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An Electronic Patient Referral Application: A Case Study from Zambia

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Abstract

Electronic medical records (EMRs) present a multitude of potential benefits for health systems, especially those in low-income developing countries. For instance, EMR systems can improve patient care by allowing medical personnel to access patients' records throughout the geographic area; they can increase medical personnel's efficiency by reducing the time required for data management and record keeping. Benefits for the overall health care system include easier collection of data for surveillance and rich data sets for further health research. Successful implementation means facing significant challenges, however, including a lack of human capital, low levels of physical and material resources, and low use once the system is implemented. This report advocates deployment of an electronic patient referral system as a reasonable first step in deploying a complete EMR system, because implementers of the smaller system can address and overcome many of the obstacles that full EMR systems commonly face. The report discusses the participatory and user-driven design, implementation, and results of an installed electronic perinatal patient-referral system supporting health personnel who referred patients through a closed-network, Web-based system in the Lusaka health district in Zambia. It demonstrates how the patient referral module laid the groundwork for a larger EMR system.

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Introduction

Finding viable ways to improve the health of mothers and newborns is an extremely serious problem in the developing world. Sub-Saharan Africa, in particular, faces a crisis in providing adequate health care in a region in which HIV/AIDS, malaria, and other diseases are prevalent. In Zambia in 2000, the maternal mortality rate was 750 per 100,000 live births, and the neonatal mortality rate was 40 per 1,000 live births (World Health Organization, 2006). The University Teaching Hospital (UTH) and 23 clinics (later expanded to 24 clinics) provide virtually all modern health care for 1.2 million people in the capital city Lusaka, with perinatal patients representing a significant portion of the total.

One way to improve health care for perinatal patients in Zambia is by introducing an electronic medical records (EMR) system. EMR systems present many potential benefits for health systems, especially those in low-income developing countries. For example, EMR systems whose information is used locally (within the health system) ease collection of data for surveillance and allow medical personnel to access patients' records—including records of previous care—throughout the geographic area. They also improve medical personnel's efficiency by reducing the time required for data management and record keeping, giving staff more time for patient care (Tomasi, Facchini, & Maia, 2004; Williams & Boren, 2008).

This case study demonstrates how the introduction of a participatory and user-driven patient referral system that is limited in scope can serve as a useful first step in deploying a larger-scale EMR system. The patient referral module, which was the first step toward the full Zambia Electronic Perinatal Record System (ZEPRS), was developed with high levels of Lusaka user input and involvement of local technical staff.[1] This interactive, participatory approach not only resulted in a system that offered practitioners direct benefits in terms of tracking referred patients (compared with the more usual handwritten notes), but it also ensured that the technical staff could use the system themselves. Moreover, the initial system clearly facilitated the construction of the ZEPRS network infrastructure. These outcomes indicate that the Zambia patient referral system directly addressed the limitations on human and physical capital that threaten the success of EMR systems in many developing countries (Kimaro & Nhampossa, 2007; Lungo & Igira, 2008), and it served as a foundation for the implementation of the fully integrated electronic perinatal records system (i.e., ZEPRS).

ZEPRS was transferred to the Centre for Infectious Disease Research in Zambia (CIDRZ), a Zambian nongovernmental organization (NGO) that continued to manage and maintain the system after deployment (January 2006).[2] This perinatal records referral system was launched in July 2004 in Lusaka. It enabled health personnel working in the clinics to refer perinatal patients to UTH for required additional care—usually for pregnancy complications—that the referring clinics could not provide. It also gave UTH information indicating the severity of an incoming patient's condition. The system allowed clinic midwives and nurses to follow their patients' care at UTH and to be informed of the health outcomes of their patients' treatment at UTH.

The results reported here are not offered to support the adoption of a simple, standalone perinatal patient referral system in other locations, but, instead, to advocate the adoption of simpler medical applications, developed with high levels of user input and participation, before full EMR system deployment. If a full EMR system is intended for a public health system in a small, densely populated geographic area and if connectivity is available, a "precursor" information system can be an effective starting point. As an example, RTI International is promoting a perinatal patient referral system built around two key concepts: (1) participatory, user-driven development, with involvement of all relevant stakeholders, and (2) local use of information from electronic records as a key driver in the adoption of such a system.

[1] The University of Alabama at Birmingham (UAB) Center for Research in Women's Health, RTI, and CIDRZ developed ZEPRS with local medical expertise and project engagement from the Lusaka Urban District Health Management Team (LUDHMT), Central Board of Health (CBOH), UTH staff, and staff from the 23 Lusaka clinics, and with funding support from the Bill & Melinda Gates Foundation.

[2] For more information about CIDRZ and its funding and project portfolios, see Centre for Infectious Disease Research in Zambia (2007).

Background

In general, a health information system "integrates data-collection, processing, reporting and use of the information necessary for improving health service effectiveness and efficiency through better management at all levels of the health services" (World Health Organization, 2004, p. 3). As a species of health information system, EMR systems—and, in particular, referral applications—have been gaining ground in both developed and developing countries as a means of facilitating the collection and use of health data. In the United States some software providers incorporate a patient referral component into their medical records software. Examples include the CaseTrakker System (IMA Technologies) and Web-based referral management systems (Patient Placement Systems, 2008). In the United Kingdom a new national health information system includes a choose-and-book electronic appointments feature—which allows patients to choose their hospital or clinic and to book an appointment with a specialist—as part of the £6 billion National Health Service National Programme for Information Technology (Davies, 2008).

Implementation of Health Information Systems in Developing Countries

Sub-Saharan Africa offers some examples of electronic patient referral systems in use for particular medical issues. One, iDART, is a software solution designed to support, in the public health care sector, the dispensing of antiretroviral drugs used to combat HIV/AIDS. When the National Health Service in South Africa requested bids for a health information system, its general specifications included capacity to collect patient referral scheduling information. Another example, the TeleMedMail application, used in Eastern Cape, South Africa, allows practitioners to send text and image referrals to the University of Transkei, Eastern Cape, South Africa (now part of Walter Sisulu University; Fraser, Jazayeri, Bannach, Szolovits, & McGrath, n.d.).

In Nigeria, in 2004, another system was developed at the Department of Computer Science and Engineering, Obafemi Awolowo University, Nigeria, for referral of patients from one hospital to another. Patients' case files, referral notes, and medical examination results, formerly transferred manually, could then be transferred over a computer network (Idowu, Adagunodo, Idowu, Aderounmu, & Ogunbodede, 2005).

Advantages for Electronic Medical Records Systems in Developing Countries

Many EMR systems in developing countries are designed to improve the quality of patient care by increasing medical providers' use of existing data for subsequent patient care decisions (Lungo & Igira, 2008; Tomasi et al., 2004; Williams & Boren, 2008). An EMR system can reach a wider group of users, including specialists in remote locations, than a paper system; it allows for easier, faster access to patient records in the provision of patient care. In addition, the improved legibility of clinical notes and the ability to track patient history (in many countries medical providers never refer to patients' paper records) can improve the quality and appropriateness of the care that clinical staff provide.

