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Requirements for an Open-Source Pharmacy Dispensing and Stores Management Software Application for Developing Countries

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Introduction

All health care delivery programs require a robust and reliable drug supply system. Stock-outs can have severe negative effects on patient care, especially in the case of complex, chronic diseases like HIV and TB when poor outcomes, such as drug resistance and death, can often result.

The last ten years have seen a significant increase in the use of computers in the developing world to track medicine inventory, dispense medicines to patients, and record and analyze patient medical records, including their medicine regimens.¹⁻⁹ Each of these applications operates primarily as an independent system.

By adding one pharmacy application that integrates data from the existing systems, we can greatly increase the accuracy and ease of the creation of medical orders and stock management, while decreasing the number of medical supply stock-outs. This new pharmacy quantification, analysis, and reporting (QAR) application, the data that must be exchanged between it and existing applications, and the required functionality. Finally, it is argued that by developing standards for this data exchange, a variety of electronic medical record (EMR) systems and other health management systems can benefit from the pharmacy QAR functionality.

Section 2 begins with a discussion of the process of determining quantities when ordering pharmaceuticals for a health program and continue with a discussion of common challenges. We then undertake a short review of existing computer applications for electronic medical records, inventory control and dispensing and explain their limitations. In Section 3 we lay out the required functionality of a pharmacy

dispensary and stores management application and identify the relatively simple types of data exchange required to greatly increase the quantification power of the system. Section 4 is the discussion and the conclusions. Information on the research methodology and references for accessing the software mentioned in this report are found in the annexes.

This paper also serves as a case study of how to select and design a medical information system for use in a developing country. We hope this will inform the design and selection of other systems for laboratories, radiology systems, and others that can be linked with EMR systems to create a full enterprise medical information system.

Background

Determining order quantities

Calculating order quantities is a multiple-step process that requires estimating future medicine need, adjusting for known changes in program delivery, determining current and predicted stock levels at the time when the order will arrive, and finally subtracting available stock from the estimated need.

Step 1: Quantify future medicine need

Because quantification is done for a time period in the future, estimation of future medicine use and the ability to estimate stock levels when the new order arrives are required. In *consumption-based quantification*, future need is based on past consumption. Data is collected from inventory records in the warehouse or dispensary. *Morbidity-based quantification* calculates estimated need based on disease incidence (morbidity), predicted demand, and standard treatment guidelines. This method includes programs that deliver regimen-based treatments – such as those for MDR-TB or AIDS. *Adjusted-consumption* quantification uses both types of knowledge, starting with a consumption-

based order and adjusting the quantities using knowledge of disease incidence.

The needs estimate is then adjusted based on factors such as planned program scale-up or scale-down, known changes in treatment protocols, and seasonal variations (e.g., no malaria during dry season). A complete discussion is available in outside literature.^{10, 11}

Step 2: Determine future available stock levels

For each item in the inventory, it is necessary to calculate the amount of stock that will be available in the warehouse when the order will arrive.

Information on current stock levels is available through the inventory control system either in the form of stock cards or a computerized system. Quantities of all medical supplies already on order are then added. Next, the expected consumption or average monthly consumption, multiplied by the number of months, is subtracted. Additional stock that will expire before the new order arrives is also subtracted from the current stock level.

Step 3: Calculate order quantities

Order quantities are found by subtracting the future available stock from the calculated need.

Challenges in calculating order quantities

There are many challenges in accurately calculating order quantities.

- Many programs are missing the data they need to make accurate forecasts. This is either because they lack robust inventory control systems and reliable consumption data, or because accurate information is not always available.
- Ordering requires some level of predicting the future. While program goals might be known, it is difficult to estimate the number of patients who might be lost to follow-up or who will change treatment due to resistance. Predicting regimen needs for as yet unidentified patients falls into this category.
- Ordering is complex because projects may use upwards of 400 medical items, and morbidity and consumption data is required for each item.
- Consumption data is often incomplete due to incomplete warehouse records, and because shortages skew usage patterns.

