E-Health Technologies Show Promise In Developing Countries

Joaquin A. Blaya, Hamish S.F. Fraser and Brian Holt

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ABSTRACT Is there any evidence that e-health—using information technology to manage patient care—can have a positive impact in developing countries? Our systematic review of evaluations of e-health implementations in developing countries found that systems that improve communication between institutions, assist in ordering and managing medications, and help monitor and detect patients who might abandon care show promise. Evaluations of personal digital assistants and mobile devices convincingly demonstrate that such devices can be very effective in improving data collection time and quality. Donors and funders should require and sponsor outside evaluations to ensure that future e-health investments are well-targeted.

E-health, defined as the “use of information and communications technologies (ICT) in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research,”1 has the potential to greatly improve health service efficiency, expand or scale up treatment delivery to thousands of patients in developing countries, and improve patient outcomes.2 In this paper, the term is used synonymously with health information technology (IT).

Information systems, such as electronic health records (EHRs) and mobile phones and handheld computers (also called m-health), can be of enormous value in providing health care in multiple settings. They can support a health worker performing clinician duties where there are no doctors and can help keep track of patients in HIV programs where the loss rate (patients who drop out of treatment) can be as high as 76 percent.3 When used to monitor inventories, these systems can save lives and prevent the increase of drug resistance by keeping medicines in stock and can provide accurate, timely information for strategic planning, especially in areas where hand-compiled data are often years out of date. Acknowledging this potential, the World Health Organization (WHO) has published a manual on implementing EHRs for developing countries,4 and many agencies are funding e-health efforts.5 Evaluating the impact of e-health on patient care is extremely difficult. Hence, there are few rigorous evaluations worldwide.6 Systematic reviews of e-health in primary health care,7,8 telemedicine,9 and its cost-effectiveness10 have found that most articles “lacked any evaluation of their concrete application to health care.” In developed countries, a few EHR system evaluations have shown that they have (1) improved outcomes for renal disease patients,11 (2) decreased rates of clinical visits by 5–9 percent,12 (3) provided a five-year benefit of US$86,400 per provider at a large academic hospital,13 and (4) improved efficiency by 6 percent per year in a large hospital network.14 Computerized phy-
Physician order entry systems have been shown to reduce medical errors, but they can also increase error rates if not well designed and implemented.

**Study Data And Methods**

**STUDIES ELIGIBLE FOR REVIEW** In our survey of studies for review, we included any qualitative or quantitative evaluation of information technology affecting health care in developing countries. We did not include telemedicine because other recent reviews exist. Developing countries were defined as those in the Emerging and Developing Economies List in the International Monetary Fund’s World Economic Outlook Report.

Evaluations were excluded if (1) data completeness of the system was the only outcome, (2) the evaluation method was not described, (3) the article only described the feasibility or technical evaluation of a system, (4) the evaluation was on attitudes toward or knowledge of e-health (not an actual system), or (5) it was only an educational tool. In the case of the Uganda Health Information Network, we report on the e-health component of the system. If an article did not have an abstract, we attempted to find the article through the Harvard or Massachusetts Institute of Technology (MIT) library systems.

**FINDING RELEVANT STUDIES** We conducted a worldwide review of the literature and requested submissions from researchers and those implementing e-health in developing countries. Literature searches were completed through October 2009 without language restrictions through MEDLINE, EMBASE, Science Citation Index (Web of Science), Social Sciences Citation Index, the Cochrane Library, and the Latin American and Caribbean Health Science Literature Database (LILACS). To find reports not in scientific journals or conferences, we also used Google Scholar. For MEDLINE and EMBASE searches, terms were derived from the MeSH database and EMTREE tool, respectively. We searched for more than forty commonly used terms to describe e-health applications, found the broadest term within each tool that maintained its context, and then used that term for the search to ensure that we included all possible studies. Among the terms used in the final strategies were medical informatics applications, reminder system, geographic information system, hospital information systems, outcome and process assessment (Health Care), evaluation studies, attitude, costs and cost analysis, developing countries, poverty, Africa, Latin America, eastern Europe, and central or southeastern Asia (complete strategies are available from the authors on request). An initial reviewer read the abstracts to evaluate the eligibility of all studies identified in our search. A second reviewer confirmed all relevant articles and retrieved full-text articles. Supplementary methods of finding evaluations included a review of article reference lists, informatics conference proceedings, information provided by primary study authors, requesting submissions from other researchers and implementers, and searching the RHINO Literature Database and other recent reviews.

