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Technical Paper

Continuity of care in Ghana: the promise of smart-med

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Abstract

Individuals tend to receive medical care from different health care providers as they drift from one location to another. Oftentimes, multiple providers operate disparate systems of managing patients' medical records. These disparate systems, which are unable to share and/or exchange information, have the propensity to create fragmentation of care, which poses a serious threat to the realization of continuity of care in the Ghanaian health care delivery. Continuity of care, which is the ability to seamlessly access, update, and manage patients' medical information as they visit multiple providers, is a crucial component of quality of care in any health delivery system. The current system of managing patients' records in Ghana—paper-based—makes continuity of care difficult to actualize. To this end, we have developed a smartcard based personal health records system, SMART-MED, which can effectively promote continuity of care in Ghana. SMART-MED is platform-independent; it can run as standalone or configured to plug into any Java-based electronic medical record system. Results of a lab simulation test suggest that it can effectively promote continuity of care through improved data security, support interoperability for disparate systems, and seamless access and update of patients' health records.

Keywords: *Continuity of Care, Fragmentation of Care, Interoperability, Personal Health Records, Smartcard.*

1. Introduction

One of the most important attributes of a good health care delivery system is the ability to seamlessly manage patients' medical information such that it can be readily and securely accessible, reusable, updatable, and devoid of redundancies. Such an attribute is the epitome of the notion of continuity of care. The concept of continuity in healthcare is quite complex, and there is no definite consensus on its definition [1-3]. Terms such as coordination of care, case management, continuum of care, integration of service, and seamless care have been used interchangeably in the literature to refer to continuity [1], [3]. However, continuity can generally be referred to as "the degree to which a series of discrete healthcare events is experienced as coherent, connected, and consistent with patient's medical needs and personal context [1]." This definition encapsulates two main core elements of continuity: care for the individual patient and care delivered over time. In other words, continuity is the coordination and integration of care services for individual patients managed consistently over time. Consequently, three main types of continuity can be identified: informational, management, and relational continuity [1]. Informational continuity refers to the utilization of past events and current patient circumstances to make appropriate care decisions; management continuity refers to responding to changing patients' conditions and needs in a coherent and consistent fashion; and relational continuity refers to the harmonization of care as the patient receives therapy from multiple providers [1].
Continuity is an essential attribute of every efficient health care delivery system. Its effects and merits as regards quality of care delivery and patient outcomes have well been document in literature [3-5]. In addition, an improved population health outcome is a sign of a strong primary care system within a country [6]. For continuity to thrive, an efficient system of managing and coordinating patients' medical records must be in place.
A medical record consists of a patient's medical history, including past and current health status and treatment plans for future health care [7]. It can contain information from a patient's identity to health insurance plans. An ideal medical record is one that contains the entire medical history of a patient—that is, from birth to present. Medical records have become a crucial ingredient of every health care delivery system. For instance, the data contained in a medical record

can serve as benchmarks to help categorize patient's conditions, and it helps physicians to make informed decisions during a differential diagnosis process. However, inefficient management of medical records can encumber the realization of continuity. For instance, as a patient visits one hospital from another to receive care each hospital keeps a snippet of her medical history, which leads to the notion of fragmentation of care.

Patients are most likely to consult and receive care from multiple providers, particularly when they drift from one location to another. Multiple providers might have disparate systems of keeping medical records leading to potential fragmentation of care. Fragmentation of care poses a serious threat to the tenets of continuity. The degree of this challenge can be enormous where medical records keeping are paper-based as in most low resourced countries like Ghana (Figure 1.1). We highlight below, some notable challenges that the current paper-based systems pose to the realization of continuity of care in Ghana.

First, providers keep the medical records, which is often in a paper folder or booklet, of their clients (i.e., patients). When a patient visits a hospital for the first time (or in an event of a missing folder), a new folder is issued for her. This can generate a lot of redundant information when a patient receives care from multiple providers (e.g., all folders could contain the same demographic information for the patient). It could also cause the fragmentation of care (e.g., different folders could contain different fragments of a patient's medical history). Second, there are no clear mechanisms for clinicians and multiple providers to share and/or integrate medical records (i.e., patient records have become silos, incoherent, and inconsistent). Third, the inability of clinicians to readily access patients' medical history during emergency care can be very frustrating and can immensely compromise continuity of care. For example, paramedics have to make swift medical decisions on treatment plans for an accident victim who is unconscious, cannot speak and means to contact family and/or friends are not readily available. Without any information on the victim's medical history, care delivery becomes very arduous. Fourth, accessibility of vital information, which has been stacked in these records, can sometimes be a nightmare (see Fig 1.1 and Fig 1.2). Last, hospitals cannot guarantee the safety and privacy of the medical records. Folders can be misplaced, stolen, catch fire, or consumed by floods.

Fig. 1.1: A Typical Medical Records Shelf in Ghana. Express Permission From MHC Ghana [8]

Fig. 1.2: Medical Staff Busily Searching for Information From a Stack of Records

Though a few hospitals have migrated to electronic medical records (EMR) systems, some of the challenges, which stand in the way of continuity, persist. For instance, the EMRs are not interoperable and therefore the problem of data silos and fragmentation of care continue. There is therefore the need for the Ghana Health Services (GHS) to consider alternative systems of managing patients' medical information that can promote continuity effectively. To this end, we propose SMART-MED, a portable smartcard based personal health records system, which is flexible, interoperable, eliminates redundancies, is relatively cheap, and highly secured.

