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Cloud-Based Open Source Primary Care Electronic Patient Record System for Sri Lankan Citizens

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***Abstract*—Sri Lankans made over 100 million visits to public and private outpatient departments (OPD) during 2015, which is estimated to double in 2027. However, these visits have no records, either paper or electronic.**

***Medical records are essential to provide continuity of care, and computer-based medical records were identified as essential technology in 1990 by the Institute of Medicine. The main initiative of the Ministry of Health addresses either OPD health information system or inward system, but it is limited to a few selected hospitals. There are no electronic health records (EHR) that can track patients as they crisscross between different primary care providers in public and private sectors, which is the normal behaviour of the majority of our patients.**

***This paper gives a snapshot of the current healthcare system in Sri Lanka, notes the existing projects related to primary care health information systems, briefly reviews the current status of the global primary care EHR and describes our solution of a generic, cloud-based, open source EHR for use across public and private sectors focusing on a patient-centred electronic 'personal health record'.**

***We opted to modify a time-tested software solution OpenEMR – https://www.open-emr.org/. OpenEMR is a free and open source, ONC certified, electronic health records and medical practice management application featuring fully integrated electronic health records, practice management, scheduling, electronic billing, internationalization, and multi-lingual support.**

***Sri Lanka OpenEMR (SLOEMR) is now used at the University Family Medicine Centre, Faculty of Medicine, University of Kelaniya at Ragama. Paper medical records of more than a decade were converted to the electronic format. We are in the planning process of piloting the SLOEMR in the Ragama Medical Officer of Health Area with a population of 70,000, with a single electronic record for each person across all private and public sector healthcare providers.**

Keywords— medical records, electronic medical records, electronic health records, personal health records, cloud-based patient records, open source, biomedical informatics, Sri Lanka, primary health care.

I. INTRODUCTION

Sri Lankans made over 100 million visits to public and private outpatient departments (OPD) during 2015, which is estimated to double in 2027 [1]. On average each citizen goes to a doctor five times a year. But no records, either paper-based or electronic, are maintained. The traditional health care record, the 'Exercise Book', is the only medical record carried by some of our patients in which their health problems and the treatments are recorded.

Comprehensive medical records are essential to provide continuity of quality care in primary care and computer-based medical records were identified as essential technology in 1990 by the Institute of Medicine [2],[3]. In 2002, Mendis & Purves defined the functionalities of a basic medical record for Sri Lankan primary care[4].

This paper gives a snapshot of the current healthcare system in Sri Lanka, reviews existing projects related to primary care health information systems, and the current status of primary care EHR globally, and discusses a solution of a generic, primary care, cloud-based Open Source EHR for use in Sri Lanka.

II. SRI LANKAN HEALTHCARE SYSTEM

Sri Lanka is a low middle income country with a population of 21.2 million and a life expectancy of 74.5 years at birth [5]. With less than 3.2% GDP investment on health, Sri Lanka provides free healthcare in public hospitals; this includes more than 90% inpatient care and about 50% of outpatient care, the rest being provided by the private sector [1]. Despite the limited funding, the health indices of Sri Lanka are similar to those of more developed countries in the region such as Thailand and Malaysia [6]. The success of the Sri Lankan healthcare system has been attributed to the policy focus on primary health care, especially maternal and child care

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through a multi-layered structure with adequate provision of basic services at community level [7].

The five-year plan for health from 2019 - 2014 envisages Primary Medical Care Units (PMCU) for a defined population of 5-10,000 [8]. Unlike in the UK where they have a single gate-keeper – GP for a group of 3500 to 5000 people, the SL system will be similar to the Australian model, where patients are not restricted to one primary care provider and can access any public or private health care provider, even on a single day.

To strengthen primary care systems that have reliable and valid data about primary care demographics, morbidity, medication and health care seeking behaviour are needed to provide quality 'patient and family centred care' to a defined population across public-private and preventive-curative domains in an accountable manner.

Current and reliable data are necessary in planning and implementing curriculum reforms focusing on strengthening primary care skills in medical, nursing and allied health care training programmes as well as postgraduate training programmes. The coordination between primary care and hospital care will immensely improve as reliable data regarding patients will be available at referral.

One of the key factors under discussion is having a unique ID for each Sri Lankan citizen. Sri Lankans above the age of 16 years have a national identity card; there is a government initiative to issue a national level health identification number to every new born infant starting with the BCG and Hepatitis B immunizations. A unique National Health ID was introduced in 2015. It is reported that a new National eHealth Card has been introduced in some hospitals.