- Morbidity data is often incomplete because in many cases the patient's medical record captures only the patient's primary diagnosis, which is often uncoded. The corollary of this is that morbidity data is often more robust for targeted programs and conditions (malaria, TB, AIDS), and less complete or less reliable for treatments for secondary and acute conditions or for palliative care.
- Calculating order quantities, order shipping times, and buffer stocks is a logistics task, but few medical staff are trained in logistics.

Patient charts and warehouse stock cards have traditionally been paper-based data management systems. As treatment programs expand, however, staff time is limited, and some reports – such as product expiry reports – are difficult to generate by hand. In resource-limited settings, where the clinic closes at 5 p.m. so that staff can be home before dark, spending evening hours working on data analysis and reports is not an option.

Computer-assisted technologies

There are four types of computerized systems used in resource-limited settings that are related to ordering and quantification:

- EMR system: Records patient data, normally within a health clinic, including patient medical history, test results, and medicine regimens. It can produce reports on the number of patients on each medicine or, for TB, each regimen and drug resistance pattern.
- Pharmacy dispensing system: Within the dispensary, records which medicines are dispensed to which patient, and how much stock entered and left the pharmacy.
- Inventory control application: Records stock levels for all medical items, including batch numbers and expiry dates, in pharmacy stores. Functionality includes normal stock control functions such as stock receipts, issues, and balancing stock totals after a physical inventory.
- Quantification tools: Calculates estimated need of various medicines. Tools range from simple spreadsheets to complex databases, and use anything from a percentage markup over previous consumption to models of patient regimens.

Currently these applications operate independently (i.e., only EMR) or with one other system (EMR and Dispensing). Although there are many software systems in use in the developed world, in developing countries only a

limited number are used outside of the original organization with documentation and technical support readily available. We review some of these systems below. Contact information and URLs for all software discussed here are listed in the appendices.

- EMR systems vary in function. All EMRs are based around records for individual patients, including identification, location, and medical history. Most have the ability to record a patient's medicine regimen – especially for those patients on either TB or HIV/AIDS medicines. In many EMRs used in developing countries, medicines for secondary and acute conditions are not recorded (e.g., aspirin or paracetamol).
 - PIH-EMR: Partners In Health (PIH) Peru and the Philippines. The system was designed to support the management of MDR-TB, and includes data on all patients tested for drug resistance in several large laboratories in Lima, Peru. A subset of these patients are enrolled in treatment (9,500 have been treated to date). All drug data is recorded, including all regimen and formulation changes. Drug regimen data is entered in a custom system that generates alerts for possible errors or contraindications. The dispensing of the drug from the pharmacy is assisted by a separate dispensing system that uses data from the EMR. There is not currently a system for the automatic transfer of data between systems though this is being created. Technical support is provided through PIH.¹²
 - HIV-EMR (PIH): The HIV-EMR system is a variation of the PIH-EMR, and is used in Haiti to support the treatment and monitoring of HIV patients. ART and supplementary medicines are recorded for each patient along with clinical data and key laboratory results such as CD4 counts. Regimen data is used to calculate future drug requirements. Dispensing occurs from regimen lists generated from the EMR but is not otherwise automated. Technical support is provided through PIH.¹²
 - FUCHIA (Follow-Up and Care of HIV Infection and AIDS): FUCHIA, developed by Doctors Without Borders (Médecins sans Frontières), is an electronic patient monitoring system for HIV/AIDS patients. In addition to patient

demographic and medical information, FUCHIA is paired with a statistical package and comes with several analyses/reports. One such report is the number/percentage of patients on each ARV regimen. FUCHIA does not perform quantification or inventory control, but pairs with the MSF Drug Order Tool (see below). FUCHIA is used in MSF ART programs worldwide, with support from Epicentre in France.^{13,14}