In addition to improving care for individual patients, an EMR system can improve the overall health care system. For example, an EMR system supports monitoring and evaluation, as well as clinical research and management, of chronic diseases (Fraser et al., 2005; Williams & Boren, 2008). It can also identify specific clinics, hospitals, or regions needing attention (in the form of training or resources, for example). Support is required from the national ministry of health, or from the provincial and district levels, for implementing an EMR system; in particular, this support must be integrated into ongoing supervision and reporting (WHO, 2006).

Barriers and Solutions to Adoption and Implementation of Electronic Medical Records Systems in Developing Countries

Numerous challenges to the introduction and adoption of EMR systems exist in developing countries. Chief among the barriers is lack of human capital, meaning both lack of skills to develop and use such a system and high staff turnover that impedes ongoing training (Kimaro & Titlestad, 2008; Lungo & Igira, 2008; Tomasi et al., 2004). For patient referral applications, a related obstacle is lack of understanding of the impact of an EMR system on quality of care. Possible solutions include flexible, user-friendly training systems and inclusion of users in developing and piloting software, which leads to skill development, ownership, and experience (Kimaro & Titlestad, 2008, p. 6; Lungo & Igira, 2008, p. 29).

Further challenges include lack of physical resources, such as secure space for computers, and lack of material resources, such as software (Kimaro & Nhampossa, 2007; Lungo & Igira, 2008), as well as the costs of access to technology (Chandrasekhar & Ghosh, 2001). A longer-term view of the EMR system can counter these problems in that longer-term sources of funding can be identified for ongoing maintenance and support (Kimaro & Nhampossa, 2007). Taking advantage of open-source medical records systems that are available and have proven successful can reduce costs from the outset (Fraser et al., 2005; Lungo & Igira, 2008). Doing so means that EMR systems can avoid licensing fees, which often are more costly than the necessary software customization.

Experience shows that, even when an EMR system is deployed, the intended users will not adopt it unless they have been involved in its design and deployment, or unless the local health authority requires them to use it instead of traditional records systems (Kijsanayotin, Pannarunothai, & Speedie, 2009; Tomasi et al., 2004). Some research shows that emphasizing user involvement in piloting and implementing the EMR system is critical in preventing low usage (Kijsanayotin et al., 2009; Tomasi et al., 2004). Such engagement ensures that users become both more invested as stakeholders in these activities and more likely to use the EMR system actively in patient care.

Methods

The analysis in this report relies on a case study of the perinatal patient referral system implemented as a precursor to the full ZEPRS in Lusaka, Zambia. In general, lessons drawn from a single case are limited by their lack of generalizability (Verschuren, 2003). Here, the case is linked to the emerging literature on EMR systems in developing countries. This approach puts the case study in a broader context and allows us to draw a greater number of general conclusions from the Zambian case.

The Situation Before the Project

Immediately before the ZEPRS project, the public health system in Lusaka, Zambia, consisted of UTH and a network of 23 public community health clinics in the greater metropolitan area (which later increased to 24 clinics). Although these clinics were general clinics, a major portion of the care given was related to maternal and child health. All the clinics provided some perinatal care, with about half of them also providing labor and delivery services.

The clinic staff generally consisted of trained nurse-midwives, certified nurses, laboratory technicians, and support personnel. Approximately 500 staff members were involved in perinatal care at the clinics and were expected to enter data into the new system. The UTH staff consisted of physicians, certified nurses, nurse-midwives, registrars, laboratory technicians, and support personnel. Additional personnel included nurse-midwives-in-training and physicians-in-training.

In 2003 the clinical staff members had low computer literacy; all were also stressed because of large patient loads. Clinics had high medical staff turnover (40 percent) because of sickness, low wages, and out-migration.

When the ZEPRS project started in 2003, perinatal records were kept in paper booklets called *blue books*—one for each pregnancy. At the start of a new pregnancy, the woman received a new blue book to record health information for her pregnancy. For each pregnancy, the first medical professional to see the patient generated a new booklet that the pregnant woman kept with her to present at each clinic or hospital visit. Nurses or midwives entered all records manually during clinic visits. A patient might visit several different clinics during her pregnancy. At the end of care, the paper booklet was kept by the clinic or UTH (depending on the location of the final perinatal visit for the pregnancy), but no systemwide file existed in which to retain a woman's previous history or from which to recover statistical information about medical care in general. No long-term monitoring of the mother over multiple pregnancies was possible on the basis of the blue book, because once one pregnancy was over, the blue book was added to a large stack of other blue books that were not filed or organized so that information could be retrieved later.

To refer perinatal patients to UTH for acute care, clinics in Lusaka used short-range radio (because most clinics lacked telephones). Sometimes clinic staff also filled out a paper-based patient referral slip, which the patients were supposed to bring with them to UTH. No system required UTH to notify referring clinics of the status of referred patients or to report whether these patients actually presented at UTH to receive additional care. Consequently, patients were often "lost" in the process, and patient care continuity was difficult at best.

The ZEPRS project's primary goal was to develop a perinatal electronic medical record system that could be used by the clinics, UTH, the Central Board of Health (CBOH), the Lusaka Urban Health District Management Team (LUDHMT), and CIDRZ. We were to develop ZEPRS by means of rapid application development, a type of software development methodology that uses planned architecture and design, with incremental rollouts. We engaged local stakeholders in determining the requirements; developing, testing, and then rolling out the application to the multiple users; and giving users appropriate levels of access to individual medical records and detailed reports.[3]

Project Objectives

The Bill & Melinda Gates Foundation provided funding for ZEPRS to the University of Alabama at Birmingham (UAB), which had established CIDRZ. UAB contracted with RTI to develop ZEPRS. RTI was responsible for developing the referral application as a precursor to the full ZEPRS. We had five main objectives:

- to work with local users to define application requirements, on the premise that participatory application development results in a product that addresses local users' needs,
- to build local capacity of the Lusaka-based local ZEPRS project team to manage and maintain the application and network, via a training initiative,
- to provide an environment that would reinforce user skills and knowledge learned during the ZEPRS training initiative,
- to provide feedback to medical staff on patient referral outcomes, and
- to validate the hardware that was put into place to support the full ZEPRS.

Participatory and User-Driven Requirements

Working directly with potential software users early and continually throughout the software development cycle was a key component of the method proposed for this application. The project design aims were to identify potential user issues early and to develop a usable application.

Capacity Building

Using and Extending Local ZEPRS Team Members' Skills. The ZEPRS project team planned to use development of the referral application as an opportunity to teach the local ZEPRS project team information and communication technology (ICT) staff how to manage a software vendor, do initial testing, and roll out the referral application.