A smartcard is a bankcard sized plastic device with an embedded integrated circuit chip [9-11]. The chip enables secure data storage, access, and exchange through dedicated readers. Smartcard systems can provide complex security schemes, such as authentication and encryption, making them ideally suitable for privacy protection and for handling sensitive information such as medical data [9], [12], [13]. Smartcard usage has become ubiquitous for various applications worldwide. For instance, they can be found in identity applications (e.g., employee ID badges, driver's licenses), telecommunications applications (e.g., pay phone payment cards), payment applications (e.g., debit cards, power metering), just to mention a few. In Ghana, they have been used successfully for prepaid electricity metering and billing.

The use of smartcard technology in the health care industry is not new [12-14]. Several projects in Europe, Asia, and some parts of eastern Africa have demonstrated its viability as an essential commodity within the health care delivery chain. Some of these projects are carte vitale in France, social system identity in Belgium, Medicare Smartcard in Australia, Gesundheitskarte in Germany, SmartCare in Zambia, and the National Health Insurance Card in Taiwan [9].

Ghana has not explored the use of smartcards in any segment of her healthcare delivery chain. We believe that a smartcard driven medical records system holds a lot of promise to alleviate most of the challenges, which are stifling the realization of continuity of care in Ghana. First, the memory chip on a smartcard can be used to store personal medical records; a chip equipped with 128 Kbytes of memory can store more than 120 pages of medical data [9-11].

Second, a patient's medical records can be summarized into an Extensible Markup Language (XML) file format and stored on the card; XML file formats are amenable to data standards, like HL7 [15], and also suitable for information exchange between disparate systems. Third, smartcards are flexible; authorized providers can readily update patients' medical information onto it. Thus, updated information would always be available to every approved provider a patient visits; redundancy and fragmentation of care due to visits to multiple providers will be eradicated. Fourth, up-to-date patient information can facilitate an authentic information sharing and/or exchange between multiple providers. Fifth, smartcards are secure; the embedded microchip can encrypt and securely store personal information, which a miscreant will find difficult if not impossible to tamper with. Meanwhile, access to the card can be controlled such that only authorized persons can access particular information. For instance, for most emergency care cases clinicians might only need information on prescription history, allergies, or blood types. Last, the use of smartcards could boost operational efficiencies in the care delivery chain, reduce costs, and promote patients' confidence and satisfaction.

Since the smartcard technology is not new, the relevant hardware requirements are smartcards and readers, which can be purchased, personalized, and adapted for specific needs within the healthcare delivery chain in Ghana. The main challenge is to develop an application interface that would manage information flow between the hardware on one hand and hospital information systems on the other. Although a couple of related applications have been developed elsewhere [9], we cannot blindly import them for use in the Ghanaian market. This is because most of them are proprietary, expensive, difficult to customize and adapt for the local market, and/or developed for a different environment and context. It is therefore essential to develop a new application that is cost-effective, easily amenable to changes, and meets specific needs of health information management within the Ghanaian health sector. To that end, we developed a Java application interface for SMART-MED. It is platform independent, can be run as standalone or configured to seamlessly plug in to any Java based EMR, and its data model is based on a simple XML format to support interoperability (i.e., the ability of two health organizations or information systems to share information and be able to interpret them). We conducted a lab simulation test of the application and the results were encouraging.

We structure the remainder of this article as follows: In Section 2, we describe the functional requirements, use cases, information flow models as well as the structure for our proposed portable personal health record data model. We present results of our implemented system and describe how it works in Section 3. In Section 4, we discuss our perspective of SMART-MED and its potential for promoting continuity of care in Ghana. We also highlight some limitations of SMART-MED and avenues for future work. We give our conclusion in Section 5.

2. Methods

2.1. Requirements

We applied the agile software development method [16] to build a rapid prototype for SMART-MED. This prototype was founded on a software requirement specification, which was highly guided by the purpose of the project—demonstrating the viability of a portable smartcard based personal health records system to address challenges that impede the realization of continuity of care in Ghana. Below, we present a high-level description of the system's requirements.

2.1.1. Flexible data management

In order for the system to be compliant with the notion of continuity of care, it is critically important to design the data model to be flexible enough to accommodate nuances in disparate health information systems. That is, the data structure for medical records must have an open and generic architecture to ease reading, writing, and updating of patients' healthcare information by authorized providers, whose information systems might not necessarily have the same data structure. This requirement is critically important so that, for instance, multiple providers can seamlessly access or update patients' diagnosis and prescription information while they provide care. This will ensure that the card always contains an authentic snapshot of a patient's medical history. In addition, this requirement will immensely improve efficiency and drastically reduce, if not eradicate, redundancies and errors that so often crop up while a patient seeks medical care from multiple providers.

2.1.2. Access control

The system must control who accesses stored information on the card. By navigating the health care delivery chain, a patient will most likely encounter different medical personnel e.g., doctors, nurses, pharmacists, lab technicians, health insurance officials, and paramedics each playing different roles in the delivery chain. To protect the privacy of patients, it is necessary to protect the patient's health information so that only authorized medical staff and hospitals can access all or certain portions of the information. For instance, access must be controlled such that a physician can view all of a patient's medical history but emergency care or health insurance authorities might have access to just a limited, but relevant information. To this end, the application must be able to enforce rules to control and restrict access to information stored on the card.

2.1.3. Data privacy and security

Personal health information is very sensitive and the systems must ensure its protection and privacy with an utmost level of security. To ensure that the information stored and retrieved from the card are accurate and tamper-proof, the application must have in place a form of multi-factor authentication system. First, when a patient presents a card at the hospital the system must authenticate her as the true owner of the card. Second, the system must check that a legitimate organization issued the card. Third, that a miscreant has not fraudulently altered data on the card. Last, to ensure that information flow across the care delivery chain is authentic the application must encrypt data read from or written to the card.

