they can work on their chosen OpenMRS project. Successful applicants are matched with mentors from the core Developer group and follow the same program as the OpenMRS GSoC program.

2.4. Collaboration with other networks

We have started collaborations with similar networks and projects working in Africa. In particular, we are collaborating with the Health Information Systems Programme (HISP; www.hisp.org), the group implementing the Electronic TB Register (www.etrnet.info) and the UNIADS-funded country response information system (CRIS; www.unaids.org/en/KnowledgeCentre/HIVData/CRIS/). In both cases, we are actively working on projects to improve interoperability between OpenMRS with the District Health Information Systems (DHIS) and ETR.Net.

2.5. OpenMRS implementation at Richmond Chest Hospital

We evaluated the potential of OpenMRS to be implemented by South African Implementers for the That's It project at Richmond Chest Hospital (RCH) in the KwaZulu-Natal province of South Africa [8]. RCH is a TB referral hospital and That's It is a PEPFAR-funded project to offer antiretroviral treatment to qualifying TB patients according to a best practices approach.

3. Results

3.1. OpenMRS collaborative web-based tools

The OpenMRS Implementers Wiki and mailing list are now the primary means of collaboration and communication among implementers and between implementers and the developers group.

There are a large number of registered users on the implementers list and a substantial daily traffic. The implementers list server has become a very popular site for discussion of implementation issues and general topics of particular interest to implementers, at times surpassing traffic on the developers list. Issues and questions pertaining specifically to OpenMRS implementers are posted to the implementers mailing list and/or forum and answered by implementers. If unresolved, issues are often answered by developers who are registered on the implementers list server. In general, the list servers have been fairly effective at dividing traffic into developer and implementer groups.

OpenMRS also has a developers list server (dev@openmrs.org) that focuses on technical issues pertaining to the development of OpenMRS. The Implementers list server traffic deals mostly with issues arising during specific implementations of OpenMRS in developing country settings. In many cases, the OpenMRS Implementers list is virtually the only mechanism by which implementers obtain support for a particular implementation of OpenMRS in addition to the documentation posted to the site.

3.2. OpenMRS Implementers Network meetings

Three annual OpenMRS Implementers Network meetings have been held to date:

1. First OpenMRS Implementer Network meeting – Cape Town, South Africa – July 2006;
2. Second OpenMRS Implementer Network meeting – Cape Town, South Africa – April 2007;
3. Third OpenMRS Implementers Network meeting – Durban, South Africa – June 2008.

The first two meetings followed a similar format and were focused predominantly on the OpenMRS Implementer community. The format of the third meeting in Durban was different from the first two meeting in two important respects. Firstly, the Durban meeting was held in association with HISA 2008 (Health Informatics in Southern Africa; www.hisa.co.za), the biannual conference of the South African Health Informat-

ics Association (SAHIA) and a meeting of the Africa chapter of OSHCA (Open Source Healthcare Alliance; www.oshca.org) through which the OpenMRS Implementers community tried to reach out to other user communities and developers from Asia. Secondly, we introduced a dedicated developer track as a parallel session to the main meeting to cater for the interests of the growing African OpenMRS developer base.

Attendees of all three events have included members of the core OpenMRS developer group as well as OpenMRS Implementers from a range of African sites. Travel and accommodation scholarships were awarded to selected African implementers. Content included keynote presentations by the lead architects of OpenMRS, technical presentations and workshops on selected OpenMRS technologies and country-level experiences by OpenMRS Implementers. The meetings generally followed an unconferencing approach and feedback from a daily After Action Review was used to adjust the agenda for the next day.

The annual OpenMRS Implementers meeting has become a notable event that is growing annually. The first meeting attracted 67 participants from 7 countries, the second attracted 167 from 20 countries, mainly Africa and the USA. The third meeting attracted almost 200 participants from more than 20 countries, including many outside of Africa and the USA Fig. 2.

The projects identified by developers and implementers at the first OpenMRS Implementers meeting in 2006 are listed in Table 1.