Using and Extending End Users' Skills. All training of end users occurred in parallel with the referral application development and testing, over a period of 6 months, with one topic per month. The plan was for the end users to interact with a simple EMR application at the end of their training; the aim was to increase their use of Web-based medical records systems and their familiarity with computers in general. End users included clinic and UTH clinical and administrative staff and CIDRZ clinical and administrative staff. The administrative staff built their skills in administering user accounts and controlling role-based access.

Patient Referral Outcomes

The electronic perinatal patient referral system was designed so that end users could see what happened to their patients and so that two-way communication

[3] For a description of the rapid application development method, see Martin (1991).

between the clinics and UTH would be complete. This two-way communication served as an incentive for clinic staff to fill out patient referral information.

Validation of the Hardware Infrastructure

The referral application, although not as computer intensive as the full ZEPRS, required all clinic and UTH perinatal departments to be connected to wireless local-area networks (LANs) and wide-area networks with reasonable performance. UTH perinatal departments (or "areas") are sometimes in separate buildings on a hospital campus; sometimes they are in separate rooms in a single building. The rollout of the referral application was staggered to give RTI and the local ZEPRS project team an opportunity to verify that the hardware was functioning, to troubleshoot and repair any open issues, and to train those who would be managing the maintenance and support of the hardware.

Implementation Plan

Stakeholder participation was key to developing an application that clinic and UTH staff could truly use and to ensuring that the referral application was user-friendly. The ZEPRS project team used the rapid application development method to develop the system architecture and then continued with software design and development, testing, and rollout. In parallel, UAB and CIDRZ staff trained the medical staff in the use of computers, with particular emphasis on Web-based browser applications.

System Architecture

A South African firm began developing the software during summer 2003, but for several reasons, including a fluctuation in the Rand (South African currency), RTI assumed this work and rebuilt the system, using a more open and flexible software framework.

The ZEPRS project team revised the project plan to work more closely with Zambian colleagues in preparing the initial high-level requirements. The ZEPRS project team created the prototype for the application, using the open-source LAMP software stack (Linux, Apache, MySQL, and PHP), which controlled costs and sped development and deployment.[4]

The following three sections describe the network, the software, and the data center (which housed the servers, the backup generators, and other hardware).

Network Overview

In early 2003 the ZEPRS project team completed an ICT assessment of UTH, the CBOH, CIDRZ, and the 23 clinics. As a result of this assessment, the ZEPRS project team worked with another South African vendor, Comsol, to design a comprehensive wireless backbone and LAN to connect UTH, the CBOH, the LUDHMT, CIDRZ, and the clinics in a private network, with a single egress point to the Internet (Figure 1). The network included

- 5.8 Gigahertz (GHz) wireless backbone network,
- 2.4 GHz wireless in UTH and clinics,
- 20 Megabits per second (Mbps) full-duplex backbone,
- 10 Mbps full-duplex subscriber links, and
- 11 Mbps links in clinic compounds.

The ZEPRS project team worked with Celtel (now doing business as Zain Zambia), a local cellular equipment provider, to locate the ZEPRS network backbone antennas on their equipment, in exchange for placing their advertisements at the clinics and UTH. Work continued during 2003 and 2004 to complete the network rollout, test the software, and train the local ZEPRS project team's ICT staff to ensure that they had the necessary skills to manage the entire network.[5]

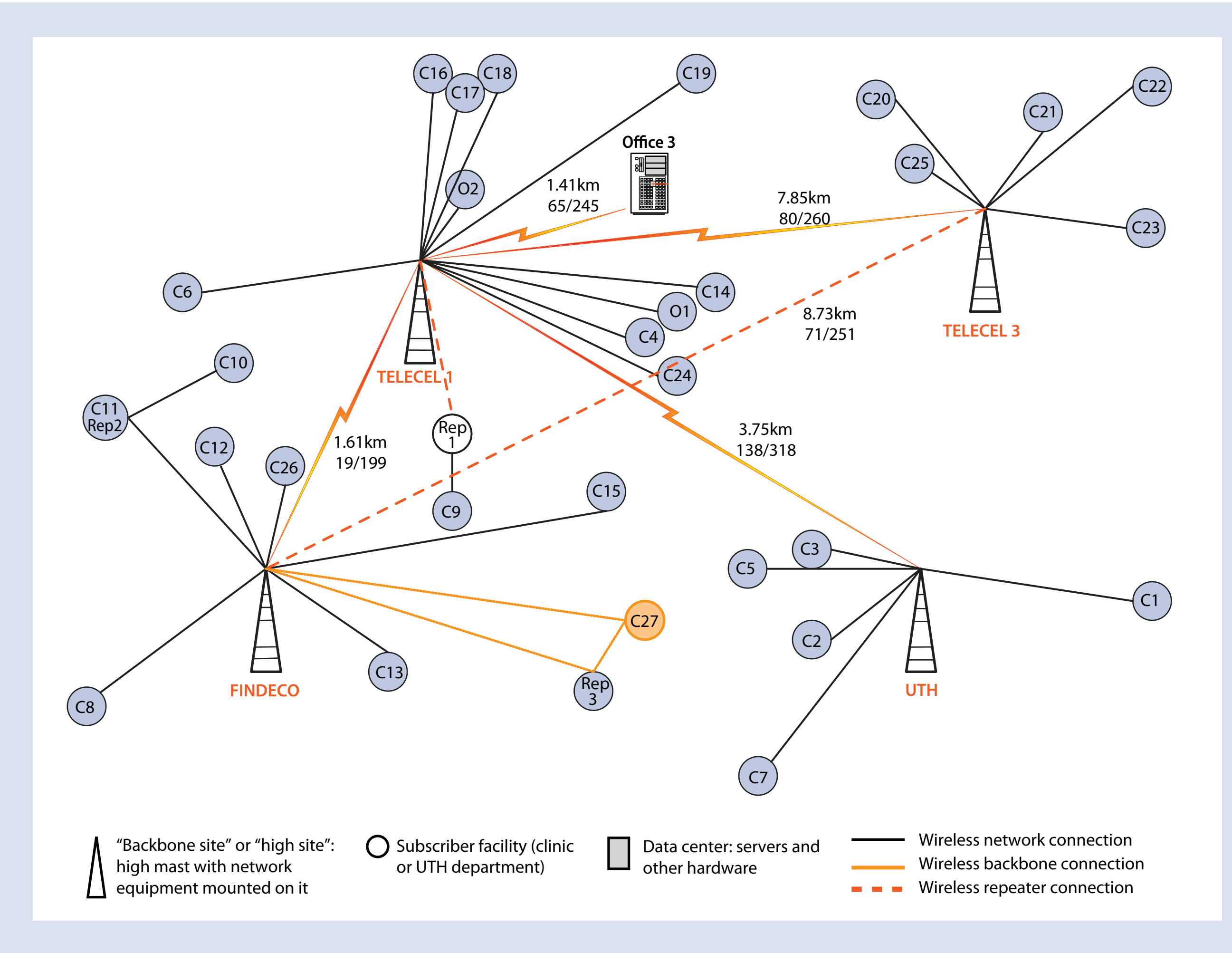
Software Environment

Because the ZEPRS project included the deployment of a high-availability wireless network accessible to all clinics, the team deployed all the software components as Web applications accessible by means of the private ZEPRS network. In addition to the

[4] For a description, see Lawton (2005).

