Evidence-Based Health Informatics
E. Ammenwerth and M. Rigby (Eds.)
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Evaluation of Health IT in Low-Income Countries

Tom OLUOCH[a,1] and Nicolet F. de KEIZER[b]

[a] *U.S. Centers for Disease Control and Prevention - Division of Global HIV & TB, Nairobi, Kenya*
[b] *Department of Medical Informatics, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands*

Abstract. Low and middle income countries (LMICs) bear a disproportionate burden of major global health challenges. Health IT could be a promising solution in these settings but LMICs have the weakest evidence of application of health IT to enhance quality of care. Various systematic reviews show significant challenges in the implementation and evaluation of health IT. Key barriers to implementation include lack of adequate infrastructure, inadequate and poorly trained health workers, lack of appropriate legislation and policies and inadequate financial 333indicating the early state of generation of evidence to demonstrate the effectiveness of health IT in improving health outcomes and processes. The implementation challenges need to be addressed. The introduction of new guidelines such as GEP-HI and STARE-HI, as well as models for evaluation such as SEIPS, and the prioritization of evaluations in eHealth strategies of LMICs provide an opportunity to focus on strategic concepts that transform the demands of a modern integrated health care system into solutions that are secure, efficient and sustainable.

Keywords. Low-income countries, medical informatics, evaluation, eHealth.

1. Background

The last three decades have seen substantial growth in innovation and development of health information systems globally, encompassing both successes and failure [1]. The World Health Organisation (WHO) and the American Institute of Medicine (IOM) report that Health Information Technology (Health IT) has the potential to reduce medical errors and improve patient safety [2;3]. EMRs can improve health care, through among other means better adherence to therapeutic guidelines and protocols, informing clinical decisions, and decreasing medication errors [4]. WHO defines eHealth as the transfer of health resources and healthcare by electronic means [5]. According to WHO, one of the three main compon3ents of an eHealth system is the delivery of health information (e.g. patient data) to health professionals through the Internet and telecommunications to improve quality of care through well informed

[1] Corresponding author: Dr. Tom Oluoch, U.S. Centers for Disease Control and Prevention, Nairobi, Kenya, hof0@cdc.gov.

clinical decisions [6]. In this contribution, we use eHealth and health IT interchangeably.

Low and middle income countries (LMICs) have lagged behind in adopting Health IT despite bearing a disproportionately large share of major global public health threats, including maternal and child health, and infectious diseases like HIV, Tuberculosis and Malaria [7-9]. LMICs, in this chapter, are countries described by the World Bank as having a Gross National Income (GNI) per capita of US$ 12,736 or lower [10]. Fritz *et al* describe LMICs as parts of the world in which resources for healthcare services (e.g. financial and human resources and infrastructure) are scarce [11]. Most LMICs are located in sub-Saharan Africa, South America and South-East Asia. LMICs, like their counterparts in the developed world, need strong Health IT to improve quality of health care. This is not without challenges, as discussed below, but done correctly also provides an opportunity to bring skills and knowledge quickly to currently under-provided areas.

Rigorous evaluation of health IT is essential in ensuring that the interventions are safe, beneficial and cost-efficient, set in the local context [12]. Various studies have shown that implementation and evaluation of Health IT in low income countries are still in early stages as shown by the limited number of published studies [13-15]. In this chapter, we describe the challenges of implementing Health IT in LMICs, the current state of evaluations, and future opportunities. We focus on evaluation of systems used in patient care.

2. Challenges of implementation and evaluation of health IT in LMICs

LMICs experience unique challenges which include infrastructural, human capacity and policy limitations. The early state of implementation of Health IT in LMICs has a direct correlation with the limited evaluation studies conducted and published so far [16]. The consensus statement of the WHO Global eHealth Evaluation Meeting held in Bellagio, Italy, in September 2011 resolved that: *"To improve health and reduce health inequalities, rigorous evaluation of eHealth is necessary to generate evidence and promote the appropriate integration and use of technologies."* [17].