- MMRS (Mosoriot Medical Record System): The MMRS system was implemented in Kenya in 2001, and is used for all primary care visits in certain facilities. Data on each patient visit is recorded on a paper form and entered in the system before the patient leaves. Drugs dispensed are recorded at this time, and this data can be used to estimate total medications dispensed. The system is implemented in Access. MMRS is a partnership between Indiana University (US) and Moi University (Kenya).^{15,16}
- BART (Baobab Anti-Retroviral Therapy system): Developed by BaobabHealth in Lilongwe, Malawi, and the US, BART is an EMR for managing patients receiving ART. BART places touchscreen workstations in clinic rooms to be used by clinicians in real time. The system was designed in collaboration with the Ministry of Health, and supports the prescribing and dispensing of all regimens used in the national ART program. BART strengthens clinic workflow and ensures that standardized treatment protocols are adhered to. The system runs on rugged, low-power appliance hardware with no moving parts, has a read-only Linux operating system to avoid viruses, and is built on the OpenMRS data model. BART is currently being used to track 18,000 AIDS patients in six locations.^{17,18}
- CAREWare: CAREWare is an MS Access application originally developed for use in the United States to manage the care and coinfections of ART patients. CAREWare includes a dispensing/pharmacy component and has a translation module, allowing easy adoption of additional languages. While CAREWare is available for free, it is not open source and requires some

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- expertise to configure the system to new settings. Technical support availability is unknown.¹⁹
- OpenMRS: This recently developed EMR system is designed by PIH, Regenstrief Institute, and the South African MRC to be very flexible, though it is currently used mainly to support ARV treatment in Africa. The system uses a dictionary of data concepts that allows the collection of a potentially unlimited range of clinical, socioeconomic, and other data. It includes tools to predict medication requirements based on drug regimens as well as an extensive range of other reporting tools. An important feature of OpenMRS is its ability to send and receive medical data using data exchange standards like HL7. OpenMRS is an open source application that is web-based but can also run on a single machine, like a laptop, in sites with limited infrastructure. Technical support for OpenMRS is provided by a large and growing community of developers and implementers accessed through the main web site.²⁰
 - Pharmacy dispensing systems record the medicines that are dispensed to patients. Patients present a prescription and the dispensing application is used to record what medicines the patient leaves with, as the medicine list is not necessarily generated by prior knowledge of the patient's drug regimen.
 - mSupply (dispensing mode): When used in dispensing mode, the pharmacist enters the medicines being dispensed, often based on a paper prescription. mSupply uses the dispensed medicines to decrease the dispensary stock levels. Stock transfers between the pharmacy store and the dispensary share electronic files that eliminates the need to enter data twice. mSupply is developed by the Sustainable Solutions team in Nepal & New Zealand, who provide training and technical support.²¹
 - iDart: iDart records each patient's regimen, which is used to dispense directly to patients or to pre-package in preparation of the patient's visit. iDart includes inventory control of the dispensary stocks and this limited regimen information. iDart is an open source application developed by Cell-
 - Life in South Africa and is used in locations throughout the country. Cell-Life provides training and technical support.²²
 - RxSolution: Developed by Management Sciences for Health, the RxSolution database provides several aspects of drug management, including dispensing, inventory control, consumption-based ordering, and recording patient regimen information. Built in SQL, the system can run stand-alone or networked. Technical support is provided out of South Africa.²³
 - ARV and OI Dispensing Tool (ADT): ADT is an MS Access database, developed by Management Sciences for Health, which models dispensary stocks and maintains a simplified patient model, including the patient's ARV and OI regimen. It can report ART and OI dispensing history, and number of patients per regimen. The system generates orders for patients on ART.²⁴
 - Inventory control software is usually geared to the warehouse level and tracks stock levels. Functionality includes stock receipts, stock issues, adjusting stock levels after inventory, and boarding off stock. A medical inventory control system tracks medicines by generic (INN) and product trade name, and records batch number and expiry date. Reports on stock levels, stock to expire, and average monthly consumption are standard.
 - SIGMED: This system from medICT in the Netherlands is an inventory control system for essential medicines and is used in several countries in Africa. The system is written in MS Access. Technical support is based in Holland.²⁵
 - ORION: From Management Sciences for Health in the US, ORION is an inventory control program that links warehouses at the national and regional levels. The original system had no dispensary functionality, but MSH is now providing other tools to handle this. The source of technical support is not known.²⁶
 - mSupply (Warehouse mode): When used in Warehouse mode, mSupply runs as a standard inventory control system, but one designed specifically for medical supplies. Stock transfers between the warehouse and the pharmacy share electronic files that
-