[5] For additional details about the network, see RTI International (2009).

Figure 1. Initial network schematics showing four backbone sites and subscriber facilities



Note: Site C24 was added to the network during 2006.

referral application, the first phases of ZEPRS system architecture included the following elements:

- centralized authentication and authorization,
- Web-based e-mail (SquirrelMail),
- user administration, and
- user training.

Some of these elements, such as the Web-based e-mail and user training modules, were deployed to encourage staff to hone their computer skills. The referral application was loaded onto industry-standard personal computers on mobile carts. The use of mobile carts with wireless LAN connections was essential because of both the limited project resources and the number of departments in the clinics and UTH. The computers were secured on these carts with Kensington locks and had 4 hours of battery backup to allow for continued use during power outages. All clinic and UTH staff members, as well as some selected CIDRZ staff, the trainers, and the ZEPRS project team, had access to the medical information for patients the clinics referred to UTH. All staff members were made aware of the importance of not disclosing any of this information to nonmedical staff or to family members.

Data Center at University Teaching Hospital

The data center was hosted at CIDRZ and managed by the local ZEPRS project team's ICT staff. Equipment included an Internet connection, a firewall, servers, external backup, power supplies, and a generator (Table 1).

Table 1. Equipment and software used to meet ZEPRS system requirements

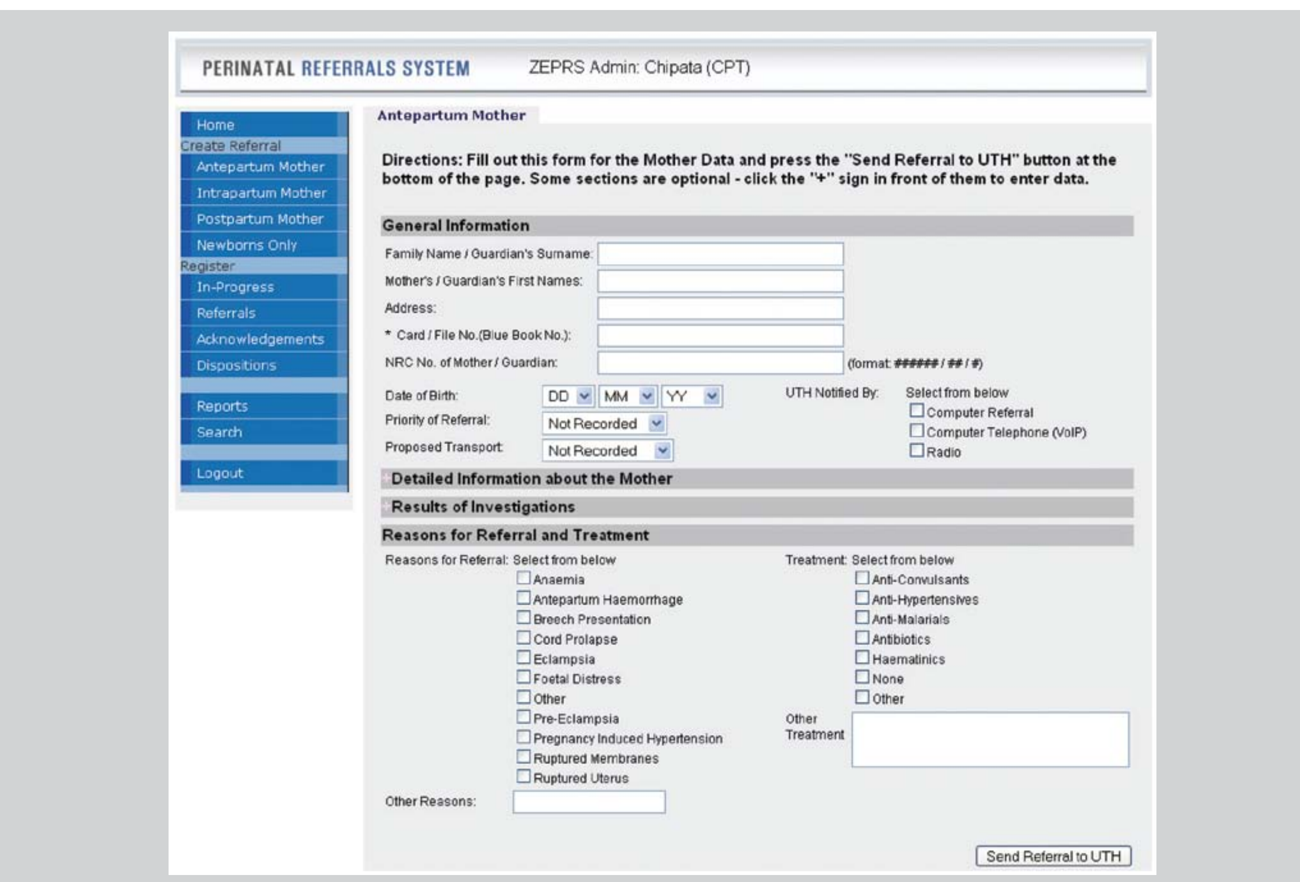
Requirement	Solution
Internet connection	Point-to-point wireless connection to UUNET's satellite-based Internet service
Firewall	SonicWALL
Servers	
• Mail	Dell PowerEdge 1650 (1.26 GHx P3, 512 GB RAM) running Postfix, Cyrus-IMAP
• Web application	Dell PowerEdge 1650 (1.26 GHx P3, 512 GB RAM) running PHP-based applications and wireless authentication server (Aegis)
• Database	Dell PowerEdge 1650 (1.26 GHx P3, 1024 GB RAM) running MySQL4
External RAID storage array	Dell PowerVault 210
Tape backup autoloader	Dell PowerVault 120T DLT 7000
Uninterruptible power supply battery backup	APC SmartUPS 3000 backup generator

Design and Development

Using this prototype, the ZEPRS project team created several iterations of the referral application, which included all the main perinatal patient referral flows (Figure 2). Working side by side in Zambia, and then remotely through e-mail and instant messaging, the team continued to change the application to meet user needs. Some important features of the design included the following:

- centralized authentication and authorization scheme,
- notification to referral clinic or to UTH of incoming patients,
- provision of critical information to prepare for patients' arrival,
- notification to referring clinic and UTH about patient status, and
- record management of all patient referrals.

Figure 2. Referral form for antepartum mother



RTI completed development of the Web-based electronic-first perinatal patient referral system in May 2004 as an interim step toward the full ZEPRS. *Electronic first* denotes a system in which medical providers enter information about the patient into the electronic system as the patient receives medical care; no medical data are tracked on paper.