**DATA ABSTRACTION AND SYNTHESIS** We extracted data according to recurring themes, defined below. We summarized these findings using tabular techniques and descriptive statistics. Reported analyses were too disparate to be pooled in a meta-analysis.

The systems described in the articles were placed into one of eight categories corresponding to the typical applications used in developing countries. The order of these categories does not infer any priority:

1. Electronic health record: an electronic record of health-related information on an individual that can be created, managed, or consulting by clinicians or staff. In literature, the term electronic medical record is used interchangeably and is used as a synonym in this paper.
2. Laboratory information management system: a system for laboratory-specific activities or for reporting results to administrators and health care personnel.
3. Pharmacy information system: any system used to order, dispense, or track medications or medication orders including computerized order entry systems.
4. Patient registration or scheduling system: any system used to monitor and manage the movement of patients through multistep processes or to maintain a census. An example is admissions-discharge-transfer systems.
5. Monitoring, evaluation, and patient tracking system: any system used for aggregate reporting of information, program monitoring, and tracking of patients’ status. Examples include district health information systems or health management information systems.
6. Clinical decision support system: system designed to improve clinical decision making, in which characteristics of individual patients are matched to a computerized knowledge base and software algorithms generate patient-specific recommendations.
7. Patient reminder system: a system used to prompt patients to perform a specific action—for example, take medications or attend the clinic.
8. Research/data collection system: any system used for collecting data from different locations or for storing, managing, or reporting on data used for research purposes.
Evaluations were classified into two major categories—qualitative and quantitative—as shown in Exhibit 1. Qualitative evaluations were those where users gave opinions regarding a system. These could be through questionnaires, focus groups, or interviews. (This definition is different from the one proposed by Anselm Strauss and Juliet Corbin of “any type of research that produces findings not arrived at by statistical procedures or other means of quantification.”)26 Quantitative evaluations were those whose outcomes were data quality, administrative changes, patient care, or economic assessment. Evaluation designs were grouped according to the definition by Charles Friedman and Jeremy Wyatt:27 (1) descriptive (uncontrolled) study; (2) historically controlled (before-after) study; (3) case-control (retrospective) study; (4) prospective self-controls (subjects performing the same action in both systems; this category was added by the authors); (5) simultaneous nonrandomized controls; (6) simultaneous randomized controls; and (7) externally and internally controlled before-after study. Two cost studies and two studies modeling future medication requirements were categorized as self-controls because they compared the impact of the system against the same situation without the system. As a result of the inherent limitation of performing a case-control, descriptive, or qualitative study without statistics, we do not comment on the limitations of these studies.

Study Results
Searches retrieved 2,043 citations. Five articles were excluded because they did not have abstracts and full-text versions were not available.28–31 After the initial screening of article titles and abstracts, we found 126 articles that appeared relevant. An additional five articles were identified by hand-searching bibliographies of eligible articles and prior reviews. Of these, forty-five fulfilled the inclusion criteria after full review of their abstracts. They are listed by type of system and evaluation in Exhibit 1 and are categorized by systems in Appendix Exhibits 2a–5a.32 We included an evaluation from the U.S. Indian Health Service, although it is not in a developing country, because socioeconomic and infrastructure conditions among the population treated are similar to those in developing countries. If a system had multiple evaluations, only those with different outcomes are listed. If they had the same outcome, we took the one with the largest sample size. There were two articles reporting an evaluation that did not occur because of a failed system implementation.33,34 These are not part of the results, but we considered them relevant to list because articles on unsuccessful systems are not commonly published.