2.1.4. Amenability to data standards and interoperability

As patients drift from one care provider to another, information sharing among multiple providers will be inevitable. To facilitate secured and easy information exchange, providers usually rely on agreed data sharing standards. According to the International Organization for Standards (ISO), "standards are documented agreements containing technical specification or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes, and services are fit for their purpose [17]." For instance, the HL7 consortium, a standards organization accredited by the American National Standards Institute (ANSI), has provided a framework for facilitating data exchange, integration, sharing, and retrieval of medical information among disparate information systems. As more hospitals in Ghana role out EMR systems, we envisage that medical data sharing and exchange among hospitals to facilitate efficiency and effective care delivery will become routine. To this end, SMART-MED must be amenable to medical data standards, such as HL7, to ease information sharing and exchange among providers.

To address the challenges of medical data silos and fragmentation of care, a requirement of portability and mobility support is essential for our proposed system. Our system already embodies this requirement because we adopted the smartcard as a device and a vehicle to respectively store and convey medical data as patients drift from one provider to another. A smartcard is portable. A patient can easily keep it in a wallet, pocket, or purse as she visits a care provider of her choice. Using the requirements described above as basis, we provide below next two sections models for data storage and information flow.

2.2. Data model

```
<? xml version='1.0' encoding='UTF-8'?>
<smart-med>
<Patient-information>
<national-ID>GHS12568</national-ID>
<first-name>Eunice</first-name>
<surname>Doe</surname>
<dob>01/06/1980</dob>
<gender>Female</gender>
</patient-information>
<health-insurance>
   <type> NHIS:District-wide Mutual Health</type>
</health-insurance>
<medical-history>
        <record id="015668338">
           <date>10/06/2013</date>
           <provider>Korle Bu Teaching Hospital</provider>
           <vitals>BP:120/90; Height:5.9; Weight:65;BPM:70</vitals>
           <chief-complaints>
                 Urinary frequency and dysuria for past 6 days, fever…
           </chief-complaints>
           <labs>Urinalysis</labs>
           <diagnosis>UTI</diagnosis>
           <prescriptions>Amoxicillin, Dispense:28tab</prescriptions>
           <notes>scheduled for review in 3 weeks</notes>
           <officer>Dr. Kwame Parker</officer>
        </record>
</medical-history>
</smart-med>
```

Fig. 2.2: A Snippet of XML Formatted Medical Records Structure for the Health Passport

To meet the requirements for interoperability, data standards, and flexibility, we used an XML file format to store patients' medical records. XML files are lightweight and can therefore store several thousand pages of medical data in a form of text. In addition, they are generally machine-readable and humans can easily interpret them as well. Our XML based data model can straightforwardly extend to share and exchange medical data through HL7. Currently, the storage capacity of a smartcard is inadequate to store medical data in the form of images and multimedia. However, metadata about such files can be stored on the XML file for processing. For example, metadata could be encoded for descriptions about an X-ray image file, key findings, its storage location, and the name of the radiologist who processed it.
Guided by the GHS patient's records template and the National Health Insurance Scheme (NHIS) clients' data format, we partitioned the data model into three main components. The first component delineates a patient's demographic information, which includes, inter alia, patient name, date of birth, gender, marital status, religion, address, telephone number, and emergency contact details. The second part entails health insurance details, which also includes type of insurance scheme, insurance number, date insured, date of expiry, and details of coverage. The last section consists of a patients' medical history. In Fig. 2.2, we show a snippet of the XML based data model. Authorized administrators at a GHS approved hospital set the demographic information while NHIS (or a health insurance company of patients choice) officials designated at a hospital provide the insurance details respectively. The medical records section is updated whenever a patient receives medical care at a GHS approved hospital. Some of the essential records of this section are date of visit, name of provider, vitals (i.e., pulse rate, weight, height, BP), chief complaints by patients, signs and symptoms, diagnosis, treatments, labs, general notes by physician, and name of medical officer who attended to patient.

2.3. Architecture and information flow model

The system architecture comprises four main components; the SMART-MED application, a smartcard reader, the smartcard based health passport and GHS/NHIS information systems and/or databases. Figures 2.3a and 2.3b depict the general architecture and sequence model for information flow, respectively. In collaboration with GHS, the NHIS issues its members with our proposed smartcard based health passport. The card bearer presents the card while she receives medical care from a GHS and NHIS approved care provider. Among other functions, such as authentication of card, the SMART-MED application also serves as an intermediary between the card reader and GHIS/NHIS information systems. After receiving care, SMART-MED updates the patient's medical records and stores an XML formatted copy on the card's memory chip. Subsequently, the application commits treatments information to the NHIS database by either internet access or private server at the hospital with NHIS accreditation. We expound details of information flow according to the sequence diagram in Figure 2.3b.

2.3.1. User and card authentication

To uphold accountability of system usage, the application keeps a user log file. Every user (i.e., medical staff) is therefore required to have secured access pass, which the system authenticates upon every login. To check the fidelity of a card, a multi factor authentication process is required between SMART-MED and the card—through the reader—on one hand and between SMART-MED and the hospital/NHIS information system on the other. Here, the authentication process involves comparing objects stored on the smart card and SMART-MED. The smartcard vendor provides the objects, also known as security keys, to GHS and/or NHIS. When a medical staff inserts the card into a reader, the application checks and verifies a match for the security keys before granting access to the card.