III. Current initiatives of electronic health records in Sri Lanka

There have been several initiatives from both the state and private sectors in implementing EHR in government and private hospitals in Sri Lanka. To facilitate inter-operability between such systems, the National eHealth Guidelines and Standards [9] and the National Policy on Health Information [10] have been published. In state sector hospitals the Hospital Health Information Management System (HHIMS) and Hospital Information Management System (HIMS) dominate the landscape.

HHIMS [11], an open-source medical record software developed for the out-patient clinic (primary care) and inward encounter management in state hospitals, aimed at replacing paper records. The system is currently implemented and managed by the Information Communication and Technology Agency (ICTA). The system implements a paperless workflow through patient registration, doctor's notes, laboratory tests and their results and prescriptions. It provides a single screen overview of all past clinical details of the patient in subsequent encounters.

HIMS developed by the National Cancer Institute and owned by the Ministry of Health, is a comprehensive electronic system to support functions carried out in state hospitals. Project management and technical support is given by a group of medical officers trained in health informatics. The aim of the system is to provide fully integrated care to the public by generating life-long clinical information in a longitudinal electronic health record system in a cost-effective manner. It is integrated with the electronic morbidity and mortality reporting system for automatic data transfer for health planning.

A cost benefit analysis [12] comparing two Type-A divisional hospitals with and without EHRs in 2015 found a saving of approximately Rs 5.5 million a year in the EMR implemented hospital. However, the study lacked implementation costs and net present value considerations in the costs of EHR to justify future investment in EHR.

IV. Current world overview of Electronic Patient Record and lessons learnt

Traditionally, the medical record was a record of care provided when a patient was ill. The current health care delivery system encourages providers to focus on the continuum of health-care from wellness to illness and recovery. The patient record should contain all health-related information of a person from all sources over their lifetime.

The 'Computer-Based Patient Record', the popular name in the early 1990's changed to 'Electronic Medical Record'(EMR) which was restricted only to the medical information of a patient; subsequently, it changed to 'Electronic Health Record' (EHR) which includes all health related information in addition to medical information [13]. EHR is a repository of electronically maintained information about an individual's health and health-care received, stored in such a way that it has many uses and can serve many users of the record. EHRs include information management tools to provide clinical reminders and alerts, linkages with knowledge sources for health care decision support, and analysis of aggregate data both for care management and for research. [14]

Personal Health Record systems (PHR) support patient-centred healthcare by making medical records and other relevant information accessible to patients, thus assisting patients in health self-management [15]-[16]. As primary care physicians play a key role in patient health, PHRs are likely to be linked to physicians electronic medical record systems, PHR adoption is dependent on growth in electronic medical record adoption. However, many PHR systems are still physician-oriented, and do not include patient-oriented functionalities. These must be provided to support self-

management and disease prevention if improvements in health outcomes are to be expected.

A. Cloud-based EHR

The cloud-based EHR (cb-EHR) is one of the emerging standards for patient health records. It is a form of patient-carried medical record system that is best suited for a population that does not have a single-entry point/gate-keeper, single provider for continuity care or single point in preventive or curative care such as in Sri Lanka Ref [17] [18] [19].

We used cloud computing for implementation of cb-EMR for stability and the ability to expand. As the whole system is not hosted in just one server but in many servers around the world, the system is stable and overcomes the risk of failure due to its duplication in multiple locations. This also provides the ability to create snapshots as we do any changes and store them, to be swiftly restored, if needed. The ability to create snapshots and automatic backups gives the system a solid foundation for reliability with a lower risk of failure.

Cloud computing using leading providers permit expansion of resources with minimum downtime. This is crucial as cb-EHR grows, we can expand its resources as needed, thus eliminating the need for doing any physical server upgrading.

These features give our EHR approach stability which cannot be achieved with either shared hosting or even hosting the site locally.

B. Interoperability

Five use cases of open or inter-operable health records (EHRs) have been identified [20]. Each of these use cases represents an important functionality that should be available to clinicians, researchers, administrators, software developers, and patients so that personal health information of any person can be accessed at any place patients receive health-care. Widespread access to “open EHRs” that can accommodate at least 5 use cases is important if we are to realize the enormous potential of EHR-enabled health care systems.

Comparing the use of health information technologies in seven countries in 2008 Jha et al. concluded that the UK, Netherlands, Australia, and NZ had nearly universal (>90%) use of EHRs among general practitioners [21]. The U.S. and Canada had less than 10–30% of family doctors using EHR. They concluded that high quality data for hospital settings were lacking in the countries studied and that only a small fraction of hospitals (<10%) in any single country had the key components of an EHR. Health information exchange efforts were a high priority in all seven nations, but with varying degrees of active clinical data exchange.