All of the identified projects have received attention from the OpenMRS developer group, as follows. The first project identified was to implement a desktop version of OpenMRS. This has been implemented by the WHO as OpenMRS Express, a version configured with the WHO-recommended forms for HIV patient and treatment monitoring. The second project was to develop an XForms alternative to InfoPath. This is an active ongoing project. Systems supporting TB and integrated care (project three) were implemented both by SA-MRC and PIH. Extension of OpenMRS to mobile phones (project four) gave rise to the OpenROSA consortium (www.openrosa.org) and the JavaROSA application development project. Project five, concept sharing, is under active development in the form of the concept cooperative and several other initiatives related to the OpenMRS concept dictionary. Lastly, as regards project six, there has been considerable progress in the development of OpenMRS reporting systems, particularly using the BIRT report designer application.

In addition to the annual OpenMRS Implementers meeting, a number of *ad hoc* meetings and in-country training courses have taken place. The South African group, through the OASIS project has delivered focused OpenMRS training programs in Tanzania, Mozambique and Zimbabwe with plans to extend to other African countries. The general format is to support in-country implementers to organize regional training meetings.

3.3. OpenMRS Internship Program

The first OIP call was published in November 2007 and a total of six interns are currently enrolled on the Programme. Projects include the following:

1. Development of a patient scheduler for OpenMRS;
2. Development of an XForms alternative to InfoPath;
3. Integration of OpenEHR (www.openehr.org) with OpenMRS;
4. Data exchange between OpenMRS and the DHIS version 1.4,
5. Data exchange between OpenMRS and the DHIS version 2,
6. Setting up a low-cost file sharing system between sites.

Fig. 2 – OpenMRS Implementers meeting 2007, Cape Town, South Africa—group photograph.

Table 1 – Historical projects identified at OpenMRS Implementers meeting, June 2006.

Project name	Description
Implement a desktop version of OpenMRS	The current version of OpenMRS is a robust, tiered application that uses an open source database server (MySQL) and necessarily requires some configuration in order to function correctly in a multi-user, client-server environment. Although OpenMRS and the required open source database and Java runtime software are relatively straightforward to install, it was suggested by some implementers that a desktop version of OpenMRS would be useful in sites that lack the technical expertise to install the client-server version. The desktop application would be limited to sites with sufficiently few patients (less than 2000) for whom a single data-entry clerk or health care provider could enter visit data. It was also suggested that the installation of OpenMRS could be streamlined and a single install program developed. A OpenMRS MD (Minimum Data) has been implemented by the Knowledge Management Group at WHO
Develop an open source XForms Design Application	OpenMRS currently uses InfoPath version 1.1 (Microsoft Corporation) to design and complete web-based encounter forms, used either by data entry clerks or by clinicians at the point of care. Although InfoPath is widely available as a core element of the Microsoft Office 2003 Professional suite, it is not available in sites using earlier versions or the Standard version of Office 2003, or non-Windows operating systems such as Linux or the Mac OS. A proposal was presented for an open source forms designer application based on the XForms (http://www.w3.org/MarkUp/Forms/) standard. The purpose of this application would be to provide a standards-based alternative that could be used in sites without access or where it is inconvenient to use Microsoft InfoPath
Develop systems specific for tuberculosis and for integrating care TB HIV co-infection;	Although most implementations to date have focused on the treatment of HIV/AIDS patients, OpenMRS is not, by design, disease specific. TB, multi-drug resistant TB (MDR-TB) and TB-HIV co-infection are all key priorities in Africa. With funding from the WHO StopTB group, PIH has developed a package of concepts, forms, reports and custom modules in OpenMRS to support the treatment of MDR-TB. An initial version is being tested in Lesotho and a full version should be complete in summer 2008. In parallel with this a second implementation of OpenMRS is being developed to support a major clinical study of MDR-TB in Peru
Develop OpenMRS applications for handheld devices and mobile phones	Cellular telephones are ubiquitous in Africa and an obvious choice for digital information processing. A main aim of the South African group is to develop medical data and patient management applications for handheld computers using the OpenMRS application. OpenMRS provides functionality for managing concepts and encounters such as medical encounters between patients and medical service providers or between persons and interviewers in ancillary support programs. The same basic process is followed for surveys in which patients (interviewees) and encounters (interviews) are managed and the observations (interviews) are associated with the encounter (interview). A plan was developed by the South African group, the IDRC and Cell-Life (http://www.cell-life.org/), to develop mobile phone extensions to OpenMRS
Enable concept sharing	Part of the power of OpenMRS stems from the creation of dictionary concepts that can be reused in multiple forms and other applications. However reuse of concepts from one solution domain to another requires careful planning Implementers can standardize concepts in domains where possible (e.g., within a program or country) and a concept mapping function used as the practical solution to concept and data integration. Some implementers (e.g., PIH and MVP) have implemented central control of concept creation and management in four or more countries
Develop OpenMRS Reporting Systems	PIH presented a pilot reporting system in 2007 based on a search and filtering tool for groups of patients (the cohort builder) and a link to the Business Intelligence Reporting Tool (BIRT). These tools are now in use in PIH sites in Rwanda, Malawi, Lesotho and Peru as well as in Kenya and Tanzania. To support the development of routine and ad hoc OpenMRS reports by non-programmers, these reporting tools will be combined with decision support tools developed by Regenstrief (including Arden Syntax support)

