Electronic Health Record Architecture for Rural Clinic Data Connectivity and Unique Patient Identification

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***Abstract*—Two major challenges currently facing health providers in the developing world are data connectivity between health centers and patient identification. An EHR system, presented in this paper, illustrates a comprehensive solution to both challenges by incorporating an all-electronic health data system and RFID card system for patient identification. The proposed system uses standard network protocols and can be implemented with locally sourced equipment and personnel. A pilot program of the EHR system in Kerala, India has been proposed and analyzed. While technical obstacles exist to the successful implementation of this system, public outreach addressing social norms of patient responsibility is paramount to making this project sustainable.**

I. Introduction

Two core challenges to providing reliable medical treatment in the developing world have been identified by remote health care providers and international emergency relief organizations. The first challenge is *establishing and maintaining data connectivity between resource-constrained rural health clinics and regional health centers* in order to effectively coordinate treatment for critical and non-critical patients. Oftentimes, rural clinics lack the infrastructure and the personnel necessary to handle time sensitive medical issues, so it is imperative to provide a streamlined data network to facilitate reliable communication via phone, internet, and two-way video stream. Furthermore, in cases of natural disaster or other events that displace large groups of people, a robust communications network must be in place to provide medical treatment to scale during emergencies.

The second challenge is the *problem of tying individual patient identification (ID) to health records*. Patient misidentification has been cited by the World Health Organization (WHO) as one of the most prevalent and preventable causes of medical error **[1]**. This problem is particularly acute in displaced populations, where delivery of effective health care en masse is a major challenge.

It is interesting to note that neither of these challenges can adequately be addressed independently – data connectivity for individual patient information is predicated on the availability of a unique patient ID to evaluate medical history, allergies, etc. Conversely, assigning unique patient IDs to displaced populations assumes the availability of an electronic network that can track and store all the patients' information. Therefore, a solution that addresses both challenges in parallel seems appropriate.

II. Overview

A. Past Efforts and Previous Designs

Several previous projects have sought to solve the identified challenges but with limited success. The Aravind Eye Hospital in India and the Baltistan Health and Education Foundation in Pakistan are two such projects which have gained international recognition due to the fact that they were more than mere pilot projects. The Aravind hospital allows eye specialists to video-conference with patients in remote clinics by using directional antennas and software to extend the range of existing Wi-Fi and achieving network speeds 100 times faster than dial-up and distances 100 times farther than traditional Wi-Fi **[2]**. The Baltistan Health and Education Foundation uses data connectivity over distances of 800 km: this telehealth facility links the major hospital in Skardu, northern Pakistan, with health specialists in Islamabad. The project required connecting the area via satellite to an ISP. **[3]** However, there were limitations with both these projects: the Aravind project could not have Internet service providers in some areas, and where there were, service was very expensive and too slow for effective video-conferencing. The Baltistan project needed USD 2,000 per month for satellite connectivity.

Another project, *Smart Connect*, is a custom device that uses cellphone network to provide limited data connectivity between a rural health facility and a server connected to the Internet. But the dire need for a compatible version of this device using other radio technologies and the unavailability of data connections at peripheral facilities inhibits its future. **[4]**

Several previous projects have also focused on the problem of patient identification. A previous IEEE Humanitarian Technology Challenge project implemented an electronic patient identification database system using RFID-embedded patient ID cards. This pilot program has been moderately successful, as cultural norms are proving difficult to overcome in convincing the local population to adopt the new ID cards **[5]**. These projects, though commendable in their own right, fell short when it came to widespread implementation, whether due to technical equipment, expensive services or cultural, social, or behavioral considerations.

In order to ensure our project builds on the shortcomings of the previous designs, we developed a solution which solved these challenges and evaluated different network technologies, each with a set of limitations. **[6]**