Testing

As the application evolved, the ZEPRS project team wrote a detailed User Guide, which the local ZEPRS project team's ICT staff validated. This staff also performed the detailed system testing in accordance with the test plan and test execution guide, as well as the integration, functional, user-acceptance, and error-handling testing. *Functional testing* refers to testing of the user functions of the software to ensure that they perform according to user specifications. This testing is usually done for each module of an application. *Integration testing* involves testing the complete application across multiple modules to verify that the whole application is performing according to user specifications. *User-acceptance testing* means having real users use the system and validate that the application is performing according to user specifications. *Error-handling testing* means validating that all user data errors are addressed as expected by the application. ZEPRS used standard bug-management approaches to track and fix software bugs.

Training

We noted during training that staff found it easier to learn the referral application than to learn some of the earlier, nonmedical computer-based training content (e.g., typing tutors, Internet searching) because the referral application content and use were directly relevant to their daily practice. During this training process, we equipped two training centers with computers configured for the referral application training. All staff could come together at either location for training, and staff could also use the computers that were installed in clinics and UTH departments. The ZEPRS team also configured a staging version of the referral application, with dummy referrals, so that end users could practice before the site went live.

Support

For general computing support, with the live application in use (i.e., after it was launched), RTI created user support documentation and posted it on all mobile computers. We explained how to diagnose some simple issues and how to contact technical support. These diagnostic issues included reasons for lack of Internet connection, user log-in problems, and rebooting of the computer. This information was included in training with volunteer staff at each facility, who agreed to provide first-tier support for referral application hardware and software issues. The ZEPRS technical support team provided second-tier support.

Results

Staff members at the clinics entered information about perinatal patients or their newborns (or both) when they referred these patients to UTH. The system tracked patients' arrival at UTH, recorded the care they received, and monitored clinic staff members' reviews of the patients' course of treatment at UTH.

Clinic and UTH staff could generate several reports to indicate reasons for referral and outcomes, either by clinic or systemwide. At any time, UTH staff could see a list of all patients who had been referred during the most recent time interval (users could specify time intervals), and they could prepare needed equipment and services to assist the arriving referred patients. The clinic's staff could see what happened to their patients and learn their patients' final status on discharge, which closed the feedback loop.

System Implementation and Satisfaction of Formal Objectives

RTI launched the perinatal patient referral system on July 22 and 23, 2004, with three clinics (Chawama, George, and Chipata) and three departments of UTH (the Neonatal Intensive Care Unit, the Labour Ward, and the Antenatal Clinic).

Participatory, User-Driven Requirements

Working with local medical staff, RTI used Agile software development methods that supported rapid prototyping of the referral system, working in one-on-one sessions with local staff to review screen flow and medical details (Cockburn, 2002). Identifying a core set of users to work with the team on requirements, early prototyping, and iterative feedback was very important in developing a usable application. We put in place a governance structure that allowed a core set of users to devote time to driving the application requirements, which were not only to replace the paper-based system, but also to add features that made the application easier to use, improved efficiency, and made information available locally

Capacity Building

Using and Extending Local ZEPRS Team Members' Skills. As mentioned earlier, RTI completed the contract early with the selected African vendor and rebuilt the system, using a more open and flexible software framework. By involving the local ZEPRS project team's training staff in both the system-level testing and the review of the User Guide, RTI created a training approach from content that was directly relevant to district health staff members. This approach also ensured that the local ZEPRS project team's training staff would be able to answer questions about the application in a timely manner, without relying on overseas support. After RTI led training in testing methods for the local ZEPRS project team's ICT staff, the ICT staff became a part of the testing team and completed the final user-acceptance tests, as described under Testing on page 9. The ZEPRS project team also used a Web-based bug tracker to test the referral application. This tool allowed the widely dispersed ZEPRS project team to work together in identifying, fixing, and retesting for bugs. Additionally, instant messaging for remote project support and for answering technical questions facilitated communication and resolution of issues, because telephone connections were poor and e-mail was not always reliable.

Using and Extending End Users' Skills. During the referral application development, testing, and rollout, many end users (clinic and UTH staff) completed up to six sessions of basic computer training, which UAB managed. This training—which used beta versions of the referral application—was provided in advance of the rollout of the full ZEPRS. Some of these early trainees were part of the ZEPRS medical staff, and they became familiar with the referral application.

Once the referral application had passed user-acceptance testing, the ZEPRS project team worked with the UAB/CIDRZ staff to develop a referral application training module. The ZEPRS project team assisted the UAB/CIDRZ staff in launching the training. The referral application training began in earnest in May 2004, and the 72-page User Guide served as the foundation for this training for medical staff (after their extensive training in basic computer literacy). The staff in the three selected launch clinics were trained initially.

When RTI launched the referral application, these original users became additional resources for the clinics and UTH departments in which they worked; they were able to support the other staff members as they started to use the referral application. For all staff using the referral application, such experience reinforced their computer training and enabled them to continue to use acquired skills so they would not forget these skills during the gap in time between training and launch of the full ZEPRS. The perinatal patient referral system tracked usage statistics for the 23 clinics and the four departments of UTH for patient referrals; such information included the patients' referral status (i.e., *referred, acknowledged,* or *finalized*). These tracking reports were used to identify sites where more training was needed. The clinic and UTH administrative end users managed the clinical end-user accounts and access to the referral application. By November 2004, all staff at UTH and the clinics had been trained.

After reviewing the time spent in training, we observed that training district health staff took an appreciable amount of time; the initial plan for training three to six clinics per week proved unrealistic. In the end, on the basis of a review of all the trainings conducted, we determined that only one to two clinics per week could be trained. In July 2004, creating a patient referral at the clinics took 2 to 4 minutes, as judged from observations during launch.

Neither we nor the other groups involved conducted qualitative studies or time-based surveys to evince the ways staff were using the application. However, ZEPRS project team observations of staff using the application, as well as system data on usage from July 2004 to July 2005, indicated that a large number of clinic staff were using the referral application (Figure 3). Figure 3 shows the total number of patient referrals by week of use of the electronic referral application.