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- save the same data being typed twice. mSupply is developed by the Sustainable Solutions team in Nepal & New Zealand, who provide training and technical support, and the user guide is very readable.²¹
- HIV-EMR Pharmacy system: This is a stock management application created as part of an HIV medical record system in Haiti. It uses electronic versions of stock cards and is Web-based, allowing the central warehouse and the procurement team to assess stock levels while also allowing sites to enter orders and acknowledge receipt of drugs. Initial evaluation showed that its use was associated with a decrease in days of stock-out of individual drugs from 2.6 to 1.1 percent. HIV-EMR is also used in Rwanda. Technical support is provided through PIH.¹²
 - Navision: This inventory control program was developed for large-scale operations, originally as an independent package, and is now part of Microsoft. Navision is not intended for low-resource settings, and must be adapted for certain medicines. There is some, but limited, technical support on the African continent (Morocco (head office, 2007), South Africa, Kenya). Navision contains accounting packages but not patient records or dispensing functionality.⁸
 - Syspro is another large ERP, designed for manufacturers and distributors. There is limited technical support on the African continent (head office, Africa, 2007 in South Africa). Numerous modules are available, such as Payroll, Human Resources, Accounts Payable, but there is not a patient records module. Syspro is a large program that requires backups, data archiving and significant storage space. It is not suitable to low-resource settings.⁸
 - ePICS (electronic Pharmaceutical Inventory Control System): This system was developed by Baobab Health in Malawi and the US for use in Malawi. It provides stockroom inventory control functionality via a touchscreen user interface. ePICS is not currently in use; it will be installed at a local hospital soon. There are plans to extend ePICS to include dispensing functionality as well as order-entry.^{17,27}
- Quantification software is used to assist in ordering. Creating an accurate drug order is complex, and the recent scale-up of health delivery programs stemming from donor funding (such as GFATM, Gates Foundation, Clinton Foundation) has required better tools. A number of quantification systems have emerged in the past few years, including:
 - FoCaMed: An MS Access/SQL application that uses patient regimen information to calculate needed quantities of HIV/AIDS commodities. FoCaMed keeps an electronic patient card with medicine data. Future need is calculated based on consumption data.²⁵
 - Quantimed: An MS Access database program that quantifies ARV need using consumption or morbidity data. There is no link to an EMR. Inventory levels must be imported for order quantity calculation.^{28,29,30}
 - Clinton Foundation/CHAI: A series of spreadsheets that calculate the quantity to order based on the number of patients on each regimen. It only handles ARVs and a few OI medicines, and includes specific tools for pediatric ARVs.
 - RxSolution: See the discussion of RxSolution above under Dispensing systems. RxSolution is a database with quantification based on historical or consumption data.²³
 - PIH-EMR: This system, designed as a clinical EMR system for MDR-TB patients in Peru, also has extensive drug quantification tools. These tools fall into two categories: the first analyze current drug regimens to assess one- to three-month stock requirements or retrospective stock use. The second set of tools predict future drug requirements based on a model of the typical length of time in treatment for existing and previous patients combined with a regimen analysis. The system has been evaluated and shown to have less than 5% error in predictions of up to six month future drug use.³¹
 - MSF ARV Drug Order Tool: This system is a set of spreadsheets developed by MSF-Holland. The user enters a small amount of ART data (number of patients on each regimen and percentage distribution of regimens
-

across new patients) and the spreadsheets calculate total number required for each ARV. Calculations

include PMTCT and pediatric patients. The data that is entered can be extracted from the FUCHIA system

Table 1: Comparison of quantification tools

Software	Consumption	Morbidity	Adjusted consumption
FoCaMed		√	
Quantimed *	√	√	
CHAI		√	
RxSolution	√		
PIH-EMR		√	
MSF-H ARV Order Tool		√	

* Quantimed uses consumption data *or* morbidity data.

As Table 1 illustrates, the existing quantification tools use either consumption or morbidity data, but none use both, which would improve order accuracy by cross-checking the data.

different health facilities in the same organization have built their own tools, but they are both numerous and anonymous.