Technology	Reach	Economics	Limitations

Cellular	Global System for Mobile Communications (GSM) is the most prevalent system; devices can be deployed immediately	As low as 25 USD; affordable in emerging world, easily charged with solar energy and relatively suitable for harsh environments	Most GSM setups handle voice only and offer no useful data services; need General Packet Radio Service (GPRS) or Third Gen (3G) for that
Wi-Fi, Wi-Max	Can connect sites to a local ISP 10^{1} km away with point-to-point connection by high gain directional antennas	Prices depend on the internet connection of the ISP and on the local situation	Low penetration in developing countries; limited public Wi-Fi, only in urban areas
Mesh networking	All nodes are connected to the rest in a network through hops; messages dynamically hop from station to station	Equivalent to Wi-Fi/Wi-Max setups; smart phones can also be connected to LAN for fast & direct access to local info system	Difficulties in extended community networks; network management, billing, administration
DSL	Further than a few miles away from a district telephone exchange, DSL does not work	Can be deployed over existing cable; cheaper than installing a new, high BW fiber-optic cable over same distance	High speed connection over dial-up [7]
Fibre	Run over large distances covering 1000 miles with hundreds of Gigabits/sec	BW & cost can be shared, based on short-run cycle: large BW charges lesser price p. u. data transfer	Controlled by IT giants and monopolists; need infrastructure and labor resources
Satellite	VSAT dishes give direct internet access to a European or American gateway and can be installed directly at site	Ku-band dish is reasonably affordable (5-10k USD); high monthly charges (500 USD) for a shared 256 kbps connection	Poor network performance; high delays and congestion in shared connections
Delay tolerant network	Non-time-critical health conditions in sparsely-populated rural areas without VSAT	Logistic costs and security issues for data service transportation	Temporary solution; cannot work in medical emergencies
Laser	Max range of free space optics is 2-3 km for land-based links	Low-cost LEDs and laser systems available	Beam dispersion heavily affected by weather and environment
Antennas	Directional antennas: up to 6 Mb/s and up to 40 miles; 100 times faster than dial-up; 100 times farther than Wi-Fi	Used with Wi-Max at USD 30,000/antenna	Need to be used with other technologies
PAN, Bluetooth	Works best at short-range radio frequencies	Cost-effective for smaller networking circles	Too many technical requirements like specific wavelength
RFID	Patient identification, asset tracking, sensing, interventions	RFID card printer USD 1500; card readers and software for each clinic USD 50-100	Social and behavioral, security, network connectivity reliance

Table 1: Assessment of communication technologies

After the evaluation phase, it was concluded that RFID would be the most appropriate technology in our project, as explained ahead, where we could extract maximum benefit while incurring optimum cost.

B. Proposed Solution

In order to solve the challenge of exchanging data between different regional centers, we determined that an EHR system divided into three tiers can be relevant to the local setting as well as be technically sound as to connect and identify patients.

Figure 1: EHR Architecture Diagram

The smallest unit of Indian healthcare systems is the sub-center while that of Pakistan is the Basic Health Unit **[8]**. By generalizing these systems and considering a single state with sub-centers, Primary, Secondary and Tertiary Health Centers, the EHR system is proposed to be installed at the following different levels:

1. **Primary Healthcare Centre (PHC):** It represents the first level of contact with individuals and healthcare system. PHCs are divided into several sub-centers and serve different number of people depending on the geographical location. It is aimed to provide a PC to each rural clinic and 10 PCs to the SHC. The SHC will be issued an RFID printer and each rural clinic will receive an RFID card reader. While every patient has a unique RFID card, their medical history is updated each time they communicate with the PHC, whether for diagnosis, treatment or routine check-up. The data generated in PHC has to be shared with the closest SHC and finally, it is transferred to central cloud for permanent storage. Different PHCs under an SHC need not be connected. If the patient data is required by PHC, it can be retrieved from central cloud **[9]**. Limiting the number of connections helps to reduce the spending on communication networks. PHC receives regular statistics from central cloud about the amount of medicines that are used by people suffering from chronic diseases and also usage of general medicines. This analysis helps them to pre-order required number of medicines to serve the people of that region.
2. **Secondary Healthcare Center (SHC):** Second tier healthcare systems are the next level of healthcare centers, providing reasonably good health services, but are not as sophisticated as THCs. These are established at district level. Each SHC in that particular state will be connected to central cloud of that state, but SHCs of that particular state are not connected to ensure security of data. Usually at SHC level, the people may not be highly educated to realize the importance of data security. So, to avoid any kind of data breach different SHCs shall not be connected. **[10]**
3. **Tertiary Health Centre (THC):** The third-tier healthcare systems are usually sophisticated health centers, providing a wide range of health services and are located in cities and district headquarters, where the datacenter is established and is connected with those of other THCs. So, this forms a central cloud which consists of the complete patient data. This central cloud can be managed by government or an organization which is formed by a consortium of THCs. This central cloud is connected to the central cloud of other states which enables the accessibility of patient data throughout the country. The central cloud also contains data of patients visiting SHCs, PHCs and sub-centers of that particular state. The data stored in central cloud can only be accessed online from anywhere and anytime. The data of patients visiting SHCs, PHCs and sub-centers has to be updated in the central cloud on regular basis. EHR in central cloud will be able to track the usage of medicines and outbreak of diseases in various parts of the state. This enables to act instantly in case of emergencies. **[11]**