2.1. Inadequate infrastructure

Lack of basic infrastructure, which includes reliable electric power, adequate computers and related hardware, secure accommodation for computing devices, and stable and fast Internet connectivity, are often a hindrance to the implementation of health IT. Some rural clinics in sub-Saharan Africa experience power outages that last up to eight hours a day. There has been limited investment in innovative, affordable and sustainable technologies such as solar power, on-site backup generators and re-chargeable invertors in rural areas. Lack of routine maintenance of hardware and software due to lack of policies or technically qualified personnel often results in extended downtime, which is a waste of valuable resources that lie unused for weeks or months.

Technologies used in telemedicine in LMICs need to be tolerant to low-bandwidth and intermittency of connectivity [16;18]. Although there has been a rapid expansion of cellular networks in many LMICs which has inspired the growth of application of mobile technology solutions in health (mHealth), high initial cost of procuring and

installing telemedicine equipment, high cost of bandwidth, poor network signal and slow data transmission rates in rural areas remain obstacles to efficient use. In areas with intermittent power supply, unreliable Internet connectivity and inadequate infrastructure, relying on servers and computers for radiographic images used in telemedicine involves considerable risks. Piette et al. suggest that for meaningful use of large-scale implementation of picture archiving and communication in clinical care in LMICs, there is need for effective off-site data backup that can be restored in case of data loss [19]. Recent initiatives such as Google's helium-filled balloons to provide nation-wide internet access to Sri Lanka might be a solution to provide cheap or free Wi-Fi to people in remote rural areas around the world [20].

2.2. Limited human capacity

Inadequate and often poorly trained health workers are a key challenge to the implementation of health IT in LMICs. Of the 57 countries classified by WHO as having an acute shortage of health workers, 36 are in sub-Saharan Africa [21]. Health care workers' limited computer skills and frequent transfer of health workers between health facilities also hinder successful implementation of technology based solutions. Many medical schools in LMICs have not yet integrated training on informatics (e.g. basic computer skills as well as specific topics such as EMRs and telemedicine) as part of routine clinical care and this poses a challenge once the doctors graduate and have to use computers to support patient care [22].

Many LMICs experience serious shortages of medical informatics personnel who are well trained and have experience in designing, implementing and evaluating health IT solutions in resource-limited settings [22]. The few highly skilled medical informaticians tend to live and serve hospitals in cities and rarely offer their services in rural areas where majority of the patient population seek healthcare services [23]. Other key cadres such as programmers, network and database administrators and hardware technicians are mainly found in cities.

2.3. Lack of appropriate legislation and policies

Health IT is a relatively new field in many LMICs and the majority of them have not revised the necessary legislation and regulatory policies to ensure appropriate application and practice. Standards and guidelines that are customized for resource-limited settings are now emerging in countries that have recognized the need for well-regulated practice of health informatics. WHO and the International Telecommunication Union (ITU) have recently launched the National eHealth Strategy Toolkit [24] to help countries develop eHealth strategies which prioritize key technology-based interventions that are relevant for their settings. South Africa and Kenya are examples of countries in sub-Saharan Africa that have successfully developed and implemented eHealth strategies, which include evaluation of health IT [25;26].

2.4 Inadequate financial investment

Health IT solutions are often expensive. The initial capital investment in hardware and software, and the recurrent costs of maintenance and ongoing capacity building, make them unaffordable to many LMICs. Despite evidence from developed countries on the benefits of health IT, there has not been adequate investment by country governments and the private sector. Additionally, rigorous evaluation of installed systems to determine their effectiveness on quality of healthcare is often seen as a low-priority activity that can be omitted when available financial resources are not adequate.