Patient Referrals

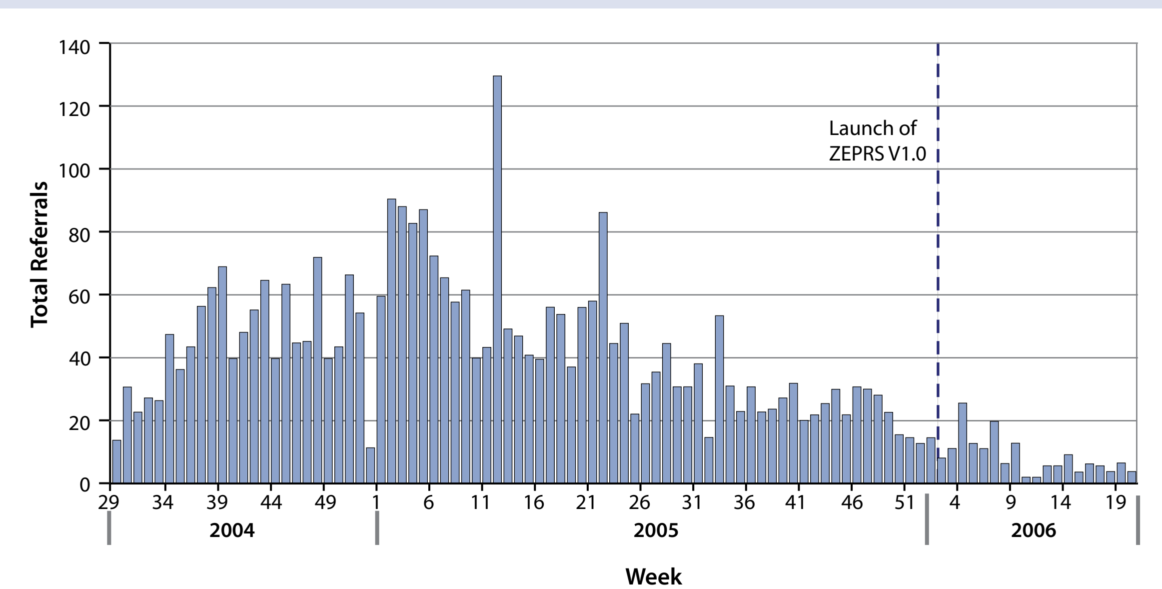
The launch of the electronic-first referral system generated great excitement at the clinics because clinic staff were now being informed of their patients' outcomes after pregnancy complications: whether they survived, whether they delivered their babies, what sex the babies were, and other outcomes. This ability for two-way communication about patients between the clinics and UTH was, in fact, a great incentive for clinic staff to fill out the information when they referred a patient. According to observations and to monthly reports presented to CIDRZ, not all patient referrals were entered with an "immediate" (emergency) status; staff seemed not to abuse the notion of priority patients. The usage reports for referrals were important in identifying sites where more training was needed and in assessing adoption of the referral application.

Having this acknowledgment and disposition data filled out for UTH had been a key motivator for clinic staff to use the referral application. The greatest problem in usage of the referral application was that the UTH staff sometimes lacked the time to fill out the referral acknowledgement and dispositions. We believed that, partly for this reason, the clinic staff's enthusiasm waned when they were consequently unable to track their patients over time. Several remedies for this situation were tried, but overcoming the underlying issue of too many patients and too few UTH staff proved difficult. After the full ZEPRS was launched, UTH staff found more system functions that were useful to them; a byproduct was more data entered into the ZEPRS referral module.

Validation of the Hardware Infrastructure

By the time the referral application was launched, the network connecting the 23 clinics and UTH had been installed, tested, and made operational. The referral application gave the local ZEPRS project team's ICT staff a prototype for putting in place all network monitoring applications, preparing backups,

Figure 3. Total patients referred, by week, using the electronic patient referral application



Note: This figure represents patient referrals from the initial launch to the introduction of the integrated ZEPRS Version 1.0 perinatal record and patient referral application launched in January and continued through the end of February 2006. The ZEPRS system was launched incrementally, by clinic.

troubleshooting the network and system, and conducting other maintenance and support activities. Users required substantial network "up time" (availability), which encouraged local staff to solve network and computer issues.

During the latter part of 2004 and 2005, the ZEPRS network had more reliable performance (85 percent or greater up time). Damage to the wireless network equipment by lightning strikes in December 2005 and January 2006, along with minor difficulties associated with handing over complete management of the network to the local ZEPRS project team's ICT staff, contributed to the decline of network availability to less than 85 percent.

Some specific contributors to the down time allowed the ZEPRS team to make some changes to improve network reliability over the longer term. For example, the lightning surge suppression on the ZEPRS wireless network was problematic. Lusaka has no centralized lightning protection, and relying on high towers to absorb lightning strikes was not feasible. The team had to install complete lightning suppression at all network ingress and egress points. Doing so reduced the number of devices that were damaged during the lightning season (October through January).

Both grid blackouts and illegal tapping of the network caused outages. To compensate, the ZEPRS project team readjusted the uninterruptible power supply battery backups for *minimum* 4-hour up time and set all uninterruptable power supply units to track power data. The ZEPRS project team installed an automated network monitoring and alert system that allowed for immediate power-related alerts to be sent to the ICT support team when issues arose, which the ICT support team could then diagnose and solve. The automated network monitoring and alert system also allowed the United States–based advisors to provide some monitoring and support help. In addition, the ZEPRS project team increased the stock of on-site spare parts to allow for faster replacement (instead of waiting for parts to be shipped to the supplier for repair and return).

Rodents' eating cables posed another challenge, as did some severe dust problems. To foil the rodents, the ZEPRS project team switched to open-wire carts for personal computers instead of closed carts. For dust, the ZEPRS project team introduced dust-prevention casings on computing devices.

A general issue that was somewhat anticipated but never fully addressed was that introducing a high-speed network could lead to widespread general Internet use. The ZEPRS project team modified the network design from a bridged to a routed network; this modification enabled the team to control network traffic and Internet access from personal computers to a more reasonable bandwidth. These steps ensured that the project allocated adequate bandwidth for the patient referral application and subsequently the full ZEPRS.

The ZEPRS project team developed application and network support processes and documentation (e.g., self-diagnostic printouts for computers, which were preprinted and displayed) to show users how to solve problems (e.g., if the computer was not on, if there was no access to the network, etc.), how to contact the local ZEPRS project team help desk staff, and how to contact user support (referral application support document). Because the final application was kept fairly simple, putting in place the user support services, the help desk, network monitoring, the lightning-strike management, and the database for managing spare parts was relatively easy. ZEPRS was rolled out with the local ZEPRS project team's ICT staff's being already trained to provide network maintenance and support. As mentioned, ZEPRS was transferred to CIDRZ for ongoing maintenance, development, and support during 2006.

Key User Functions

The referral application's security setup involved role-based access. Each user (staff member of the clinics or UTH) had to enter his or her username and password (i.e., log in) to gain access to the application. The authentication and authorization scheme was centralized. Because each computing station had multiple users, the application displayed on the screen the name of the person who was logged into the application, together with that person's location.

If another staff person went to the same computer to enter a new patient referral, he or she could either log out the current staff member and then log in or go to a new browser window or tab and then log into the application.

When users logged into the referral application, they could choose to do one of the following:

- create a referral for antepartum mother, intrapartum mother (a mother who is in the first, second, or third stage of labor), or postpartum mother and newborn,
- view the referral register (including list of referrals in progress and a list of all referrals), view the UTH acknowledgement of referrals, and view the UTH disposition of referrals,
- run reports that gave information on different referrals, over a date range, by clinic or clinics, including summary report details and type of referral,
- search for referrals over a date range, by clinic or clinics and by patient names, or
- log out.

Users could create referrals at all 23 clinics and the four supported UTH departments. Any of these four UTH departments could acknowledge the referrals, meaning that any UTH staff person with access to the application could log in and enter the acknowledgment, referral, and disposition data.