C. Implementation Plan and Goals

After group discussions, creating maps of the concerned region of existing connectivity was decided as a useful starting point. The existing network coverage of GSM in Kerala, India, was focused on as a starting point to see its penetration to help us build a case study by using a variety of online resources **[12] [13]**. However, the GSM network is inefficient for data transfer services, as it is communicates in bursts, is asymmetrical and has security issues. **[14]**

To enable transfer of data between three centers and set up an infrastructure at these levels that will maintain and store health records, we have endeavored to use the RFID system that will be easier to handle at both the user's and the system's end. Ideally, this project hopes to build a pilot project in five months and then create a system where in a period of three months one rural area (with a population ranging from 500 to 10,000) would be connected to the EHR network. Subsequent rural areas would take lesser time depending on the local situation.

D. Stakeholder Analysis

There are several key stakeholders necessary to the successful implementation of the proposed EHR solution. The governmental and non-governmental medical institutes will be primarily responsible for legislation and overseeing of EHR, since damages caused due to EHR system may pose legal issues and risks **[15] [16].** The hospitals and health centers will be primarily responsible for business concerns and structural changes in health care delivery **[17]**. System administrators will be needed to handle the increasing needs for sophisticated utilization review and risk management tools **[18].** Finally, patients themselves are cooperatively responsible for the safety of medical data, high-quality care, and expectation of privacy, rights of access and correction, and the opportunity to give consent for research uses of their health information **[19].**

This is a short synopsis of an extensive stakeholder analysis, but represents the most important users. Successful EHR implementation depends on the support for the idea from health care regulators, third-party payers, hospital administrators, and physician advocacy groups.

E. Constraints

Several constraints govern the implementation of the proposed EHR system. Due to the vast amounts of medical data processed by the EHR system, adequate network and legal constraints must be considered. Each patient's medical information must be confidentially stored by the network, and accessed only by users with the correct permissions. This requires a robust data security system for backing up the medical data and ensuring the information remains secure **[20]**. The legacy health record information databases (hardcopy) must be transposed to the EHR system by each health care provider, so the system must also be capable of handling large influxes of data securely. **[21]**

Other technical constraints include consideration of standardization issues with the IT process, specifically when storing, coding, transmitting, and receiving data. The proposed EHR system must balance the unique demands of each clinic, while ensuring each component of the EHR system adheres to a universal standard. This will greatly simplify the training and maintenance of the system during operations. Furthermore, standardization will allow the system to be interoperable with other EHR systems.

While there are several technical constraints that make solving these problems difficult, perhaps the most severe constraint is behavioral. As was demonstrated in several previous medical development projects, convincing the end users (patients) of the benefit of the proposed technology is paramount to the overall success of the implementation. Other non-technical constraints include cultural, regulatory, and political.

III. System Design

A. Design Overview

Using the proposed system, electronic records of a patient will be accessible to the healthcare provider, doctor, patient and healthcare worker. The electronic record of each patient is associated with a unique RFID signature; the patient's medical record can only be accessed by scanning their issued ID card. To implement the RFID card system, legacy work in this area by Zalzala et al. will be continued and scaled to meet the demands of larger health care networks **[10]**.

The ***healthcare provider (HQ)*** maintains the central cloud. Our proposed methodology intends to secure electronic health data by preventing the healthcare provider from accessing unencrypted patient data. When the data is maintained by the HQ, only the data corresponding to particular ID will be known along with the region to which patient belongs, but the identity of the patient will be secure. Providing the health care provider with access to this data enables them to track the health condition of a group of anonymous patients in a particular region to assess the overall medical health of the region *in situ*.