In addition to the quantification tools listed here, numerous projects have developed their own spreadsheets or small databases to quantify their drug orders. These range from tools that increase the previous quantity purchased by a fixed percentage to rather complex modeling of patients and their medicine needs. At times,

Linking quantification to existing systems

Quantification systems would work best with access to data from EMR, dispensing, and inventory systems. As the summary in Table 2 illustrates, no one system provides all four areas of functionality.

Table 2: Examples of existing software and their functionality

Software package	EMR	Invent. control	Dispensing	Quantification
PIH-EMR	√		√	√
HIV-EMR	√			√
FUCHIA	√			MSFH Order Tool
MMRS	√			
BART	√		√	
CAREWare	√		√	
OpenMRS	√			√
mSupply (Dispensing)		√	√	
iDart	+	√	√	
RxSolution	+	√	√	√
ADT			√	
SIGMED		√		FoCaMed
ORION		√		
mSupply (Warehouse)		√		
HIV-EMR Pharmacy system		√		
Navision		√		
Syspro		√		
ePICS		√	+	

Pluses (“+”) indicate partial functionality, or functionality in development.

None of these software packages combine all four functionalities, although RxSolution provides some modeling of patient regimen data and PIH’s HIV-EMR pairs with the PIH pharmacy system.

Limitations of existing systems

Despite the extensive use of computerized medical records, stock tracking, and dispensing software in the developed world, there are few

effective software systems for dispensaries and small pharmacy stores in developing countries. The systems that do exist have several limitations: they are large, complex and designed for national warehouses, or they were developed for dispensing in retail pharmacies, or they are very simple and limited in function. More complex and proprietary systems may provide little or no access to technical support should they fail. Few systems provide the functionality to model a patient's medicine regimens, to track current stock levels and to calculate order quantities based on all of this information. Existing software is difficult to translate into local languages and cannot normally be adapted to local need (e.g., local workflow) because the code is proprietary. Finally, these systems are frequently resource-heavy – requiring high bandwidth and large hardware platforms and are not fault tolerant.

In summary:

- With the exception of OpenMRS, iDart, and the PIH and Baobab systems, all systems are completely or partially closed source, making customization and technical support difficult and costly.
- With the exception of the PIH systems, OpenMRS and CAREWare, existing systems are at most bilingual. CAREWare includes a translation module, making it easy to adapt to new languages.
- With the exception of PIH-EMR, iDart, MMRS, OpenMRS and BART, existing systems are resource-heavy and require high-bandwidth connections.
- Existing quantification tools either use consumption data or morbidity data, but none we reviewed use both. (Note that QuantiMed

reports that either consumption or morbidity data are used.)

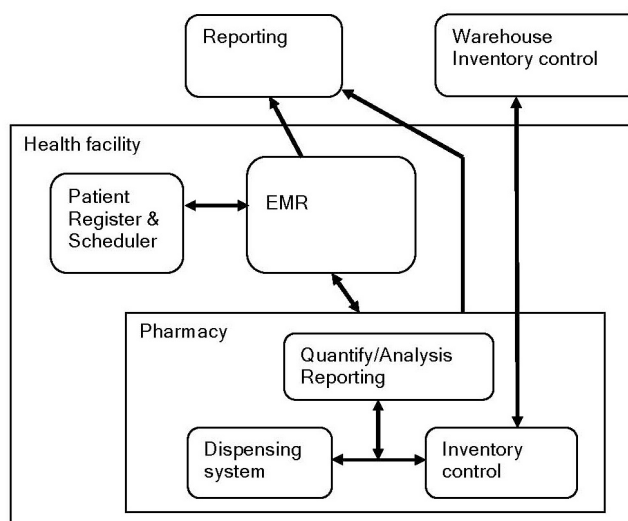
- Existing quantification tools handle ART, TB, and a few OI medicines using morbidity data. Medicines for acute conditions tend not to be regimen based and, in general, are quantified using consumption data.
- Quantifying other supplies needed in ART delivery – tests, lab reagents – is different than quantifying medicines and requires special attention.
- No existing systems have been evaluated and shown to provide benefits using scientific tests.