Outcomes

The rollout of the referral application was rapid (July 19 to October 31, 2004) because of coordinated training and rollout efforts and the medical personnel's enthusiastic acceptance of this application. As shown in Figure 3, referrals for the 24 weeks of operation in 2004 averaged 41 per week. Usage reached a peak in the first 6 weeks of 2005 and then tapered off to an average of approximately 40 patients per week. The average rate for all of 2005 was 45 referrals per week. The number of patients referred with the use of this system began to taper further, beginning around week 26 of 2005, and the decrease was much more noticeable in week 52 of 2005. By the end of week 20 in 2006, the electronic referral application had been used to refer 3,541 patients.

The average rate of referral for the first 20 weeks of 2006 was eight per week, a 19 percent decline in the average rate from 2005. The six clinics that converted to using the integrated ZEPRS Version 1.0 application during 2006 accounted for nearly 28 percent of all referrals in 2005. Declining use of the electronic referral application may be attributed to a combination of factors, including lightning damage to the wireless network equipment and the corresponding decline in availability of the ZEPRS wireless network, the introduction of the integrated ZEPRS Version 1.0 application, and turnover of medical personnel.

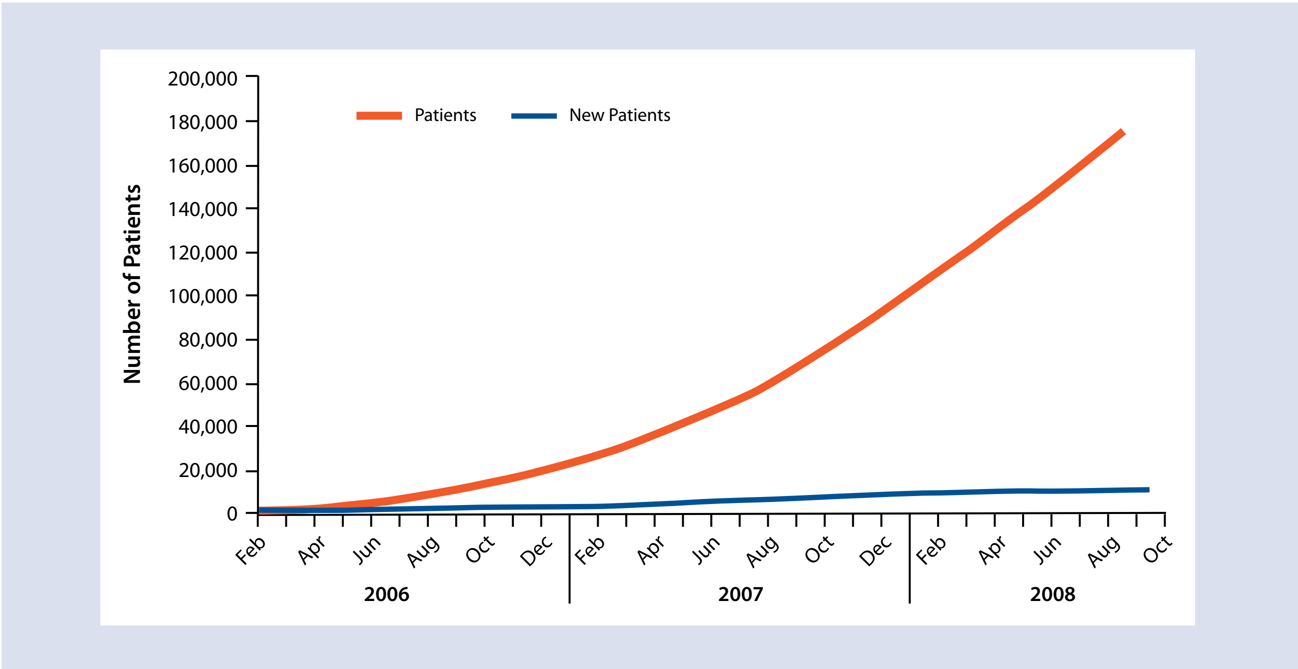
As noted earlier, over time the UTH staff's usage of this application also declined. Not all referred patients were being acknowledged or assigned a disposition by UTH. For example, at the George clinic, of the 110 patients referred from July 21, 2004, to November 24, 2004, only 91 were acknowledged by UTH staff. This decline in turn reduced the clinic staff's enthusiasm, because the ability to follow their patients was the main incentive for them to use the application.

The perinatal patient referral system was always intended to be an introductory system to the full ZEPRS. ZEPRS was launched in January 2006, and clinics and UTH sites were incrementally added to the EMR system so that perinatal patients could be tracked electronically.

The perinatal patient referral system met the formal objectives that had been established for it. The system allowed the testing of both the ZEPRS network infrastructure and the ZEPRS technical support functions (operating procedures, ways to gain technical support, tracking of inventory and replacements, etc.) so that they were validated and fully operational for the ZEPRS software launch. The medical staff developed their Internet skills by using the perinatal patient referral system from July 2004 through January 2006 and transitioned to using the full ZEPRS without having to learn new Internet skills.

The important groundwork laid by the perinatal referral system was reflected in the rapid and consistent uptake of the full ZEPRS (Figure 4). After the full ZEPRS launch in early 2006, usage continued to increase, with persons added as new perinatal

Figure 4. Patients added to the full electronic medical record system



patients going to either UTH or one of the clinics for perinatal care. After the launch in early 2006, UAB and CIDRZ made ZEPRS available to clinics in stages: one or two clinics were added to the system every 3 to 4 weeks. As shown in Figure 4, system use continues, with CIDRZ now managing and maintaining the system. As of August 2009, ZEPRS had several patients with subsequent pregnancies tracked in the system.

Discussion

The referral application was released as a prototype for the main ZEPRS application. It was the first electronic-first perinatal referral system in sub-Saharan Africa and enabled users to enter patient data in real time. Using a patient referral system as a first step in launching a full EMR system helps address common limitations in implementing EMR systems in developing countries.

Advantages of Using Patient Referral Systems Initially

One advantage of this approach is that countries or their health institutions can completely replace a paper-based patient referral system with an electronic referral system. To optimize opportunities for success, however, RTI recommends building a participatory, user-driven electronic patient referral system (or equivalent simpler medical record application) only as part of a larger rollout of a more complete EMR system. We discuss below how using a precursor referral application can address some of the common obstacles to EMR system implementation in developing countries.

Several approaches to developing an EMR system can encourage use of the deployed system and therefore help overcome the problem of low use. Key approaches entail (1) involving users of the system in design and development and (2) fully testing and deploying the application with limited errors so that, once it is launched, users do not become frustrated with a buggy system.