Blaya et al. recommend that major funding agencies of health IT in LMICs, such as the US Centers for Disease Control and Prevention (CDC), the US Agency for International Development (USAID) and the World Bank should include resources for evaluation of eHealth systems developed and implemented in LMICs and make it a requirement for future funding [27]. This is consistent with a recommendation by Ammenwerth et al. that rigorous evaluation of health IT is of high importance to decision makers and users [28]. A meeting of the heads of eight global health agencies and the Global Health Information Forum (GHIF) in 2010 recommended an increase of investments to strengthen country health information systems [16].

3. Current status of Health IT evaluation in LMICs

The barriers for health IT implementation need to be addressed before new systems are implemented and their effectiveness evaluated. Furthermore these barriers can be part of the outcome measures used in evaluation studies and/or taken into account when interpreting the results on process and outcome measures. Many LMICs now have eHealth strategies; however, there is still sub-optimal financial investment by national governments in the implementation and evaluation of the strategies. Health systems projects and evaluations are often funded by donors and collaborators who in many cases drive the agenda and the identified evaluation topics may not always align with the top priorities of the country where the evaluations are conducted [23;29]; they may even find the evaluation concept challenging to their decision-making, or a potential source of criticism for apparently diverting investment money from direct service investment [30].

The rapid increase in use of health IT in LMICs is mainly driven by reduced cost of hardware (including digital cameras, videoconferencing units, and medical equipment used in telemedicine), wider coverage of Internet access and availability of affordable mobile technology. However, systematic reviews conducted recently show the pre-mature state of health IT evaluation in these settings [11;19;27;31]. The types of health IT systems assessed in evaluation studies include EMR based clinical decision support systems (CDSS), mHealth and telemedicine. Within mHealth, mobile devices include cellular phones and smartphones, tablets, personal digital assistants, patient monitoring devices, and mobile telemedicine devices.

3.1. Description of studies conducted

The eight published systematic literature reviews on health IT in LMICs that informed this contribution were conducted between 2010 and 2014 in diverse geographical settings including Southeast Asia, South America, the Caribbean and sub-Saharan Africa [11;14;15;19;27;31-33]. Of the eight systematic reviews, five described studies on EHR/EMR and CDSS, four focused on mHealth while three reviewed evaluations in the area of telemedicine. Some reviews described more than one focus area (Table 1).

All the systematic reviews concur that the studies are of varying and overall low quality. Blaya et al. included two articles in which an evaluation was never conducted because the systems implementation was not completed but also noted that studies on unsuccessful systems or those with negative associations between health IT and anticipated health outcomes were rarely reported [27]. Earlier evaluations in low income countries were mainly descriptive studies, but recent ones apply more rigorous quantitative methods including randomised controlled trials [27]. The reviews describe the application of health IT in maternal and child health, communicable (infectious) and non-communicable diseases, and for acute and chronic care. An area with a big gap in evaluation studies is the effect of health IT on maternal and child health; Fritz et al. report that only 2% of the studies included in their systematic review had outcomes related to maternal and child health (9).

The various studies described the effectiveness of health IT on major public health problems in the respective locations LMICs. For example, studies conducted in sub-Saharan Africa were likely to describe the application of health IT on AIDS and HIV, TB or Malaria while those conducted in South America were likely to be on TB and non-communicable diseases such as diabetes, hypertension and cancers. The IT solutions described in the majority of papers were implemented in public clinics and hospitals.

3.2 Study design and outcome measures

The majority of the studies reported in the eight reviews were quasi-experimental although two included some randomized controlled trials (RCTs). The quasi-experimental studies applied some quantitative measure of effectiveness and were either descriptive or used a before-after design. Many of the telehealth studies were descriptive of experiences in implementing telehealth solutions (including technological modalities such as synchronous, real-time teleconsultations and asynchronous technologies). Khanal et al. reported that out of the 46 studies fulfilling their inclusion criteria, 36 had some quantitative measure of effectiveness on process although clinical effectiveness and cost-saving were rare [14]. This is similar to the review by Blaya which reported that 72% of studies were quantitative, of which 40% had some statistical analysis [14;27].