Accurate quantifications can only be achieved by using both morbidity and consumption quantifications for patients whose treatment protocols and treatment schedule are available in an EMR, by confirming patients' dispensed medicines, and adjusting order quantities based on usage patterns as reported by the Inventory Control application. This requires a quantification application which links data in the EMR, the Dispensary and the Inventory Control application.

Proposed Pharmacy Application

In order to make the most accurate orders possible, we propose developing a new Quantification, Analysis and Reporting application as part of the Pharmacy application. This system will operate at the health facility level, gather patient visit and diagnosis data and inventory consumption data. It will cross-check these data locally, effectively establishing a "closed loop" system, and report aggregated data to the regional or national level. One possible layout for functionality is shown in Figure 1 below.

Figure 1: Applications at the Health Facility Level and Their Interactions



Each health facility would have its own copy of the EMR and Pharmacy management system. The components are:

- An EMR containing patient medical data and medicines regimens.
- A Patient Scheduler/Registration application that records all patient visits at the health facility, which includes registering patients when they arrive for a consultation or scheduling appointments for repeat patients. For in-patients, this includes scheduling clinic admission and discharge. The application records the patient's diagnosis.
- A Dispensing system that records all medicines dispensed to each patient. Manages a small inventory of medicines.
- An Inventory Control to manage stock levels in the health facility Medical Stores facility.
- The Pharmacy Quantification, Analysis, and Reporting (QAR) application.

The Pharmacy QAR application will utilize data that already exist in the system but will organize and use it in new ways. By clearly defining 1) the required functionality, 2) the data to be exchanged, and 3) the flow between applications, the resulting straight forward data exchange will greatly increase the power of the system and the accuracy of the orders.

Pharmacy application functionality

The Pharmacy QAR application must provide this functionality:

- Dispensary: Generate dispensing list to be printed for each patient.
- Dispensary: Decrement Dispensary stock totals with medicines dispensed.
- Dispensary: Calculate the quantity of regimen medicines required for patients with scheduled appointments, and confirm adequate stock in the Dispensary.
- Dispensary: Forecast the quantity of palliative medicines and medicines for acute conditions, likely to be dispensed, and confirm adequate stocks in the Dispensary.
- Dispensary: Issue warnings for any stock items that fall below "minimum stock" levels.
- Inv Control: Issue reports for any medicines that will expire in less than 30 days.
- Dispensary: Issue re-stocking orders to the Pharmacy Stores for any Dispensary items that fall below "minimum stock" levels.
- Inv Control: Transfer "emergency orders" to the Dispensary from the Pharmacy Stores to cover extra daily medicine need.
- QAR: Calculate predicted monthly need of chronic medicines. (Multiply the number of scheduled patient visits in the next month times their medicine regimen.)
- QAR: Calculate predicted monthly need of acute medicines. (Adjust the previous month's acute-treatment consumption with respect to expected number of patient visits.)

- QAR: Total the estimated quantity of medicines needed per month; confirm adequate stocks.

Additional optional functionality:

- Dispensary: Record all medicines dispensed to each patient in the patient's EMR.
- Dispensary: Report missed refill appointments in the EMR.

Monitoring and reports from the Pharmacy Applications:

- Report totals dispensed of all regimen/chronic medicines.
- Report totals dispensed for all consumption/acute medicines. (Some medicines can be dispensed for both chronic and acute conditions (e.g., fluconazole).)
- Aggregate regimen/chronic medicine usage. (Multiply the number of patient visits times their pharmaceutical regimen.)
- Aggregate acute medicine usage. (Total all acute-treatment medicines recorded as dispensed to patients.)
- Combine the chronic/regimen and acute medicine usage.
- Issue restocking order for the pharmacy stores from the warehouse to cover need.
- Compare total medicine usage (patient records), against stock dispensed from dispensary, and stock issued from pharmacy stores.
- Report number of patient visits, morbidity data and aggregated medicine usage to national reporting center.
- Compare medicine consumption (dispensed medicines) with morbidity data; cross-check with Warehouse issues.

Developing a pharmacy application that provides this functionality will greatly increase the quantification power of the system.