Involvement of Users

Focusing on participatory and user-driven design, development, and deployment is key to the system's success. From our experience, an application like ZEPRS can work only in a health district with two main attributes: (1) complete buy-in from all local stakeholders and (2) a shared understanding that the

EMR system must be developed from the perspective of local users. Although the requirements of donors or other project collaborators can be included, the overall design must be driven by local users. In addition, a commitment must be made to using information from the EMR system at the local level; this commitment helps ensure that continuous local supervision and support lead to improvements in health care service delivery.

Implementers have multiple ways to engage users in design, development, and deployment of an EMR system. Where possible, the EMR system should prompt health staff members with care options or make summaries of patients' critical medical information readily available, or both. A group of users can become an advisory committee. To engage local users, practitioners can also apply established guidelines, such as guidelines for community-based participatory research (Viswanathan et al., 2004), which aim to ensure that data are useful to community members, health care practitioners, and researchers. Community-based participatory research is accruing more significance in the United States because of the need to reach out to racial and ethnic minorities, low-income populations, and non-English-speaking communities, where working with community leaders and integrating them into service delivery is crucial (RTI International, n.d.).

Testing and Debugging the System

The EMR system must be completely tested so that it is robust when users are introduced to it. Ideally, users should not see unexplained errors; otherwise, they are likely to stop using the system. New computer users have less tolerance for buggy applications than do experienced users.

Ways to Address the Lack of Physical and Material Resources

Physical resources include space within facilities for computing equipment, secure structures such as bars on windows to prevent theft, and carts or furniture on which to keep the equipment. Material resources include software applications, wireless applications, and Web-based services and financial resources to fund the material and physical resources or physical upgrades. Below we describe approaches that mitigate the lack of physical and material resources with which to develop an EMR system.

Use of Open-Source Software

Using the LAMP approach for the perinatal patient referral system allowed RTI to use its limited project funds to develop and deploy systemwide software without paying any licensing fees. Finding developers with adequate skills for programming posed no problems because a large global community of developers with LAMP experience exists.

Development of Electronic, Web-Based Infrastructure

Network reliability and performance is critical to adoption of a system like the one described here. Using the perinatal patient referral system as a precursor allowed RTI to test the network and resolve issues as the infrastructure was being built for the complete ZEPRS. If, in replicating this process, implementers anticipate much network down time, then developing an EMR system that works in off-line, as well as online, mode is important to ensure that the system can be used at any time.

Funding Resources

An important consideration for developing and deploying an EMR system in Zambia (in the broader context for RTI and other implementers) is ensuring that such a system can be sustained over time after deployment; this consideration implies the need for adequate funding for all needed resources. In many cases, developing-nation governments lack adequate funds to manage and maintain otherwise donor-funded electronic health information systems. This general issue affects all development projects, which must address sustainability and aid-dependency in their design and implementation.

ZEPRS has been successfully transferred to CIDRZ, a Zambian NGO, which is managing and maintaining the EMR system. As a research and services organization, CIDRZ relies on external funding sources, but anchoring the EMR with a local organization ensures that local researchers and practitioners will continue to support the system.

Ways to Address the Lack of Human Capital

The lack of human capital related to EMR systems in developing countries is an enormous challenge. Several approaches can help to mitigate this problem.

Small-Scale and Staged Deployment

Deploying a simpler application before deploying the full ZEPRS allowed for trial-and-error experimentation in terms of training, network infrastructure, logistical support, and functionality. Staging deployment a few clinics at a time allowed the local ZEPRS project team's ICT staff time to develop their skills as the number of users increased gradually.

Staffing

One important lesson learned was that the team needed a strong, full-time project manager in Lusaka. Without such a person in place, management of the local team, interactions with CIDRZ and the LUDHMT, the schedule, the budget, and the associated computing and network infrastructure proved extremely difficult. We recommend that implementers of similar programs identify and hire a local project manager in the main location in which the EMR system is being deployed.

Training

Anyone who undertakes to create an EMR system must incorporate adequate training into the overall project plan. In addition, the training team should include medical staff, as well as ICT specialists and a committee of users. Training of medical personnel should be by medical personnel, and it should include continual, supportive supervision, as well as incremental hands-on experience. In our case, adding one UTH nurse and one district nurse to the training team greatly improved the training; doing so also encouraged the more reticent health staff to participate. Adding a trainer who was closer in age to health staff members older than 50 years of age also encouraged more of this group to attend training sessions.

Development of Local Technical Capacity

The local ZEPRS project team was able to add to its technical skills as the network was being built. As application usage increased, the staff became more skilled in network and application troubleshooting, and they developed technical support operating procedures to be followed that were in place for the rollout of the full ZEPRS.

Drawbacks to the Deployment of the Perinatal Referral System

Decline in Use

When overworked UTH staff failed to complete information on patient acknowledgments and dispositions, the clinic staff became less interested in completing patient referral information, resulting in a decline in use over time. Also, because users knew that the full ZEPRS would come online in January 2006, not surprisingly, in the months before that launch, usage declined.

Need for Ongoing Training

Owing to medical staff shortages in Zambia, staff turnover was high; therefore, the project faced a continual need for training in computing, particularly in Web-based medical application skills. Because high medical staff turnover is typical in many developing countries, managers and users of the system must have a strong commitment from the outset to lifelong learning with the new EMR system (Fraser et al., 2005). The project team for an EMR system must establish governance structures that support ongoing training of new or replacement hires.

Simple Application

The perinatal patient referral application described here solved a single need, although it was designed and implemented as part of a larger EMR system. The trajectory of implementation of the perinatal patient referral system through to the launch of ZEPRS underscores the importance of embedding such a single or simple application in the larger program and its goals. We therefore recommend that small, standalone applications not be deployed; they may not constitute a viable "whole" program, and the costs would likely far outweigh the benefits.

Recommendations for Future Project Design

The referral application was released as a prototype for the full ZEPRS. Its programming style and technology platform matched well with its short development time frame, and it was a surprisingly low-maintenance effort. Nevertheless, we determined that a more extensible technology would better suit the full ZEPRS EMR system. The ZEPRS EMR system had a built-in referral capability for tracking patients through all entry points in the Lusaka health care system, which meant that the standalone perinatal patient referral system was eventually retired.

Conclusions

The original circumstances and eventual findings of this project do not support the adoption of a simple, standalone perinatal patient referral system in other locations. Instead, they support the adoption of simpler medical applications, developed with strong participation by end users, before full deployment of an EMR system. If a full EMR system is intended for a public health system within a small, densely populated geographic area, and if connectivity is available, a precursor information system can be an effective starting point.

The example that RTI is promoting is a perinatal patient referral system built around two key concepts: The first is user-driven development, with involvement by all relevant stakeholders. The second is local use of information from the electronic records system as a key driver in the adoption of such a system.

As the implementation of the referral application has shown, running a small-scale system as a precursor to a more complete EMR system can help planners overcome the challenges that EMR systems commonly face in developing countries. In this case, the careful planning and implementation of the perinatal referral module addressed numerous obstacles, including lack of human capital, lack of physical and material resources, and low usage, clearing the way for successful launch and continued use of the full EMR system.

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