3.4. OpenMRS Implementation sites

A complete list of all OpenMRS Implementation sites and uses of OpenMRS is difficult to obtain. However, Table 2 summarizes data from the first three OpenMRS implementations in East and Southern Africa. In addition to the representative implementations detailed in Table 2, pilot and production applications have been implemented at sites in a significant number of other African countries.

During February 2007, Mbarara University of Science and Technology in association with Makerere University and the Universities of Indiana and San Francisco implemented an OpenMRS system at the ISS Clinic in Uganda for registered HIV/AIDS patients. The clinic is run jointly with the Mbarara regional referral hospital and is currently collecting all patient–clinician encounter data as well as laboratory data.

In January 2008, the National AIDS Control Programme and University Computing Centre implemented an OpenMRS system at Morogoro Regional Hospital in Tanzania. The system caters for the HIV/AIDS care and treatment programme within the hospital and allows for entry of detailed forms as well as the national forms. There is a separate report and export tool which links to OpenMRS for purposes of producing reports and export files to the National AIDS Control Program (NACP).

Table 2 – Three typical OpenMRS Implementations.

Site name	Implementers	Implementation date	Patients registered	Brief description
AMRS, Ampath Clinic, Eldoret, Kenya	Regenstrief Institute, University of Indiana, USA	February 2006	70,353 (35,000 patients on treatment or follow-up)	The system captures HIV and AIDS structured medical record forms. 748 users are registered in the system. All data for all HIV visits are stored in AMRS and clinical summaries are generated to guide clinical care. AMRS is being expanded to non-HIV care as well. Data is primarily captured via printed forms that are transcribed into the system. Most data entry happens centrally; however remote data entry is being rolled out to enable data entry at remote sites. The software is free and information drawn from the system guides clinical care and drives the reports for granting and governmental agencies. The group is able to collect and manage millions of data points for thousands of patients, provide decision support to clinicians, facilitate report generation, identify patient's lost to follow-up, and save many lives thanks to information management
Rwinkavua Hospital, Rwanda	Partners in Health, USA	July2006	7060 (2900 on treatment or follow-up)	The system captures HIV and AIDS structured medical record forms and includes a laboratory reporting system linked to OpenMRS and modules to simplify interactive use of the EMR by medical staff. Data is collected on paper forms. 124 users are registered on the system including data entry staff, providers and data managers and researchers although usage varies significantly and it is likely that most users don't use the system regularly. The system is used to generate alerts, warnings and patient summaries as well as to track loss to follow-up of ARV patients, assist drug forecasting and for observational research. Rwanda, paper forms. Much development work has been done so costs are higher in Rwanda than at other sites. Initial work could have been done in Microsoft Access but as numbers and data quantity per patient scale, OpenMRS is easier to use and more powerful. In Rwanda, OpenMRS has impacted on patient care, reporting, drug quantification and research
That's It Project, Richmond Chest Hospital, KwaZulu-Natal, South Africa	Medical Research Council and University of KwaZulu-Natal, South Africa	July 2006	1020 patients on treatment or follow up	The system captures HIV/AIDS and Tuberculosis structured medical record forms based on the standard HIV/ART and TB paper-based structured medical record forms implemented by the Department of Health. The forms are translated directly into Microsoft InfoPath. Primary data capture is onto paper forms and then the data is captured into OpenMRS system by a dedicated data manager. The system is used mainly to track patients and to generate routine reports. The system was configured from a free download of OpenMRS by a single implementer in approximately one month and, as implemented at RCH, is a highly cost-effective and appropriate solution. The system has also been replicated for use in the same program in other provinces of South Africa, further increasing the cost-effectiveness of the solution