2.3.2. Data Encryption and decryption process

The application encrypts information stored on the card as well as dataflow across the various components of the system. To make meaningful use of data stored on the XML file, an application will first have to decrypt the data before processing it for usage. In addition, the SMART-MED application encrypts data before sending to relevant hospital or NHIS information systems. Subsequently, the hospital or NHIS information systems decrypt the data they receive through specially arranged encryption keys among the stakeholder systems.

2.3.3. Reading from and writing to card

Sandwiched in between authentication and data encryption, are the main functions of SMART-MED—writing to and reading medical data from the card. Only pre-approved medical staff (i.e., designated administrators, physicians, or senior nurses) can modify data stored on the card. Nurses and other junior medical staff have read-only access to information stored on card through the application interface.

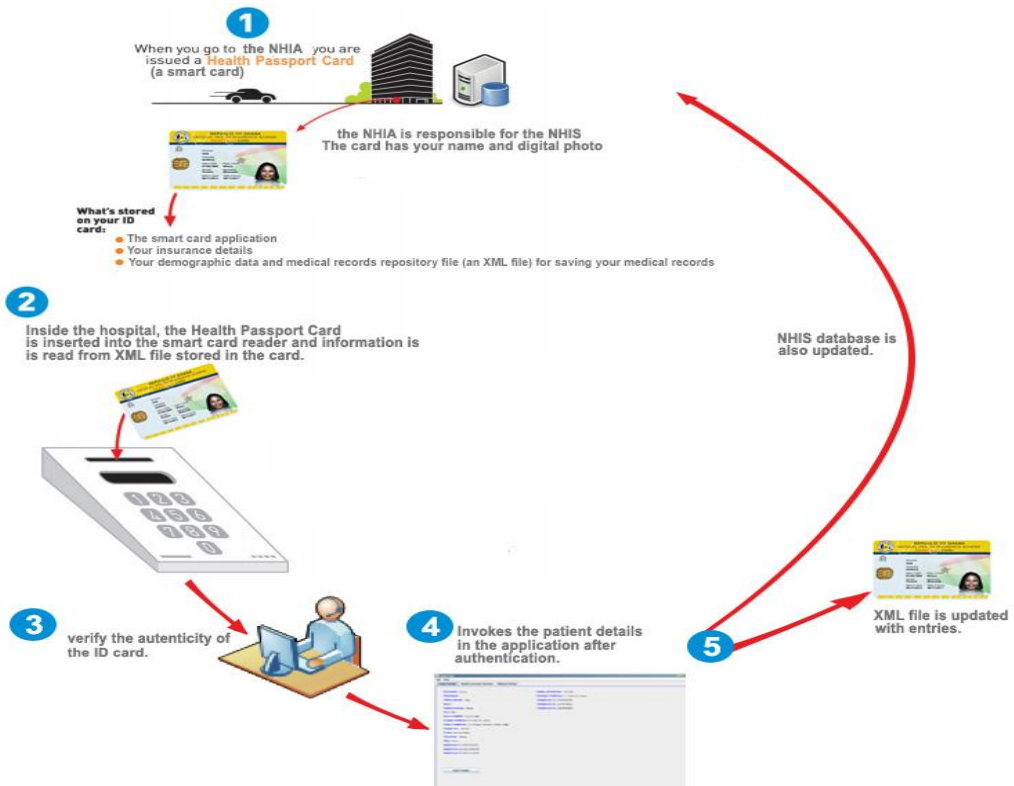

Fig. 2.3: A) an Overview of the Smartcard Based Health Passport for Ghana (SMART-MED). (1) the GHS In Collaboration with the National Health Insurance Authority (NHIA) Issues a Subscriber a Health Passport Card; (2-3) when A Patient Presents the Card at A Hospital It Goes Through Authentication and Other Security Checks; (4-5) and after Treatment, the SMART-MED Application Updates Records on the Card While It Sends Relevant Information To NHIS Information Systems.