The ***healthcare workers*** are primarily responsible for managing the patient identification effort. The HQ maintains the RFID card printer and is responsible for issuing blank cards to the primary and secondary health care centers. The blank cards are then issued and encoded with unique patient information at the rural health clinics. Healthcare workers will facilitate this process: working with local populations to raise awareness and promote health education about the importance of securing the patient ID cards. They shall be able to receive messages from patients in case of emergencies, and track the health condition of patients in a particular locality and provide them assistance, when required.

The ***doctors*** are primarily responsible for patient care, being vital to successful EHR implementation, but they will not have permission to edit history or download the data. In particular with patient identification, doctors will need time and resources to enter each patient's medical history into a database to encode the information on the ID card. Healthcare workers will work with doctors to streamline the process of encoding patient information to EHR database and ID cards.

The ***patient***, being the recipient of this system, plays an important role in the successful realization of the proposed system. By having a smart card carrying their identity whenever they visit a hospital, patients cannot view their data anytime, but can view on request. Their medical data will be updated on regular basis and acceptance of any new system must follow bottom-up, so it is vital to gain the trust of the local population who ultimately benefit from the EHR system.

The end goal of the EHR system is the creation of a large dedicated repository to which each of these distributed clinical system components all feed on a frequent basis. A comprehensive, multi-enterprise EHR can be established by interfacing the specific clinical applications and databases that are each tailored to the needs of individual healthcare delivery centers. **[22]**

During the project, the team examined the federation approach as well as the two-level modeling approach. The Federation Approach is a validated mechanism for realizing a distributed EHR service, which can be physical or logical. **[23]**

There are strengths and weaknesses associated with this approach: live federation places considerable demands upon network and server performance, and requires constant and reliable availability of all participating feeder systems; a caching mechanism becomes dependent on potentially large repositories and on regular version checking to ensure updates to each feeder system are forwarded to cache repository in real time in order to avoid the risk of a requesting client receiving outdated or incorrect information.

The Two-Level/Dual-Model approach to the design of the EHR information architecture devises a standardized, scalable and maintainable model to represent and communicate diverse health record entries. The combination of the *Reference Model* and the use of Archetypes (as the EHR information architecture) faithfully preserve the set of contexts relating to a health record entry, to ensure the intended clinical meaning of the original author is preserved within the generic representation.

B. Standards and Interoperability Assessment

Setting and maintaining uniform network and interface standards is necessary in order to make the rural EHR system scalable to different communities throughout the developing world. Ideally, one standard would be the de facto guideline for establishing network connectivity for all rural health centers. In much the same way that all internet browsers use standardized web protocols (HTML and HTTP), one medical network protocol could form the backbone for all electronic exchange of medical information and services [source interfaceware.com]

HL7 is a widely accepted network standard for electronic health information developed in the United States **[26]**. The HL7 standard defines the format for medical related data transmission, and is the most suitable standard for the proposed EHR system. The real value added by using HL7 lies in the standardization (and thus technical simplification) of electronic patient records, patient IDs, patient medical histories, laboratory results, billing information, and remote medical consultation. By relying on the HL7 standard for the proposed EHR solution, future interfaces to the EHR system will be greatly simplified.

Technical interoperability is another major concern from a systems engineering perspective. Using a standardized network protocol is a major step towards ensuring system interoperability, but there are also hardware considerations that need to be accounted for when designing an interoperable system. This is especially important when dealing with medical images or two-way video streams, since both the sender and receiver must have the hardware capability to utilize such tools. To address interoperability, the team has relied upon the HL7 standard along with special hardware considerations at each of the three levels of health care centers.

C. Energy Requirements

An often-overlooked consideration when implementing any rural medical development project is the energy requirement necessary to support the infrastructure and equipment loads (lighting, refrigeration, radios, incubators, etc). Electricity is also a necessary foundation for any electronic health record system.

Energy is the fundamental enabler to any modern development project, especially since many areas in need of improved medical care do not have reliable access to a regional power grid. USAID has an extremely informative paper outlining rough estimates for rural clinic energy load requirements based on size of the clinic and category of care given. These estimates were used as the starting point for the energy requirement analysis for the team's final project **[25]**.