The systematic review by Oluoch et al. showed that very few studies had been conducted in low income countries on the effect of CDSS on HIV care. Of the 12 papers included in the review, seven (~60%) presented descriptive studies while pre-post (n=3), controlled trial (n=1) and qualitative (n=1) designs were also reported. None of the papers described a study based on an RCT. Nearly all the studies described improvements in clinical processes but none demonstrated associations between health IT and a health outcome [15]. Although the review by Piette et al. did not provide a

Table 1. The most common design and outcome measures of reported health IT studies in low income countries.
EHR = Electronic Health Record, EMR = Electronic Medical Record, CDSS = Clinical Decision Support System, RCT = Randomized Controlled Trial

Systematic review	No. of studies (No. of RCTs)	Focus	Region	Included Study Designs	Outcome Measure(s) Identified
Blaya et al.	45 (9)	EHR, lab and pharmacy systems, CDSS	Sub-Saharan Africa, South America, Asia, Eastern Europe	Qualitative, Descriptive, Controlled Trials*, RCT	Staff productivity, patient waiting time, staff satisfaction, data quality, time communicating lab results, time ordering drugs, prescription errors, patient tracing, provider performance, tuberculosis treatment completion rates, cost effectiveness and clinic attendance
Fritz et al.	47 (0)	EMR	Sub-Saharan Africa, South America, Asia	Descriptive	Factors for successful EMR implementation
Hall et al.	76 (4)	mHealth	Sub-Saharan Africa, South America, Asia, Eastern Europe	Controlled Trials*, RCT, Pre-post	Treatment adherence, appointments, data collection, diabetes control, antenatal care, vaccination rates
Kallander et al.	Not stated	mHealth	Sub-Saharan Africa, South America, Asia	Descriptive	Appointments, health behaviour
Khanal et al.	46 (0)	Telemedicine	Sub-Saharan Africa, South America, Asia, Eastern Europe	Descriptive	Cost-effectiveness, clinical effectiveness
Luna et al.	11 (0)	EMR, Telemedicine and mHealth	Developing countries (continents not specified)	Systematic review of reviews	Efficiency in process management, diabetes patients prognosis, data quality
Oluoch et al.	12 (0)	EMR/CDSS	Sub-Saharan Africa, South America	Qualitative, Descriptive, Pre-post and Controlled Trial*	Lab orders, data errors, missed appointments, patient waiting time and barriers to CDSS implementation
Piette et al.	N/A	EMR, mHealth, Telemedicine	Sub-Saharan Africa, South America	Systematic review of reviews	Practitioner performance, guideline adherence, lab ordering, data errors, hospital stay, telemedicine diagnostic accuracy

* - non-randomized controlled trial

breakdown by study design type, the main outcomes were on the effectiveness of health IT on quality of care and healthcare cost [19]. Fritz et al. indicate that only 25% of the papers included in their review were evaluations. The majority were descriptive studies that discussed key areas of successful implementation of EHRs [11].

While there has been a growing number of evaluation studies on mHealth solutions in LMICs, as reported by Hall et al. and Kallander et al., the quality and quantity of the evidence is limited by several factors (e.g. high risk of bias and heterogeneity) and only a few demonstrate impact on clinical outcomes [31;33]. Some key areas which have not been rigorously evaluated and reported include the use of mHealth in clinical decision support, job aids and use of mobile devices in telehealth.

Although the studies mainly reported benefits on patient care and clinical processes, none reported the cost of implementation and maintenance of such systems. The review by Luna et al. did not include specific study designs or outcomes but in their synthesis of the evidence from various studies reiterated that the majority of published reviews concurred that the papers evaluated were generally of poor quality [32].

3.3 Study limitations

The studies reviewed had several limitations. The findings reported in most papers were not generalizable due to the limitations of the study designs, small sample sizes and the statistical analysis methods used which may not have effectively corrected for confounders. In the mHealth systematic reviews, for example, it was unclear whether the reported effects of mobile technologies could have been due to the "novelty" effect resulting from the excitement of use of new technology but which gradually wears off as the users get more accustomed to the mobile devices.