C. EHR Expenditure and outcomes from UK, USA & Australia

We studied the outcomes of probably the largest ever health information system project in the world – the £12.7 billion National Programme for Information Technology (NPfIT)" [22]. The UK government chose a top-down, government-driven approach: " a nationwide implementation of EHRs, known as the NHS Care Records Service that commenced in early 2002, and it was one of the largest and most ambitious health IT projects globally. The NPfIT attempted to create a national EHR system for the entire UK that would eliminate the challenges of interoperability between various competitive EHR systems around the UK." "Launched in 2002 and officially dismantled in 2011, NPfIT included the first sustained national attempt to introduce a centrally-procured EHR system across the NHS's hospitals, including mental health settings."

In 2009, as a part of the Health Information Technology for Economic and Clinical Health (HITECH) Act, the federal government set aside $27 billion for an incentive program that encourages hospitals and providers to adopt EHR [23] [24]. EHRs can slash drug-drug interaction rates, decrease mortality rates among the chronically ill, cut nurse staffing needs, and lower costs. A meta-analysis of HIT-implementation studies found that 92 percent of published reports to date had predominantly positive results [25]. Yet the adoption of HIT in the United States has been slow. Only about 10 percent of physicians use what might accurately be described as a fully functioning electronic medical record system, while slightly more than 50 percent have at least partial EHR systems in place. By contrast, 90 percent of doctors in the Netherlands, the United Kingdom and New Zealand use EHRs [21].

Australia’s approach to the provision of a personal digital health record for all citizens is the “My Health Record” system [26] which was passed by Australian Parliament as the My Health Records Amendment (Strengthening Privacy) Bill 2018. This secure online summary care record allows individuals to access their own health information, control its content and control who is able to view it with a range of privacy and access controls. The information in the “My Health Record” system flows from connected and conformant clinical information systems in hospitals, general practices, pharmacies, specialists’ rooms, and pathology and radiology providers. It can be securely shared between these providers depending upon the privacy settings of the individual My Health Record recipient. Countries with similar national PHRs include, for example, Austria and Sweden [27].

D. Electronic health records for low resource settings

Published literature of low resource settings were mostly evaluations or lessons learned from African countries, published from 1999 to 2013. Almost half of the EMR systems served a specific disease area like Human Immunodeficiency Virus (HIV). The majority of criteria that

were reported dealt with the functionality, followed by organizational issues, and technical infrastructures. Sufficient training and skilled personnel were mentioned in roughly 10%. Political, ethical, and financial considerations did not play a predominant role. More evaluations based on reliable frameworks are needed.
Highly reliable data handling methods, human resources and effective project management, as well as technical architecture and infrastructure are all key factors for successful EHR implementation.

Implementing an EHR is not cheap. Real-world comparisons of the cost-effectiveness among the economically developed countries show that the availability of huge amounts of funding will not necessarily bring about a gold standard EHR. Cost is frequently cited as the main obstacle to broader adoption of such systems, but it is not necessarily the cost of an EHR system itself that pauses many physicians. Instead, the more significant cost involved may be lost revenue incurred during the months of preparation, planning, training, and workflow redesign that typically come with switching to an EHR.

V. Cloud-Based Open Source Primary Care Electronic Patient Record System

We designed a system that is currently on a par with the global standard primary care patient health record system considering the context and resources available in Sri Lanka.

Two options were open to us, first to start from scratch or to use an open source software. We opted to modify a time-tested software solution OpenEMR[1], which is a free and open source electronic health record and medical practice management application. OpenEMR is Office of the National Coordinator for Health Information Technology (ONC) certified fully integrated multi-lingual package supporting electronic health records, practice management, scheduling and electronic billing[2]. A systematic review of open source electronic health systems for lower resource settings, taking into account 20 different criteria, listed OpenEMR within the top three choices [28].

A. Functionality of the OpenEHR for Sri Lanka

Sri Lanka is a low to middle income country which is in many ways unique tilting towards the economically developed countries than low income countries. Sri Lanka's primary health care performance is above average, and people have a high illness sensitivity (28), which means that they consult doctors for even trivial reasons; in addition the Sri Lankan clientele change healthcare providers if they do not obtain satisfactory outcomes within a short period of time. Because of the existing free and fee-for-service consultation system with no formal referral system patients frequently change from public hospital OPDs to private practitioners and sometimes end up with government consultants doing private practice after hours.
The average consultation in primary care in Sri Lanka varies from five minutes or less in the government hospital OPDs to ten minutes in private hospital OPDs and general practitioner clinics. The vast majority of doctors in both sectors do not even have paper medical records. What they may keep with them or handover to the patient are 'prescriptions'.

Having considered the Sri Lankan context in 2002, we proposed three modules that are essential for a Sri Lankan EMR – Basic, Clinical Notes and Prescription [4]. Shortliffe proposes five functional components: integrated view of patient data, clinician order entry, clinical decision support, access to knowledge resources, integrated communication and reporting support [14].