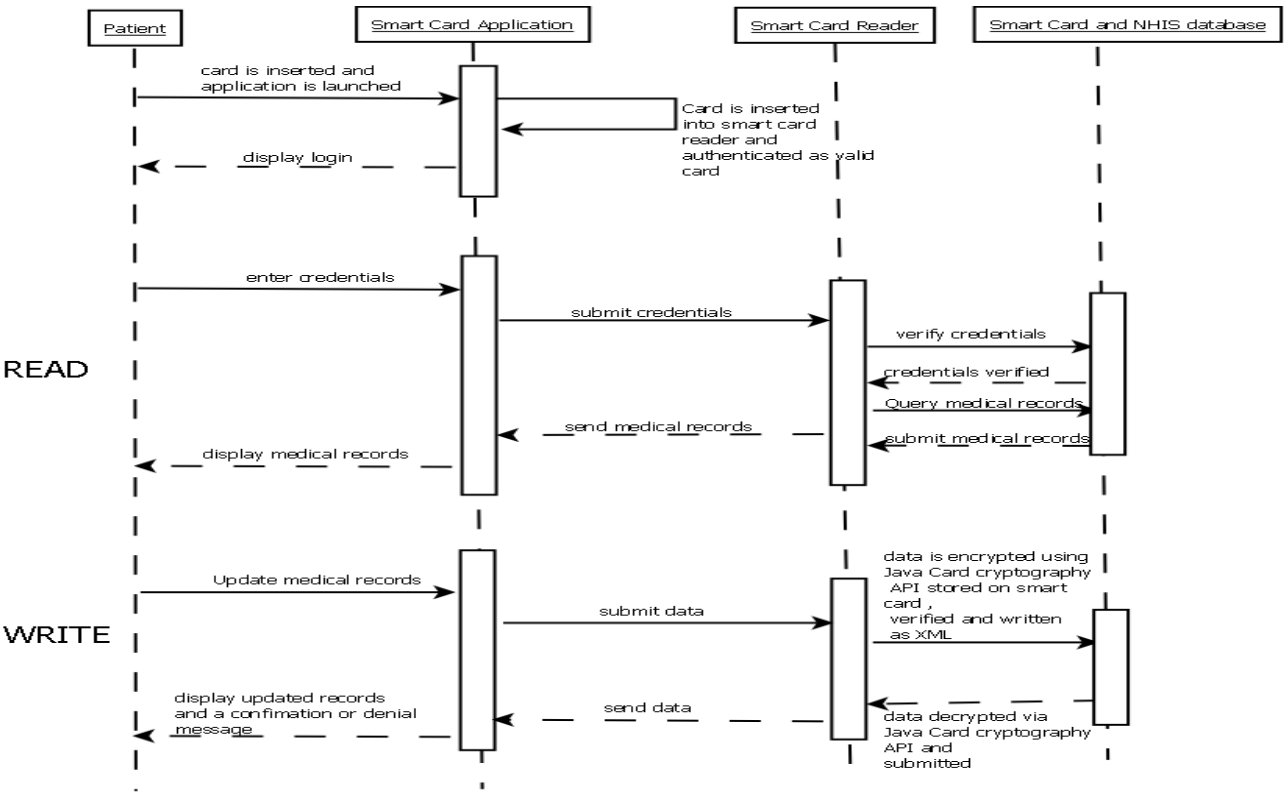

Fig. 2.3: B) A Sequence Model For Information Flow within the Health Passport System

2.4. Lab simulation test

To verify that our system functions according to the specified requirements, we performed lab simulation tests. Since we were constrained by not having access to a real and fully functional EMR and health insurance information system, we focused our testing on security, protection of patient privacy, accuracy, and flexibility of records retrieval and updating. We checked that information written to and read from the XML formatted records were akin to how a clinician would read or update information on a patient's records folder. Since security was paramount to this exercise the tests also included authentication of user log in, encryption, and decryption as the system updates or retrieves medical records respectively.

3. Results

Guided by the requirement specifications, we implemented SMART-MED in Java [18]. The attributes of Java suited, particularly well, the goals of this project. Among others, Java is not platform dependent; it has good features and routines for data security such as encryption; and it has rich graphical user interface components to facilitate relatively easier user interaction with the system. We present, below, some relevant features of SMART-MED and how it works.

3.1. Authentication

SMART-MED manages access control at the authentication level. Upon inserting a valid card into a reader, the system will prompt the user with a login page. In order to access the XML file information, a user must input the right username and password matching combination. If the input matches the login details on the smart card, then permission will be granted; otherwise, the user will be denied access. Moreover, if the user fails to key in the correct username and password after a number of attempts (default is 5), the system will block the card automatically. Only an authorized systems administrator can unblock the card. The system also keeps logs of user logins—date, time, location of login.

3.2. General features

The patient's medical information consists of three main features namely, personal information, health insurance, and medical history.

3.2.1. Personal information

This interface displays basic personal and demographic information of a patient from the XML file. Some of the personal data provided are patient name, date of birth, gender, contact address, telephone number, and occupation (Figure 3.1). Note that most of the demographic data are unlikely to change for a while therefore general clinicians—like doctors and nurses—have read-only access this interface. Here, only a dedicated system administrator can modify patients' data. The demographic data are recorded when a patient first visits a hospital.

3.2.2. Health insurance

The health insurance interface provides information, including history of patients' health insurance. This feature provides up-to-date insurance details of patients. This component of SMART-MED particularly suits information continuity as far as health insurance is concerned. As patients receive care from NHIS-approved providers, managing insurance claims could be much easier. For instance, the NHIS can collate all insurance-covered care within a desired period, say a month or quarter, from a simple query of the card. Like patients' demographics data, only authorized health insurance administrators (like NHIS) can modify information on this interface. Note that, this feature could be extended to include history of how patients, who do not have any form of health insurance coverage, pay for care.

3.2.3. Medical history

This component displays the snapshot of every hospital visit of a patient. It is the flagship of SMART-MED as regards promulgating continuity of care in Ghana. It displays details of a patient's personal medical record as stored on the XML file storage (Figure 3.2). For every SMART-MED compliant hospital a patient receives medical care, the date of visit, chief complaints, signs and symptoms, any medical lab/image test and results, diagnosis, prescribed medications, name of provider, and name of physician or appropriate clinician who handled the case are displayed. As the other two components, access to patient information on this page is limited. For instance, only physicians can update a patient's medical history. All other clinicians have read-only access to medical records. Provision has also been made for authorized clinicians in special care, such as emergency, to update a patient's record in case of emergency care. Meanwhile, whenever medical records are updated, SMART-MED encrypts and saves a log of the update, including date, name of clinician who added the information, and the content of information added.