A key limitation noted by Blaya et al. was that evaluations were conducted by the developers of the systems hence potentially introducing bias. Low data quality was also cited as a factor that reduced the validity of findings in some studies. The RCTs reported were based on small pilots with limited sample size and generated evidence that is not easily generalisable. Hall et al. and Kallander et al. both recommend scaling up the use of mHealth solutions in order to strengthen the evidence base [31;33]. Finally, there were rarely studies that triangulated multiple methods, including quantitative and qualitative methods, not only to measure a possible effect but also to understand barriers and facilitators of effective implementation of the health IT intervention.

4. Future opportunities for evaluations of health IT

The systematic reviews included in this contribution (Table 1) demonstrate that the potential of health IT in LMICs remains largely untapped, but equally importantly that the evidence on the best forms of investment and on how to overcome the natural barriers effectively remains minimal due to the lack of investment in objective scientific evaluation. Multilateral and bilateral partnerships, increased investments by country governments, as well as the engagement of the private sector present new opportunities for investing in technology solutions that address the unique challenges in resource-limited settings. Development and implementation of eHealth strategies is increasingly highlighting the relevance and importance of evaluating health IT

solutions and recommending implementation models that are context appropriate. These will see an extension of coverage of health IT (and thus effective healthcare availability) in rural settings which have been previously underserved and not adequately evaluated.

Large randomised trials such as that by Zurovac et al., provide strong evidence of the benefits of health IT [34]. As conducting large RCTs in low income settings might still be rare, Piette et al. recommend the adoption of new approaches to operational research, incorporating qualitative and quantitative methods as well as community-based participatory research and organizational theory to complement RCTs as a way of demonstrating that the benefits of health IT can be adaptive to multiple environments, including resource-limited settings in low income countries [19].

It is important to identify and develop skills and competencies, consistent with low-resources settings and health systems, that will be necessary to achieve the full potential of health IT applications [35]. Synthesizing the expertise of indigenous knowledge and understanding of individual countries or regional groupings, and generic expertise on the potential of eHealth innovations, is necessary to create an informed picture or possibilities or effective evaluation [12;36]. Collaborations and experience sharing between universities and research institutions in LMICs and those in developed countries with mature curricula for post-graduate training and health IT evaluation capacity can do much to help improve the quality of evaluations [37]. Such skills can be cascaded down to lower level health workers and health IT staff to enhance the ability to conduct evaluations in LMICs. Leveraging the research capacity within local universities, research institutes and industry to design and implement evaluation of health IT that informs delivery of appropriate technology is a practical solution.

5. Discussion and conclusion

Implementation of health IT in LMICs needs to grow from its current early phase. Due to the disproportionately large population suffering from major infectious diseases like HIV, tuberculosis and malaria, the increase in reported cases of chronic and non-communicable diseases such as diabetes and cancers, and high maternal and child mortality, the potential benefit of health IT to improve health care by informing clinical decisions, better adherence to therapeutic guidelines and protocols, increasing access to quality healthcare services in rural areas and decreasing medication errors is large. To gain the most benefit from health IT implementations we need robust evidence-based knowledge about antecedents of health IT implementation success in low-resource settings.

Implementation of health IT in LMICs still faces major challenges including weak infrastructure, limited computer skills among health workers and lack of appropriate policies. A recent study by Tilahun et al. [38] used the updated Delone & Maclean model [39] to identify antecedents of EMR success. They concluded that EMR implementers and managers in those settings should give priority to improving service quality of the hospitals like technical support and infrastructure; providing continuous basic computer trainings to health professionals; and paying attention to the system and information quality of the systems they want to implement. There is need to address the barriers to implementation of health IT and partnerships between LMICs and multi-lateral, bilateral organizations as well as the private sector provide an opportunity for

investment in context-appropriate technologies that are sustainable. Universities and research institutions also have an opportunity to integrate training on application and evaluation of health informatics.