B. Security of cb-EHR

As security plays a vital role in the trust of the system, we implemented multiple layers of security for the system. All the interactions with the website was encrypted end to end using HTTPS layer for the added security in the form of two layers; 1. User authentication based and 2. User access based. [30] [31]
The first layer of security through the layer of user authentication has a 2 Factor Authentication (2FA) requiring a second layer of authentication when a user logs into the system. The primary authentication method was the password and the second layer through 2FA was by using another method such as a SMS message to a registered phone number on the account with a one-time passcode.

The second layer of security was access based. One sub layer was added to prevent a DDoS (Dynamic Denial of Service) attack through Cloudflare an accepted form to protect the website and restrict the track if it detects a potential attack. The second sub layer was geo-fencing, to restrict access to the server to only the network in which the EMR is implemented. The geo-fencing layer is an additional restrictive layer when the system needs an extra layer of security. This may be optional for other uses when the portal needs to be accessed outside the network for patients.

C. Modifications to OpenEMR

With all these concepts at hand, we modified OpenEMR for the Sri Lankan community. The modifications were based on the requirements gathered through the use of it in the University Family Medical Clinic, Ragama and private practitioner clinics.
We initially started with the modifications to the patient demographics introducing the Sri Lankan post-codes and common surnames. OpenEMR was designed for a global community, and Sri Lanka has specifics such as town and post-codes. These modifications included support for the national identity card number, driver's license with facilities

[1] https://www.open-emr.org/
[2] https://www.healthit.gov/topic/certification-ehrs/about-onc-health-it-certification

for integrating with 'Patient Health ID' when it is available. We modified the search interface for patient identification to one search box that can search for surname, phone numbers, and date of birth.

Since prescriptions were the main document that doctors used in almost 80% of the visits, we focused on the prescription interface. We studied the doctor's requests and modified to make available prescribing multiple medications in one page.
At the same time, we added another requirement to make available all the medications, either according to generic or brand names. We used the drug list from National Medicines Regulatory Authority (NMRA) as it is the accepted list of all the drugs which can be legally sold through vendors. As there is no openly available dataset for this, we had to scrape the entire website using "Beautiful Soup" python library. This primary list was used as the medication list for the system, and it is updated as NMRA updates their database on the website.
The next stages of modifications were based on the interface for clinical notes by introducing the standard structured clinical notes according to SOAP (subjective, objective, assessment, plan). Furthermore, we included the primary care classification and coding system, International Classification of Primary Care (ICPC) [32]. As OpenEMR was primarily designed for USA the coding/classification systems included by default were ICD-10-CM and SNOMED. These were important changes that made the system usable in a primary care setting where consultations were on average 5-10 minutes.

All these changes were in the form of implemental upgrades to the base version of OpenEMR. These were done on top of their prior existing system preserving the security and privacy of the existing system. The physician facing side of the system has been developed throughout and undergoing changes, at the same time we are implementing the portal for the patients, which is an essential component in that implemented patient-centred personal health records. This would give them the ability to refer to their medical records at their convenience. This will be important when they consult a doctor who does not have an EHR.

D. University Family Medicine Centre

We implemented the SLOpenEMR in the University Family Medical Centre (UFMC) at the Faculty of Medicine, University of Kelaniya. The system is running on DigitalOcean[3] and has the ability to expand as the resources are needed. We have our primary version of the cb-EMR on GitHub repository as the master branch, and it is cloned and implemented onsite as there is a requirement for it. This enables us to remotely push updates to the system and to maintain the open source nature of the project.

UFMC has been functioning as a teaching centre since 1997 and had maintained paper-based medical records from the onset. In 2018 November, we started by creating a new electronic record with the available demographic details for each paper-record owner. Once this was completed, we stopped paper registrations and started a new electronic record for all new patients.
Subsequently, we started to complete the essential items of the EMR, Medical Problems, Medications and Allergies. Currently we are implementing printing of prescriptions, clinical notes and vital signs.

We have more than 1500 patients on the system and will soon proceed to the next stage where we will extend the SLOPENEMR to the OPD of the Colombo North Teaching Hospital, Ragama and selected 10-15 private general practitioners within 5 km from the Ragama town centre.
Our pilot study will be in the Ragama Health Area with a population of 70,000 people. A grant application has been submitted to the World Bank under the PSSP innovative projects category and the latest information we have is that it has been shortlisted.

We started building on top of a gold standard for medical record systems and modifying it for Sri Lanka. This has potential to be used nationwide as a system at outpatient departments of all hospitals and by general practitioners / family doctors.

[3] https://www.digitalocean.com/

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