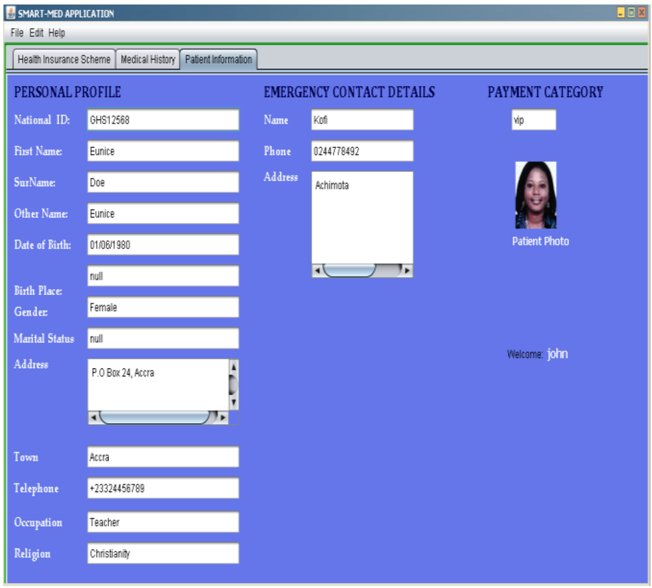

Fig. 3.1: Medical History Screenshot

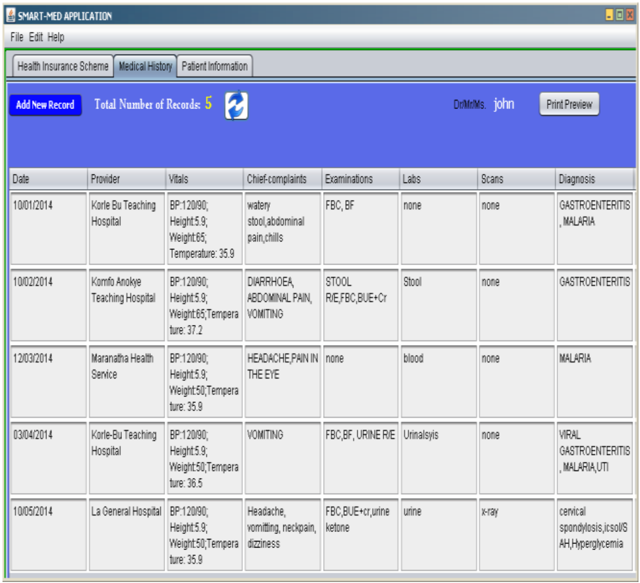

Fig. 3.2: Patient Information Screenshot

3.3. Lab simulation test results

The purpose of the lab simulation test was to ascertain whether SMART-MED could facilitate continuity by ensuring that, at most times, patients' medical records are up-to-date as they receive care from multiple providers. To this end, we tested the system under a simulated environment where different login profiles represented different providers and/or access level of clinicians. We set three actors in our simulated environment, (1) the "Patient", (2) "Clinician_1" as all from "Hospital_1", and (3) "Clinician_2" from "Hospital_2". The assumption here is that, the "Patient" receives medical care from two different providers: "Hospital_1" and "Hospital_2". In addition, "Clinician_1" and "Clinician_2" attend to the "Patient" while at "Hospital_1" and "Hospital_2" respectively. We also assume that the "Patient" visited "Hospital_1" before "Hospital_2".

After a successful authentication and login, "Clinician_1" can view the medical history of a patient (Figure 3.3). At the end of consultation, the clinician can update or add a new record through the "Add New Record" button and enter the relevant information into the required fields. A "save" button can then be clicked if the clinician is satisfied with the information supplied. Following that, a confirmation dialog message pops up requiring confirmation of a new record to be added. The new medical record is encrypted and the XML file is subsequently updated with it. Similarly, as the patient visits "Hospital_2", "Clinicain_2" can view her medical history, including the new record from "Hospital_1", and update the medical records of the "Patient" after attending to her care needs. Note that, the medical records that have been stored on the XML are decrypted before the clinicians can view them.