3.5.   Collaboration with other networks

OASIS (Open Architectures, Standards and Information Systems) is a new project funded by the IDRC that has been used to establish implementer nodes in several developing countries implementing OpenMRS. The project is also developing FOSS interoperability laboratories and developing interoperability with other open source health applications and is also working with the Knowledge Management and Sharing Department of the WHO to develop data transfer methods between OpenMRS, the DHIS, the ETR.Net and CRIS using the Indicator Exchange Format (IXF) and, using HL7 messaging, other EMR applications.

3.6.   OpenMRS Implementation at Richmond Chest Hospital

In June 2006, a single implementer (CJS) installed and configured an early pre-release version of OpenMRS, available from the OpenMRS web site (www.openmrs.org/downloads) to satisfy the data management requirements for the PEPFAR-funded That's It project in KwaZulu-Natal. The application only includes functions included in the original OpenMRS download and available by configuring the application, specifically excluding any customizations requiring programming. New releases of OpenMRS and selected modules were successively applied to the system as they became available.

The provincial HIV/ART forms were used to implement a data capture user interface in InfoPath for HIV/ART patient and treatment information management and the forms used by the South African National TB Control Program were used to implement a data capture user interface in InfoPath for TB patient and treatment information management. A total of thirteen different forms were implemented with each form comprising between one and four pages.

The first step in the process of electronic forms development was to create a metadata dictionary in which fields on the forms were matched to existing concepts in the OpenMRS concept dictionary or, where necessary, new concepts were created. Once the metadata dictionary (concept dictionary) had been developed, one page forms were implemented in InfoPath in about one hour and the more complex forms took up to a day to implement.

Clinicians capture data on paper-based structured medical record forms which are then entered into the OpenMRS application. Initially, a small network was implemented with a single OpenMRS application and three client computers and data capturers working off a single database. Once the backlog data was captured, we reverted to a single standalone database application. The system currently contains a little more than 1000 patients and 200,000 observations and is easily maintained by a single data manager working mornings-only, five days a week. The entire has been maintained remotely for two years by the same implementer with occasional onsite help from postgraduate students at the University of KwaZulu-Natal.

We also established a pilot system where the OpenMRS application and database server were located 80 km away in the city of Durban and accessed by client computers via the mobile phone network. Although slow, the application was workable in this configuration and may be used to facilitate data capture for future implementations of OpenMRS in remote rural settings.

The OpenMRS system was found to be extremely cost-effective. The cost of installing the data management system amounted to the cost of the hardware, networking equipment, operating system (Microsoft Windows XP) and the front end application (Microsoft InfoPath or Office Professional 2003). The OpenMRS software itself is distributed free under the OpenMRS Public License. Configuring the forms and implementing the system required approximately one person month of time and upgrades were implemented after routine project meetings.

4.   Discussion

OpenMRS is fulfilling its potential as a low cost, rapid development, open source application for developing HIV and TB patient and treatment management systems in resource-poor settings. The generality of the core application design-based on the clinical encounter with flexible addition of observations linked to concepts will likely support extension to information management in a number of primary healthcare settings in developing countries.

With the rapid growth in OpenMRS functionality, the OpenMRS Implementers Network fills a very necessary requirement to support the use of OpenMRS by African implementers without which it would be difficult to advocate using the application or to make it sustainable. Importantly, the OpenMRS Implementers Network also provides a vehicle for including developing country perspectives and information to guide the development of OpenMRS. The current and expected growth in Internet access in Africa will further enable this mode of operation and support. To our knowledge, this is one of few examples of an open implementer's network being developed in Africa with a tight linkage between developers and implementers, the only other notable example being the HISP network [10]. The inclusion of the OIP will also grow a cadre of OpenMRS developers in Africa which will continue to influence the development direction and provide local expertise.

Although internet-based collaboration tools have proven to be highly effective in supporting OpenMRS implementations, regular face-to-face meetings and training courses are fundamentally important to supporting this process. It seems unlikely that OpenMRS would have reached the same level of success in Africa without an annual meeting and training courses.