The basic question proposed by this analysis is "given a particular load (based on clinic size and category), along with geographic location and pertinent economic data, what is the best combination of diesel generator, solar, wind and battery power inputs to meet the standalone energy needs of the clinic?" This question assumes that grid connection to the clinic is either technically unfeasible or not economically viable, a reasonable assertion considering in some parts of the developing world grid extensions cost as much as $10,000 US per km **[25].**

Using the US National Renewable Energy Lab (NREL) micropower optimization software model HOMER, a simulation of a Primary Healthcare Center in Kerala, India was developed. From the combination of solar power, wind power, diesel generator, and battery sizes input, over 8000 possible configurations were simulated and HOMER output the top ten for consideration. These ten results are rank ordered based on holistic economic feasibility, taking into consideration not only initial costs but operation and maintenance (O&M) costs as well.

From the simulation results, the optimum energy configuration for this hypothetical clinic in Kerala is 3 kW of PV and 5-7 kWhr batteries. The initial capital cost to install this system is estimated to be $12,400 US while the O&M costs are relatively low at $275 US per year.

The real takeaway from these results is that in this case, because the yearly solar insolation is so high in southern India, a standalone PV-battery energy system makes sense given the modest energy demands of a rural clinic.

D. Operations, Administrative, and Maintenance Plans

When operating the proposed EHR system, medical data will be stored at secure servers maintained by the host government. EHR data should be accessible from anywhere and anytime, regardless of whether the patient goes to PHC, SHC or THC. Unique EHR permissions will be defined to the health care provider, patient, doctor and health care workers.

Proper training of all personnel (including maintenance personnel) is essential to successful implementation and operation of the proposed EHR system. The operations plan should be a standardized, published document accessible to all system stakeholders. From the central government medical center, to the regional and rural health clinics, the "ops plan" should clearly define roles, responsibilities, and regulations of the EHR system. The operations plan will serve as the guideline for proper day-to-day operations, including a contingency plan for natural disasters and diaspora.

Maintenance is also an essential consideration to the overall sustainability of the proposed EHR system. The maintenance plan will focus on training the local workforce in task-specific skills ranging from IT support, to electrical generator repair, to communication system troubleshooting. Where possible, the maintenance plan will work with University and vocational centers to develop relevant curricula to meet the demands of each medical delivery center.

E. Economic, Legal, and Social Considerations

Sustainable economic development in rural communities includes recognizing the significance of the local health sector in economic matters and community development. Accordingly, the team has proposed several economic goals to ensure the sustainable development and implementation of the EHR system. The first goal is to enhance the opportunities for employees by widening the scope of medically essential personnel (health care providers, IT administrators, data entry clerks, infrastructure developers, etc.).

The second economic goal is to attract and retain local residents for business and public service. To do this, the team has recommended a strategy where the health care providers pay for licensure and membership fees for patients, versus having them pay for it themselves, therefore removing the economic burden of a new clinic from the local population. To finance construction and renovation projects, the team has recommended the strategy of public-private partnerships such as government financing and private provisioning.

The final economic goal of the proposed EHR solution is to enhance local leadership capacity through the sponsorship of rural clinics and EHR providers. Getting local leaders interested and involved in these EHR development projects will greatly enhance the economic sustainability of the rural medical centers.

Due to the politicized nature of health care delivery systems, a solid legal foundation must be in place to facilitate standardized regulations across country borders and to ensure that patient outcomes are protected as the first priority. The proposed EHR system will be managed by the host government. Adequate and up to date licensure will be ensured for all medical providers and health care workers. International legislation will ensure that cross-border delivery of health care will remain secure. Penalties will be enforced by the host government for health care providers that breach licensure requirements.

Social and behavioral issues must also be considered when deploying and operating the EHR system. Social norms guiding current behavior of doctors, patients, and other health care stakeholders must be addressed to incorporate a digital transition of all medical information. Use cases for each stakeholder have been analyzed to understand exactly how these social and behavioral norms will affect health care delivery interfacing with the EHR. Using the EHR alert management system, the patient obtains vital information regarding any severe breaking news by three mechanisms: mobile phone alerts using SMS text messaging, pole display system (paper or electronic), and social media.