Fifteen articles performed qualitative evaluations, and forty performed quantitative evaluations. If an evaluation performed both types, it was counted in both categories. Two qualitative evaluations and sixteen quantitative performed statistical analysis. Of all evaluations, two (13 percent) of the qualitative and seven (18 percent) of the quantitative were performed by an outside evaluator. The number of evaluations has more than tripled comparing periods before and after 2002.

**Electronic Health Records** Because EHRs are the core clinical application, they usually encompass a variety of functionalities, which makes their implementations complex35 and prone to failure.36 This complexity provides an additional...
challenge in their evaluation. Most evaluations found provided insight into possible impacts of these systems, but had limited scientific rigor, as seen in Appendix Exhibit 2a.32,27

The Indian Health Service’s Vista system was the most complete system we reviewed, and its rigorous qualitative evaluation showed that a majority of clinicians viewed its implementation positively and hence used it more. The Mosoriot Medical Record System evaluation in Kenya provides data on the impact that an EHR can have on improving staff productivity and reducing patient wait times. All other evaluations were qualitative and provided insights into EHRs’ ability to improve staff satisfaction, providing high-quality data to relevant personnel and ultimately improving patient care.

LABORATORY INFORMATION MANAGEMENT SYSTEMS
There were only three evaluations of laboratory information management systems, all quantitative, with only one having a control group (Appendix Exhibit 3a).32 However, they suggest two major benefits that such systems can provide: (1) decreasing times for communication of results, and (2) improving the productivity of the laboratory. An additional impact, reduction in errors, has not yet been studied, although there are groups currently performing such trials.37

PHARMACY INFORMATION SYSTEMS
Computerized order entry can provide a key incentive for clinical staff, especially clinicians, to use an information system, because such systems can reduce the time to order medications (especially repeat orders) and provide easy access to past information. The four qualitative evaluations shown in Appendix Exhibit 3a32 cite these as their system’s main advantages. The two quantitative evaluations with a control group (Socios en Salud in Peru and Hamadan University of Medical Sciences in Iran) showed a reduction in errors, which is a main outcome cited in developed country studies. An additional benefit from some pharmacy systems in developing countries is their ability to forecast medication requirements (Socios en Salud in Peru). This is useful if a country or organization needs to order medications months in advance to get lower prices, which is currently the case for drug-resistant TB medications.

PATIENT REGISTRATION AND SCHEDULING
The two quantitative evaluations of registration systems, seen in Appendix Exhibit 4a,22 showed that fingerprint scanners and barcode readers decreased the time to locate records by 74 percent and 97 percent, respectively. The small sample size of thirty in these randomized controlled trials was their biggest limitation. In the qualitative evaluation of the Baobab system in Malawi, users preferred it to paper despite limitations in training and technical support and the need to maintain a parallel paper system.

MONITORING, EVALUATION, AND PATIENT TRACKING SYSTEMS
Evaluations of systems to track and monitor patients’ status are limited to two case-control studies performed by the same organization in Haiti (Appendix Exhibit 4a).32 Both of these studies suggest that an electronic system can effectively alert staff of patients who have “fallen through the cracks” and prevent rates of patients lost to follow-up, which were found to be as high as 76 percent (after two years) as reported in some HIV programs.3

Two randomized controlled trials looked at the effect of Global Positioning Systems (GPS) in finding households once a patient has been identified. An evaluation from South Africa showed that GPS reduced the time to find a household by 20–50 percent, whereas one from Nicaragua showed no difference between the paper and GPS systems. Both the South African and Nicaraguan systems were tested in similar urban settings with novice users, so no immediate reason for the difference can be found. Both studies had small sample sizes (identifying ten to fifty households) and lacked statistical analysis.

Two evaluations, one descriptive and one cost analysis, looked at monitoring departments within a hospital in Cambodia and health establishments nationwide in Tanzania. They suggest that electronic systems can help allocate resources efficiently and improve infection control and can be relatively low cost, respectively. However, both evaluations lacked detail on the tasks affected, as well as control groups.