Data exchange required to support Pharmacy QAR

To achieve the functionality outlined above, the following data and information must be exchanged between the subsystems:

- Patient medicine regimens and diagnoses (from EMR).
- Patient appointment schedule for specified time (from Scheduler).

- Current stock levels in the dispensary; minimum stock levels.
- Current stock levels in the pharmacy stores; minimum stock levels.
- Consumption data for the dispensary by week, month, etc.
- Consumption data for the pharmacy stores by week, month, etc.
- Treatment protocols by diagnosis.

Given the correct application infrastructure, and the correct application functionality, exchanging just a small number of data variables between applications greatly increases the power of the pharmaceutical application, and we believe will greatly improve order accuracy and therefore improve the availability of medicines.

Open source

The new Pharmacy application should follow the model of OpenMRS and openELIS and be an open source application. An open source design philosophy allows each country or project to adapt the code to suit their needs by translating into other languages, creating additional reports, etc. It also allows for the sharing of functionality: for example if one country or project builds a good program any other country or project using this system could download and start using it immediately. Furthermore, open source code often simplifies technical support: proprietary systems often require a technical specialist from Europe or the US to adapt the code to the developing world situation. Finally, open source ensures that the project or country has control over the data entered into the system: there have been cases where companies building closed-source solutions have demanded further payment to give the original data back to the project or country.

Proposal

We propose to develop a modular pharmacy system with the key features discussed above in collaboration with other organizations with similar needs. The development of the application will include an HL7 data exchange interface to OpenMRS. The application will be developed using open source standards, and will be available for dissemination as a stand-alone tool that may be customized to work with other EMR systems already in place that support HL7 data exchange. This application will utilize several use cases during its development to ensure that it fits the needs of projects and governments in developing countries. This will require an in-

depth needs assessment of the projects chosen as use cases before development begins. During application development, the system will be stepwise rolled out to these sites to ensure it meets their needs and to receive feedback. Finally, an evaluation will be conducted during the stepwise implementation with other sites (that are not use cases) serving as study controls.

This work will be done as part of an open source development community.

Discussion

Computer systems that are easy to use and can be tailored to a specific setting can increase productivity and improve accuracy. Computerized tools can produce reports in moments that it would take staff hours or days to tabulate. Stock-to-expire reports can be generated as needed. Sudden changes in stock levels or stock usage can be identified and analyzed. Instead of spending time creating the report, staff can divide their time between caring for patients and analyzing the reports.

By providing staff with these tools, we create the possibility for them to switch their time from report generation to report analysis. They will then have sufficient time to analyze the report contents within the context of their health facility. Reasons for drug shortages or drug overstocks can be investigated, and the pharmaceutical management system modified to correct these issues.

Additional analysis tools that we would consider implementing at a later stage include:

- Analyze patient treatment statistics from the Pharmacy QAR to inform procurement, e.g., the frequency of opportunistic infections or acute conditions in patients.
- Analyze adult patient regimen changes with respect to weight change as a response to therapy, against time on therapy.
- Analyze patient regimen changes with respect to drug resistance to certain medicines, based on user-selected demographic (e.g., age and location) and medical (e.g., HIV status, previous history of treatment) characteristics.
- Build pediatric growth charts for local HIV and TB pediatric patients on treatment, to be used to define expected weight gain and to inform ordering.

The Pharmacy QAR application described in above will establish a “closed loop” at the facility level, whereby consumption data is cross-

checked with morbidity data, and corrections can be justified and made. This would not be possible at a national scale, as data from multiple facilities would obscure problems and it would not be possible to identify where order errors had occurred.

However, once the data is collected and checked at the health facility level, it can easily be passed up to either the regional or national level. This is the case whether multiple facilities are running OpenMRS or other systems are in use.

OpenMRS can easily be extended with an application to export patient data, pharmaceutical data, morbidity data, etc., to other applications, such as statistical packages, spreadsheets, and reporting mechanisms. In particular, it supports the export of aggregate reporting to district and national systems and reports back to the facility level – in a standard format.

We believe that the Pharmacy QAR application and the analysis tools reported here can serve as a model to integrate other applications into an “enterprise medical information system.” This could include laboratory, patient registration, and radiology information systems.