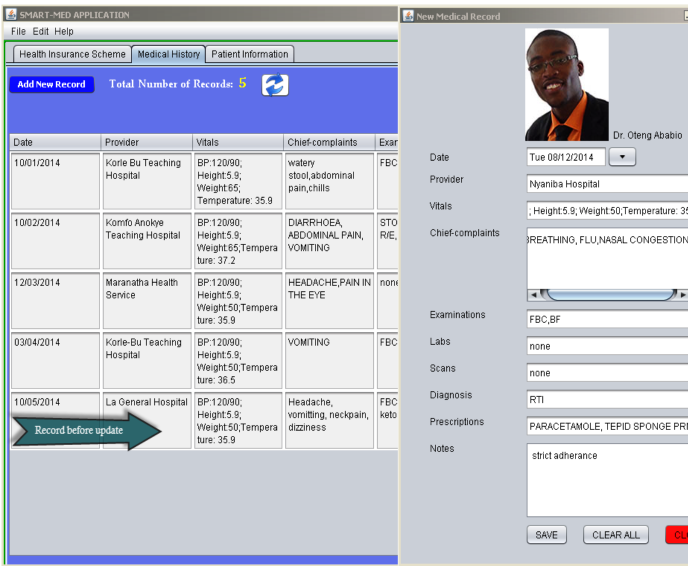

Fig. 3.3: Medical History before Update

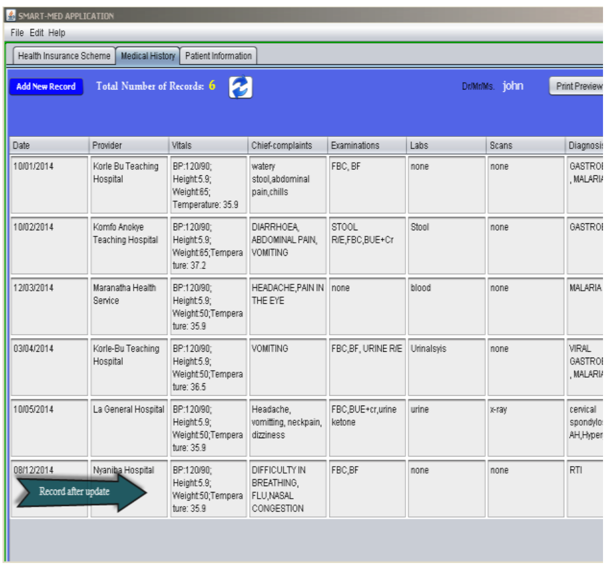

Fig. 3.4: Medical History after Update

In Figure 3.5 and Figure 3.6, we show the state of the XML based personal medical records of the "Patient" before and after receiving care from "Hospital_1" and "Hospital_2". On the file, "Clinician_1" and "Clinician_2" refer to "Dr Abbey" and "Dr Oteng Ababio" (both physicians) respectively, while "Hospital_1" and "Hospital_2" denote "La General Hospital" and "Nyaniba Hospital" respectively. A medical "record" tag in the XML file represents an instance of a hospital visit. As the file illustrates, every hospital visit has been encoded with a unique identification number to aid in information retrieval. In addition, associated with every record (or visit) is the date of visit, name of provider, name of physician, patient's chief complaints, signs and symptoms, lab investigations (if any), diagnosis, prescriptions, and the physician's note (Figure 3.5).
This illustration shows that, with the concept of SMART-MED, a patient can visit and receive medical care from multiple providers, which might run disparate EMR systems. However, her medical history would be intact, up-to-date, and accessible by all providers. This is a clear manifestation of continuity, which is difficult, if not impossible to realize, with the current system of managing patients' medical records in Ghana.

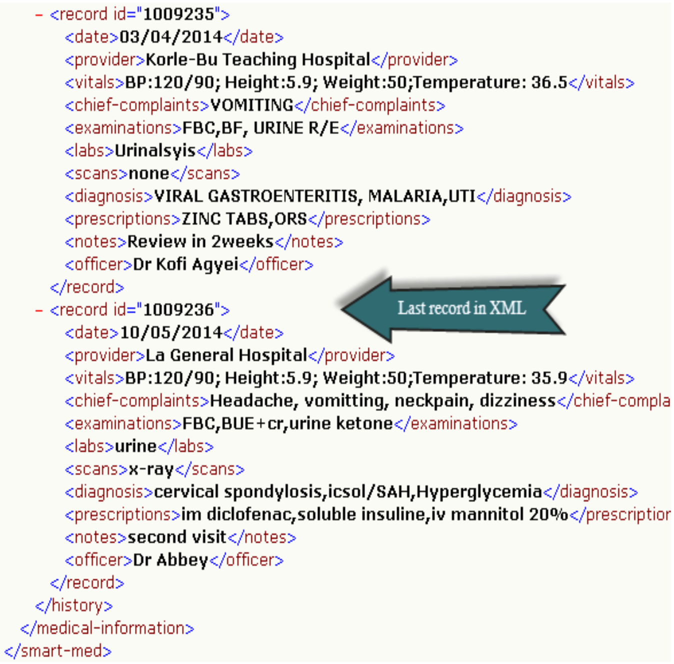

Fig. 3.5: XML Structure before Receiving Care

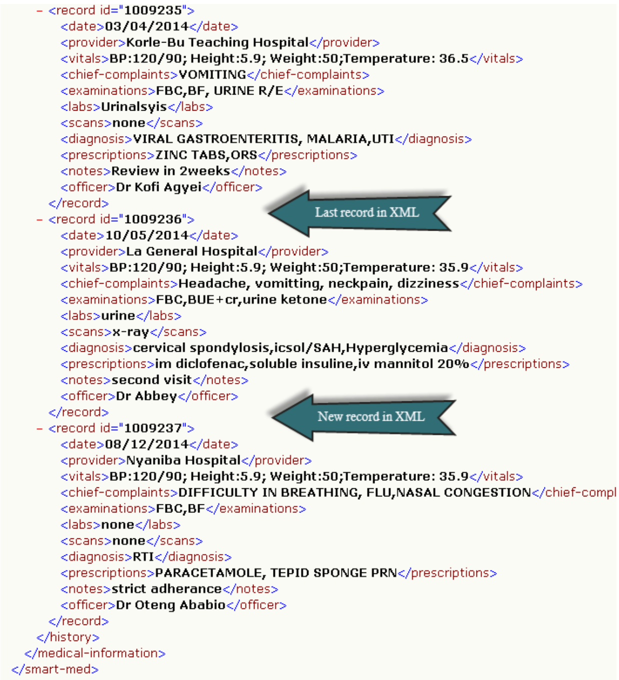

Fig. 3.6: XML Structure after Receiving Care

4. Discussion

In this paper we have demonstrated the potential of a smartcard based personal electronic health records system, SMART-MED, that could address numerous challenges facing the realization of continuity of care in the Ghanaian health care system. Continuity, through SMART-MED could significantly improve the quality of healthcare delivery in Ghana, which could also strengthen the primary care system within the country. In addition, the promulgation of continuity, through the SMART-MED approach, could reduce medical errors, increase patient safety, reduce redundancies in patients' medical records, reduce cost of healthcare, and improve patient satisfaction.
For the notion of continuity to thrive, its information needs must be managed efficiently. The primary information need of continuity is an accurate patient medical record. Ideally, an accurate medical record contains the entire medical history of a patient from birth to present. That is, records of every hospital encounter in a patient's life. The concept of SMART-MED is particularly suited for managing the information needs of continuity. Parents or guardians can keep cards for infants and present them at the hospital at all times. What is more, SMART-MED is well suited for low-tech environments like Ghana, where there is lack of infrastructure for network-based EMR systems particularly in most rural areas—most telecommunication systems are unstable and power supplies are unreliable. A smartcard based EMR, like SMART-MED, can address these challenges. The concept of cloud technology can also be leveraged for SMART-MED so that, periodically, it can store, update, or retrieve content from the cloud or a dedicated file server. In the likely event of a missing card, this feature would be handy for downloading information onto a new card.
It is therefore feasible that the concept of SMART-MED can efficiently address the information needs of continuity since it can create an avenue for the realization of accurate medical records keeping and management. SMART-MED can easily access, update, and save medical data in a secure manner that can totally eradicate fragmentation of care, which has become ubiquitous in the current healthcare delivery system of Ghana [19].