CLINICAL DECISION SUPPORT SYSTEM
Decision support systems have received attention for developing countries as a possible solution to the lack of trained clinical personnel, especially in rural areas. The three quantitative evaluations seen in Appendix Exhibit 4a22 were of high rigor. The expert system for mechanically ventilated newborns showed that nurses performed better on a standardized test and felt that they had better judgment after receiving training on the system. The evaluation of the personal digital assistant (PDA) device to perform the Electronic Integrated Management of Childhood Illness approach in Tanzania showed that more clinical staff completed the electronic questionnaire compared to the paper booklet. It also showed that it took the same amount of time (12.5 minutes) to fill out the questionnaire by either method. The evaluation of the Early Diagnosis and Prevention System in India showed higher satisfaction among patients if they were seen by a computer operator before their clinical visit and that there was a large increase in new pa-
patients at health centers with the system. However, the two studies with simultaneous controls had major limitations. The evaluation of the Electronic Integrated Management of Childhood Illness was performed by the developers of the systems, and because the technology was new to the users, the novelty rather than its usefulness could account for the additional completeness. In the case of the Early Diagnosis and Prevention Systems, the increased attendance and patients’ opinions could have been easily biased by the presence of the computers, the motivation of computer operators, and the length of time spent with operator, none of which were present at control sites.

**PATIENT REMINDER SYSTEMS** The quantitative evaluation of the South African text messaging system (Appendix Exhibit 5a)\(^3\) found that after the system was implemented, there were higher completion rates of TB treatment. However, the comparison was made to the city’s TB program register, for which the data quality was not verified and the data were different from the source of the prospective data. A randomized trial in Malaysia found that both text messaging and mobile phone reminders significantly increased attendance (by 21 percent) over the control group. Although they both had similar effectiveness, the text messaging system was half the cost of the mobile phone reminders. This evaluation had no major limitations.

The Malaysian study performed a well-designed cost-effectiveness study showing that text messaging, implemented correctly, can be a cost-effective method to increase clinic attendance. This is especially important since both TB and HIV treatments require constant supervision of patients and strict adherence to a daily regimen of medications. Such systems can help patients in resource-poor settings who encounter many obstacles that can prevent them from getting their medications.

**RESEARCH/DATA COLLECTION SYSTEMS** Research/data collection systems was the group with the largest number and most rigorous evaluations (Appendix Exhibit 5a).\(^3\) All systems, except the Mexican National Institute of Public Health’s Audio Computer-Assisted Self-Interview (ACASI) system, were on PDAs. Four randomized trials showed that the main benefits of PDA-based systems were data quality similar to paper systems or higher, less time taken to perform interviews, and decreased time to collect data. However, many of the studies had major limitations. The systems from the Universidad Peruana Cayetano Heredia and the South African Medical Research Council compared the PDA system to paper and not to a gold standard. The study performed by Socios en Salud had a small number of users (\(n = 4\)), and the study performed by the London School of Economics was performed seventeen years ago. The organizations that implemented the PDA-based systems in Uganda and South Africa have experience with hundreds of users and more than a dozen implementations combined, which empirically shows the feasibility of such systems.

The cost analyses show that these systems are able to recoup the high initial costs by providing increased efficiency and continuous material costs. The Uganda system showed a cost savings of 91 percent over the paper system. The South African analysis calculated that after using the PDA system for data collection in eight studies of medium scale, it would equal the costs of paper. The PDA system in Peru would pay for expansion to other health districts in three months as a result of increased efficiency.