Conclusion

This paper has laid out the basic functionality standards that describe the behavior, interaction, and data flow between the EMR, the pharmacy dispensing application, the pharmacy inventory control application, and the QAR application. What is required now is a working group to refine the functionality and data standards so they can be integrated with multiple systems. Questions about differences in pharmacy management between specialized care programs and general medicines will need to be reviewed. The functionality might be extended to include a Reporting application to the regional and national levels and a Patient Registration and Scheduler application.

There is a cost to developing and testing a new application and, later, the training associated with the rollout of the system in the field. We believe the development costs are likely to be a worthwhile investment: the HIV-EMR used in Haiti cost around \$30,000 to develop and handles \$3 million per year in medicines.

No drug order can ever be perfect: patient attendance cannot be predicted with complete accuracy, patient response to medicines is unknown, and secondary conditions are unpredictable. Having real-time access to stock levels, order status, and enrolled patient profiles

can be helpful in responding to such changes and uncertainty. The cost of inaccurate and incorrect orders – to the health of the patients and to the finances of the project – can be significant. While there is a cost to developing the new Pharmacy QAR application, the long-term benefits of more accurate orders and tighter communication between the EMR, the Dispensary and the Pharmacy Stores inventory control application are expected to outweigh the cost.

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Appendices

Vocabulary

Throughout this paper we adopt the following terminology:

Dispensary: Location from which medicines and medical supplies are delivered to patients or caregivers. Examples include: hospital ward or a pharmacy.

Pharmacy Store: Small warehouse, depot or stores that holds a few months' supplies for one or more dispensaries.

Warehouse: Often at the regional or central location, storage facility for pharmacy stores and dispensaries.

Methodology

A list of the major EMR, Dispensary and Inventory Control software was built from references in recent review articles (6,4,20, 22), the WHO./AMDS PSM Toolbox at <http://www.psmtoolbox.org>, and the EngenderHealth and Open Society Institute Health Toolkit at <http://www.healthtoolkit.org>. Each software system identified was searched for using Google and PubMed. Direct email was sent to several software managers and users. A general request was sent to the electronic discussion forum E-Drug.

Literature searches were conducted in MEDLINE, PubMed and the E-Drug archives. Search terms included: "pharmacy software Africa," "dispensing software," "computerized dispensing Africa," "computer dispensing," "software dispensary," and "ARV dispensing tool," papers were searched through May 2008.

The authors have worked in a broad range of developing countries with HIV and MDR-TB programs and have experience in the design, deployment and reviews of such systems. Through personal knowledge and experience of systems in use, they are familiar with several of the more commonly used systems.

Sources for software listed in this report

ART Dispensing Tool (ADT)

Contact: cpm@msh.org

BART, ePICS

www.baobabhealth.org

CAREWare

<http://hab.hrsa.gov/careware/>

Clinton Foundation HIV/AIDS ARV Procurement Forecasting tool

Information available from: procurement@clintonfoundation.org

FocaMed

http://www.medict.nl/Focamed/content_001.cfm

FUCHIA

From Médecins sans Frontières' Epicentre.

<http://www.epicentre.msf.org/tools>

iDart

www.cell-life.org

<http://www.cell-life.org/content/blogcategory/38/125/>

mSupply

<http://www.msupply.org.nz/>

Navision

http://en.wikipedia.org/wiki/Microsoft_Dynamics_NAV

OpenMRS

www.openmrs.org

ORION

<http://www.msh.org/seam/3.3.2.2.htm>

PIH-EMR, HIV-EMR

www.pih.org

Overview: http://model.pih.org/electronic_medical_records/pih_emr_overview

Quantimed

<http://www.msh.org/projects/rpmpplus/Resources/ToolsResources/QET.cfm>

RxSolutions

Contact <http://www.msh.org>

SIGMED

www.medICT.nl

Syspro

<http://www.syspro.com>

http://www.syspro.com/corporate/SA/Home_Main_Zone60.html

WHO/AMDS PSM Toolbox

<http://www.who.int/hiv/amds/highlights/en/index.html>

<http://www.psmtoolbox.org/tools.php>

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