The OpenMRS meeting has become an important mechanism for the transfer of knowledge concerning OpenMRS. The meetings serve as an opportunity for OpenMRS Implementers to interact with the core developers and attend technical training sessions and are also an opportunity for the developers to hear from the community and identify needs that make their way into future releases of OpenMRS. It will be important that this community develops as a community of practice so that master implementers are able to help beginning implementers with common issues and reduce the support burden on the core developers who need to remain focused on developing and testing new functionality.

The implementation of OpenMRS at RCH is important in that it shows that OpenMRS can be implemented and maintained with limited or no programming support removing another one of the perceived barriers to EMR implementations in developing countries [11,12]. It is important to recognize that OpenMRS is a fully fledged EMR and should only be implemented by experienced informatics professionals who adequately understand how to structure data and implement clinical systems. However, many implementers in Africa lack the programming skills required to develop functional applications and, therefore, while capable of implementing effective data capture and reporting systems, are dependent on functionality in the core application and the configurable modules to implement a system suitable for their needs. The implementation at RCH elegantly demonstrates that a system can be effectively implemented and maintained in this way.

Many implementers, particularly in Africa, develop in-house EMRs using applications such as Microsoft Access especially in circumstances where there is no alternative and no budget for computerization. However, it often results in substantial amounts of time being spent on development and/or less than optimal data storage and functionality. It is encouraging to see that some developers have opted to develop applications using the OpenMRS database that provides a well-tested data storage platform that minimizes the potential for catastrophic data corruption.

Cost-effectiveness is another important benefit that was realized in this study. The OpenMRS implementation at RCH was highly cost-effective and much less-expensive than either a commercial application or an application developed *de novo*. These systems would have required at least as much implementation time as the OpenMRS implementation and additional costs for licensing or development, respectively. The cost benefit of FOSS is often over-exaggerated as software cost is only one (fairly limited) part of the overall system cost and the benefit is often more important in other aspects, such as collaborative local software development and community building. However, it is important that applications are cost-effective, particularly in resource-constrained settings, where as much budget as possible should go directly to patient care. The fact that OpenMRS is scalable and the licensing permits unlimited copies of the configured application to be freely distributed supports the scale-up of ART in Africa without simultaneously scaling the license costs.

Longitudinal, EMR applications are an increasingly important part of sustainable African ART programs. HIV infection is now treated as a chronic condition and patients need to be managed for life. In addition, ART programs are required to report sophisticated indicators to justify conditional grants to buy drugs. It is much more efficient to manage patients and programs using well-structured data from EMR applications. OpenMRS is still a relatively new application and some of the current limitations are related to the lack of sophisticated functionality typical of EMR's by clinicians in secondary and tertiary institutions [13,14]. However, the present forms-based application combined with the ability of non-programmers to rapidly configure a powerful data capture application meets the most pressing need in developing countries. Much development work is currently being undertaken to extend the OpenMRS functionality for healthcare facilities with additional needs.

Many new systems need to deal with the issue of legacy data and the client server implementation of OpenMRS used in the initial phase of the project was highly effective at rapidly capturing the backlog data. However, this is a relatively small system where it was feasible to create a six month job for two local persons to enter data and we are presently working on tools to facilitate data import from other databases, such as Microsoft Access.

Collaborations with other open source health software developer communities is another important aspect to the OpenMRS community which, we expect will expand the usefulness of these open source applications. Through data exchange between OpenMRS and the DHIS and ETR.Net, routine patient-level data can be captured and managed at facility level then selected, aggregated and/or, de-identified before being exported to other applications re-using the same data for public health reporting. Once these systems are matured and implemented, they will assist with local information management and improve the quality and efficiency of indicator and aggregate reporting. In adopting a systems approach to health information, it is fundamentally important that applications support appropriate open standards and open interfaces and that implementers adopt open architectures and a flexible approach to implementing standards [15].

Open source software has much potential to alleviate the lack of health information and information systems support in developing countries and there are now a substantial number of open source health software applications being used in developing countries. Unfortunately, many applications are not used to their full potential due to difficulties in using such software and, we suspect, because of a lack of an Implementers Network. While it is not completely understood why some open source projects succeed and some fail, community building is a core component of a successful open source project.

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