**Discussion**

This review shows that with the exception of PDA-based data collection, there are still few scientifically rigorous data on the effectiveness and cost-effectiveness of e-health systems in developing countries. Further, the evaluations have mostly been performed by organizations connected to academic settings and not by other, larger recipients of donor funding. When looking at the software systems included in the U.S. President’s Emergency Plan for AIDS Relief (PEPFAR) Anti-Retroviral Therapy (ART) Software Inventory Report\(^5\) and EngenderHealth—Open-Society software tools\(^3\) comparison, only three systems, the Partners in Health—Electronic Medical Record/HIV—Electronic Medical Record in Kenya, Mosoriot Medical Record System in Kenya, and Vista in the U.S. Indian Health Service, have had any evaluations performed. Although a few studies have been commissioned by the U.S. Centers for Disease Control and Prevention (CDC), it is particularly important that large funders such as the U.S. Agency for International Development or PEPFAR include resources for the evaluation of e-health systems developed and deployed in developing countries and perhaps make them a requirement for continued funding. This could include standard designs for studies that are suitable for resource-poor environments, that minimize biases, and that are easily comparable to the results from other projects.

The overall pattern of e-health evaluations in developed countries reflects an initial focus on qualita-
tive and descriptive evaluations, with an increase in the number of quantitative and larger evaluations published in the past decade. Developing countries seem to be following this pattern as well, so in this study we found mostly qualitative and descriptive studies but saw an increase in the number of randomized trials performed in the past few years. This suggests that as e-health implementations become more robust in developing countries, we can expect more rigorous studies, such as randomized trials or cost-effectiveness studies.

Initial evaluations suggest that the following functions are of positive impact in developing countries:

1. Ability to track patients through the treatment initiation process, monitor adherence, and detect those at risk for loss to follow-up.
2. Tools to decrease communication times of information within and between institutions.
3. Tools to label or register samples and patients.
4. Ability to electronically monitor and remind patients of health care needs or treatment.
5. Collection of clinical or research data using PDA applications.
6. Reductions in errors in laboratory and medication data.

Important findings include the user preference for the Baobab touch-screen system in Malawi, one of the only fully electronic point-of-care systems in use in Africa, which is now in daily use for more than 35,000 HIV patients. The benefit shown for patient tracking and reminders is also important, given the loss to follow-up rate of up to 76 percent for HIV patients in Africa. The Malaysian systems that texted patient reminders showed a significant decrease in missed visits, at a reasonably low cost, and the On Cue Compliance Service in South Africa was well liked by users several years after implementation and, perhaps more importantly, by an independent evaluation team. These systems can be of high value because intermittent treatment puts patients at grave risk of deterioration and death, as well as causing increased drug resistance and further transmission of disease to the wider community.

Tools to store and communicate such data with low error rates have been early successes in developing countries, and the positive evaluations described here should drive their use in the developing world. Evaluations of PDAs and mobile devices were particularly rigorous, and they convincingly demonstrate that such devices can be very effective in improving data collection time and quality. An additional benefit is their light weight and lack of printing costs compared to large paper forms, which is crucial in remote areas with poor infrastructure. These results are important for the growing field of mobile health and cell phone–based tools, because these devices are also playing an increasing role in communication directly with patients.

Evaluations of e-health systems are challenging and require significant resources in addition to funds creating and implementing systems. Implementations should have evaluations built into the process. This will provide useful feedback to improve the project (formative evaluations) and will also demonstrate the impact of the system in the long term (summative evaluations). Evaluations in resource-poor environments face many challenges when compared to those in developed countries, such as the physical environment, power, networking, and availability of technical staff. Measures of short- and long-term system usage and data completeness are important and a necessary prerequisite to a full evaluation study. Poor data quality is a constant problem in health projects, whether they use paper or electronic systems, so tools that can reduce errors as well as benefiting other aspects of care are likely to be well received.

Some benefits of electronic systems are difficult to quantify. One is the ability to perform operational research with greatly reduced costs. During our search we found eight studies that used electronic databases and probably could not have been performed if manual data collection was required. Another is the impact of emergency communication across large distances, such as in the cholera outbreak in India or refugee situations. The strongest evidence for beneficial impact of e-health on health care will come from long-term follow-up of this sort carried out by independent evaluators.