Models such as the Software Engineering Initiative for Patient Safety (SEIPS) [40] might be useful before health IT implementation to check whether the five components of the work system (person, tasks, tools and technologies, physical environment, organizational conditions) are ready for implementation. Furthermore this model can be used in the evaluation phase to obtain better understanding of the antecedents of health IT implementation success.

A majority of the systematic reviews on health IT in LMICs mentioned weak study designs and reporting quality of evaluation studies in low income settings hampering evidence-based health informatics. Extending application of existing guidelines such as the Guidelines for Good Evaluation Practice in Health Informatics (GEP-HI)[2] and Statement on Reporting of Evaluation studies in Health Informatics (STARE-HI) [41;42][3] to fit LMICs' needs is important. The guidelines can be applied to elaborate on how specific barriers to the implementation of health IT in LMICs (e.g. lack of reliable electricity and low computer literacy among health workers) were addressed and how they impacted the evaluation of the effectiveness of technology on healthcare in these settings. Application of such guidelines as part of national eHealth strategies would be an initial step towards having a structured approach to evaluations and reporting of findings.

As technology changes and new health challenges emerge (e.g., the increase in cases of non-communicable diseases), there are new opportunities for implementation and evaluation of context-relevant health IT that demonstrate the ability of technology to improve the quality of care, practitioner performance, clinical processes, cost effectiveness and expanded access to healthcare. Health IT, appropriately designed to the setting, has the potential to bring health knowledge and skills quickly to underserved areas. However; there is need for targeted investment to address infrastructural, IT skills and policies to facilitate focused evidence from evaluations informed by appropriate tools and principles [17].

In conclusion, evaluation of health IT projects has to focus on strategic concepts in order to provide the firm evidence on how to transform the requirements of a modern integrated health and social care system into solutions that are relevant, user-friendly, secure, efficient and sustainable within the context of the LMICs.

Disclaimer: The findings and conclusions in this contribution are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention or the Agency for Toxic Substances and Disease Registry.

[2] See also: P. Nykänen et al., Quality of health IT evaluations, in: E. Ammenwerth, M. Rigby (eds.), Evidence-Based Health Informatics, Stud Health Technol Inform 222, IOS Press, Amsterdam, 2016.

[3] See also: E. Ammenwerth et al., Publishing health IT evaluation studies, in: ibid.

Recommended further readings

1. P. Carayon, H.A. Schoofs, B.T. Karsh, A.P. Gurses, C.J. Alvarado, M. Smith, et al., Work system design for patient safety: the SEIPS model, *Qual Saf Health Care* **15** Supl 1 (2006), i50-i58.
2. P. Nykanen, J. Brender, J. Talmon, N. de Keizer, M. Rigby, M.C. Beuscart-Zephir, et al., Guideline for good evaluation practice in health informatics (GEP-HI), *Int J Med Inform* **80**(12) (2011)**,** 815-27.
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5. B. Tilahun, F. Fritz, Modeling antecedents of electronic medical record system implementation success in low-resource setting hospitals, *BMC Med Inform Decis Mak* **15 (**2015): 61.

Food for thought

1. Within the STARE-HI guideline the health IT system and the context in which the system is implemented needs a more detailed description. Based on section 2 and your own thinking what kind of information is essential to report?
2. How would you deal with the barriers mentioned in section 2 before evaluating the health IT interventions? Would the SEIPS model be appropriate to prepare a resource limited setting before implementation of a health IT intervention?
3. With the increased use of health IT, especially in clinical decision support, is there a risk that clinicians may fully rely on the recommendations of the CDSS, thereby compromising their own judgment? This may be more likely in busy and under-staffed clinics.
4. What are the most important pieces of evidence needed in a LMIC work setting in order to enable introduction of effective health IT support to meet unmet health needs? Is such evidence available, or how might it be obtained?

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