With its potential to eradicate fragmentation of care, SMART-MED can significantly boost the efficiency of managing medical records in Ghana. More than 80 % of care providers operate a paper-based method of managing health records, while the few EMRs are not interoperable [20]. Receiving care from multiple providers is inevitable but it is prone to redundancies in the health records. There is a wide variation of data per patient either because of their medical records or due to their frequent visits at the same hospitals or with different hospitals. It is most likely that clinicians would duplicate information from patients' previous visits. These redundancies are an immense waste of time and resources considering the fact that the health care system in Ghana is under-resourced and efficiency of care delivery is at a premium.

In addition, fragmentation of care and redundant data pose a serious threat to quality of care and patient safety [21]. For instance, a physician, without the benefit of accurate medical history of a patient, is more likely to err in her judgments, which might lead to dire consequences like avoidable patient demise [22]. SMART-MED can easily handle redundancy by providing clinicians with a reliable up-to-date medical history and patient information, which is devoid of redundancies. Thus, SMART-MED might hold the keys to an efficiency and quality of care delivery, which might also improve patient safety and satisfaction.

The realization of continuity would have been much easier if hospital information systems—paper or electronic—were interoperable. A primary hospital might refer a patient to a secondary one for complicated cases. Ideally, the referred hospital must have a copy of the entire medical history of the patient in order to boost the chances of a quality care delivery. If the medical records have been stored on paper, it becomes cumbersome to transport between the hospitals. At best, some physicians might discuss the patient on phone or exchange notes, but it is not efficient. Similarly, the few EMRs that have been implemented in the country are also not interoperable and therefore exchanging patients' medical information can be difficult.

SMART-MED has the capability to resolve interoperability issues. With its XML based data model, which is amenable to HL7, an accepted standard for medical data exchange among disparate information systems, SMART-MED can interface seamlessly across a variety of health information systems. For instance, when a primary hospital refers a patient to a secondary one all that is required according to the SMART-MED concept is her smartcard based health card. The SMART-MED application can easily access and update information on the card in a secured fashion.

Generally, clinicians and patients prefer to maintain a continuing relationship with each other. This continuing relationship can foster continuity, which in turn enhances health outcomes, patient satisfaction, and confidence in the healthcare delivery system. It is very difficult for a patient to maintain a particular physician for a lifetime, particularly in big cities and urban centers, where people are highly mobile. However, continuity through SMART-MED creates the platform for coordinating the care delivery chain such that transitioning from one provider to another is seamless; the card provides up-to-date records of the patient.

Finally, continuity through SMART-MED can meet—if not exceed—all requirements and mandates for patients privacy, safety, system security, and confidentiality. When patients know that their personal medical records are securely stored and more so their physicians can access their medical history with relative ease, their confidence and trust in the medical delivery systems will most likely increase [3].

4.1. Implementation needs and potential challenges

Throughout this paper, we have espoused the promise of SMART-MED and how it can promote continuity of care in the Ghanaian healthcare delivery system. However, its adoption and implementation might face challenges. First, the GHS must address the infrastructural, information technology, and support requirements for the concept. Every patient will have to be issued a card, hospitals will need card readers, and software and/or servers will have to be installed at vantage points of care locations. Nevertheless, as alluded above, majority of these infrastructures have been installed by the NHIS, which through partnership can yield significant cost savings in implementation. Second, for a rollout to be successful, the GHS will have to embark on a massive training of clinicians and educate the public on how the system works. Third, the parliament of Ghana will have to either enact new laws or strengthen existing ones on medical data security, confidentiality, ownership, and fair protocols to facilitate exchange of patient data among providers; some providers might not like the idea of sharing their patients' records with their competitors. Last, the GHS must adopt realistic strategies to manage the transition to SMART-MED and any potential resistance by the public, particularly care providers.

4.2. Limitations and future work

SMART-MED is conceptually sound and technically feasible according to our preliminary results and evaluation. Since we only tested its utility in a simulated environment, we cannot vouch for its robustness in the field. Furthermore, we were unable to test the integration of the system to a fully functional EMR and/or health insurance information system. To assess comprehensively the impact of the system on quality care delivery in Ghana, a field evaluation would be required.

For future work, SMART-MED could be piloted in a hospital to facilitate a full field evaluation study. This pilot study could include the integration of an EMR and health insurance information system. The evaluation study could devise instruments or metrics to measure how the concept influences the workflow of healthcare delivery, quality of care, health economics, patient safety and satisfaction, health outcomes, and human factors and general usability of the application.

5. Conclusion

Continuity of care is highly regarded as a component of quality of healthcare delivery. It influences the processes of care by providing avenues for efficient patient management, which can yield positive health outcomes. In this work, we have presented the potential of SMART-MED, a smartcard based EMR that can promulgate continuity of care in Ghana. Results from a laboratory test suggest that an adoption and successful implementation of SMART-MED can benefit patients, hospitals, healthcare providers, GHS, and health insurance companies on several ways. For instance, it could improve patient identification and authenticity, improve medical records management, improve privacy, security, and confidentiality of medical data, enhance quality of care delivery, and improve patient satisfaction and confidence in the healthcare delivery system of Ghana.

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