F. Cost Analysis

A quick analysis estimates the initial cost at around USD \$391k, while annual recurring costs total about USD \$8,500, including a satellite connection plus maintenance. Table 2 below shows the estimated costs for each component of the proposed EHR system at a small network of PHC, SHC, and THC clinics:

Equipment	**Quantity**	**Cost ($USD)**
Wi-MAX antennas	10	300k
HQ access-point equipment	1	10k
Backhaul Wi-Fi connection to VSAT	1	10k
Computers	20	24k
Software installation and training		20k
Power generation equipment	10	20k
HQ Power equipment	1	5k
HQ RFID printer and software	1	1.5k
RFID readers	10	500
Total		391k

Table 2: Cost Estimates

The annual amortized cost for a complete installation for this district will be \$15,000 to \$30,000 for its 5-to-10 year lifespan, bringing the total annual cost to less than \$40,000. These estimates include installation, operation and maintenance. Various studies of information and communication technology's (ICT's) impact on healthcare estimate that the increase in operating efficiency alone could be between 15% and 30% **[27]**. For an early implementation in a developing country, the increase may be even higher.

For an aid organization administering a \$2M US program annually, this could make for a very convincing case for more investment and expansion in this region. Also recognize that perhaps a bigger advantage of ICT is the opportunity to deploy new services and functions heretofore impossible to provide.

IV. Discussion

A. Metrics for Success

To analyze the efficacy of the proposed solution, several measures of effectiveness (MOEs) were identified for both challenges. For the data connectivity challenge, one of the most important MOEs is the bi-directional data transfer capabilities to store and forward data at the same speed in each direction (transmit and receive) at a minimum rate of 128 kbps and at a low cost structure (USD 50 per month) for unlimited data transfer. Another MOE for data connectivity is that networks should be interfaceable, connectible, and modular to accommodate future expansion, using technology that is previously validated. Components should be commercial-off-the-shelf (COTS) and readily available worldwide, and standardized to avoid being monopolized.

For the challenge of tying unique patient IDs to health records, one of the primary MOEs was the request, issue and assignment of a unique patient identifier capable of interfacing with the EHR system and storing health encounter information within that system. Another MOE is the training the medical staff to look up and review patient information and support that access once they are trained, and link information from different services to form a complete health record for disease management and continuity of individual care. The final MOE for the patient identification challenge is that the system should detect and track epidemics and emerging diseases, and also help tailor an appropriate response from this health system with a public outreach able to train patients how and why to use their unique patient ID.

B. Potential Problems

A longitudinal person-centered EHR system is a much-anticipated solution to this problem, but the challenge of providing clinicians of any profession or specialty with an integrated view of the complete health and healthcare history of each patient under their care has so far proved difficult to meet.

Our analysis shows that a broad adoption of standards-based EHR systems in developing countries could dramatically reduce national health care spending at a cost far below the savings. Further, these potential savings would outweigh the costs relatively quickly during the adoption cycle. But key barriers in the market directly impede adoption and effective application of EHR systems; these include acquisition and implementation costs, slow and uncertain financial payoffs, and disruptive effects on practices. In addition, providers must absorb the costs of EHR systems, but consumers and payers are the most likely to reap the savings. Also, even if EHR systems were widely adopted, the market might fail to develop interoperability and robust information exchange networks.

C. Way Forward

Given our analysis, we believe that there is substantial rationale for government policy to facilitate widespread diffusion of interoperable health information technology (HIT). Actions now, in the early stages of adoption, would provide the most leverage. Taylor and colleagues discuss several alternatives for government action to remove barriers, correct market failures, and speed the realization of EMR system benefits **[20]**. We have shown some of the potential benefits of HIT in the current health care system. However, broad adoption of EHR systems and connectivity are necessary but not sufficient steps toward real health care transformation. For example, adoption of EHR systems and valid comparative performance reporting would enable the development of value-based competition and quality improvement to drive transformation. A HIT also should facilitate system integration for broader optimization, and comparative benchmarking should encourage development of market leading examples of ways to better organize, pay for, and deliver care. It is not known what changes should or will take place after widespread EMR system adoption—for example, increased consumer-directed care, new methods of organizing care delivery, and new approaches to financing. But it is increasingly clear that a lengthy, uneven adoption of non-standardized, non-interoperable EMR systems will only delay the chance to move closer to a transformed health care system. The government and other payers have an important stake in not letting this happen. The time to act is now.

D. Conclusion

The proposed EHR system demonstrates a comprehensive solution to the two health care challenges identified. We believe that by migrating hardcopy patient medical records to an electronic system connected to an interoperable network, health care delivery centers can more adequately meet the demands of large rural populations. Furthermore, by implementing a secure RFID patient ID system, patient misidentification can be dramatically reduced. While the implementation costs are relatively high, health outcomes will be strengthened across the board with a consistent, standardized implementation of the EHR system.