Conclusions

With the rapid growth of e-health in developing countries, there is clearly an urgent need for solid evidence of its impact to justify and guide the investment of resources in such systems. Despite major increases in evaluations in recent years, most large e-health implementations have little or no evaluation data. To date, most studies have been small; focused on process indicators rather than patient outcomes, or on the attitudes of users and patients; and performed mostly by academic groups. An increased focus on including evaluations as part of e-health implementations is necessary and should be adopted by organizations implementing or funding such systems. One method is for large funders to include resources for evaluations or make them a requirement for implementation.

Although evaluations of important indicators of care are difficult to do well, this review has confirmed that they are feasible even in very
challenging environments. Initial benefits were shown in systems that track patients through treatment initiation, monitor adherence, and detect those at risk for loss to follow-up; tools to decrease information communication times within and between institutions, as well as errors in reporting laboratory data; barcoding for patient identification cards and laboratory samples; handheld devices for collecting and accessing data; and the ordering and management of medications. Because of the lack of infrastructure and backup systems in resource-poor environments, well-designed e-health solutions may have a much larger impact on quality of care than in more developed areas. As e-health becomes widespread in developing countries, these and other benefits will need to be identified by more rigorous evaluations that include long-term follow-up and are carried out by independent evaluators.

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NOTES
27 Friedman CP, Wyatt JC. Evaluation...
32 The Appendix Exhibits are available online; see the Appendix Exhibits link in the box to the right of the article online.

ABOUT THE AUTHORS

Joaquin A. Blaya

Africa, and Asia. Blaya, 31, who was born in Chile, is a Harvard and Massachusetts Institute of Technology (MIT)-trained Ph.D. in health sciences and technology. Fraser, age 47, was born in Scotland and was educated and trained in medicine and cardiology in the United Kingdom. They met in 2004 when Blaya was at a joint Harvard-MIT program working on his Ph.D. and Fraser became his supervisor. Then, as now, Fraser was an assistant professor of medicine at Harvard Medical School and director of informatics and telemedicine at the nonprofit organization Partners in Health, which focuses on providing health care for the poor in a number of developing countries, including Haiti, Rwanda, and Peru. Back then, Fraser was working on developing and implementing an electronic health record for use in managing multidrug-resistant TB patients in Peru. He and Blaya teamed up to produce a Palm Pilot-based system to collect laboratory results on behalf of these patients. In a study published in 2009 in the International Journal of Infectious Diseases, the system was shown to decrease delays in getting those results from thirty days to eight days, and to reduce errors in the communication of these tests to clinicians by 59 percent.

Since then, the two have worked on implementing a Web-based system to communicate laboratory results to TB clinicians in more than 220 health centers throughout Peru. Fraser’s group (the Electronic Medical Records Team at Partners in Health), with the Regenstrief Institute in the United States, the Medical Research Council in South Africa, and others, have developed an “open source,” or nonproprietary, electronic health record system for developing countries, called OpenMRS. The system is used by more than forty-five organizations in twenty-three countries and is available for download at http://www.openmrs.org. “My focus has been on practical systems that are useful for doctors and other health care staff,” says Fraser, who is also an associate physician at the Brigham and Women’s Hospital in Boston. In addition to his medical degree, he trained in the development and use of so-called knowledge-based systems—computer systems to diagnose and analyze real-world data—at Edinburgh University in the United Kingdom. He also completed a fellowship in clinical decision making and cardiology at MIT and the New England Medical Center. Blaya, who today is a research fellow at Partners in Health, is also a National Library of Medicine Fellow at Harvard Medical School. In addition, he recently cofounded a company, eHealth Systems, which aims to implement open-source technologies, including OpenMRS, in health systems in Latin America. Having emigrated from Chile to Miami, Florida, twenty-two years ago, he plans to move back to Chile in 2010. His five-year goal is for a majority of public health centers in Chile to use OpenMRS and to expand their use in Nicaragua, Argentina, Brazil, and other countries.

Hamish Fraser

Coauthors and frequent collaborators Joaquin Blaya and Hamish Fraser share a passion for using e-health technologies to improve health care in Latin America.