In the course of our project design and development, we considered requirements as design feasibility, product features, standards, interoperability and economic considerations, established a reasonable reference that can be tweaked to adapt to different regions, and collaborated with health and information system specialists in the hope that we are part of the team who develop the actual system to be deployed in the local environment.

References

[1] http://www.who.int/patientsafety/solutions/patientsafety/PS-Solution2.pdf

[2] http://www.berkeley.edu/news/media/releases/2006/06/06_telemedicine.shtml

[3] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3599541/

[4] R. Anderson, E. Blantz, D. Lubinski, E. O'Rourke, M. Summer, K. Yousoufian, "Smart Connect: Last mile data Connectivity for rural health facilities", 2010 ACM ISBN 978-1-4503-0193-0/10/06

[5] http://theinstitute.ieee.org/benefits/humanitarian-efforts/medical-records-program-expected-to-save-lives

[6] http://www.cse.wustl.edu/~jain/cse574-08/ftp/rural/

[7] http://www.bth.se/fou/forskinfo.nsf/0/d4a67a995a8aade6c12578b800518a37/$file/Broadband%20Access%20Technologies%20for%20Rural%20Connectivity%20in%20Developing%20Countries.pdf

[8] M. Akram & F. Khan, PIDE Working Papers, 2007:32, "Health Care Services and Government Spending in Pakistan", Pakistan Institute of Development Economics, Islamabad

[9] "Essential Package of Health Services, Secondary & Tertiary Care: The District, County & National Health Systems" The Ministry of Health & Social Welfare, Republic of Liberia, Monrovia, November, 2011

[10] Mehmet Ulema, "Data Connectivity of Rural District Health Offices", pp 3 of 29

[11] "Community Assessment for Public Health Emergency Response (CASPER) Toolkit", Centers for Disease Control and Prevention, National Center for Environmental Health, Division of Environmental Hazards and Health Effects, Health Studies Branch

[12] http://www.cellumap.com

[13] http://network.rcom.co.in/Coverage.aspx

[14] Wei Zhang, "GSM Security Issues", Iowa State University, Department of Computer Engineering

[15] Heard S., Grivel A., Schloeffel P., and Doust J. The benefits and difficulties of introducing a national approach to electronic health records in Australia in: National Electronic Health Records Taskforce. A Health Information Network for Australia. Department of Health and Aged Care, Commonwealth of Australia; Jul 2000

[16] http://www.healthimaging.com/topics/diagnostic-imaging/bigger-focus-compliance-needed-emr-marketplace

[17] http://www.huffingtonpost.com/ben-kerschberg/how-electronic-health-rec_b_806793.html

[18] Tenner, Edward. Why Things Bite Back: Technology and the Revenge of Unintended Consequences. ISBN 978-0-679-74756-7, 1997

[19] Tim Wafa (2010). "How the Lack of Prescriptive Technical Granularity in HIPAA Has Compromised Patient Privacy". Northern Illinois University Law Review

[20] L. Comini, M. Mazzu, S. Scalvini, "Security aspects in electronic personal health record: data access and preservation", Fondazione Salvatore Maugeri IRCCS, Servizio Autonomo di Telemedicina, Lumezzane (BS) Italy

[21] "Defining and Testing EMR Usability", Healthcare Information and Management Systems Society (HIMSS), June 2009

[22] D. Kalra and D. Ingram, pp 21 of 37, "Electronic Health Records", Centre for Health Informatics and Multiprofessional Education, UCL, London, UK

[23] The EHR Synapses project (1996-8)

[24] Richard Hillestad, James Bigelow, Anthony Bower, Federico Girosi, Robin Meili, Richard Scoville, and Roger Taylor "Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings, And Costs: The adoption of interoperable EMR systems could produce efficiency and safety savings of $142-$371 billion", by Health Affairs, pp 1103, Volume 24, Number 5

[25] "Electrification Options for Rural Health Centers", USAID, http://www.poweringhealth.org/Pubs/PNADJ557.pdf, 2010.

[26] "HL7 Version 3 Standard: Study Design", Health Level Seven International, http://www.hl7.org/implement/standards.

[27] "Improving Health Sector Effeciency", OECD Policy Studies, http://ec.europa.eu/health/eu_world/docs/oecd_ict_en.pdf , 2009