Interoperable Medical Record Exchange System among Hospitals in Ethiopia using EMR

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Abstract

In healthcare, interoperability is the ability of health information systems to work together (within and across organizational boundaries) in order to advance the effective delivery of healthcare for individuals and communities. It is the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged.

In Ethiopia we are just beginning to use health information systems to facilitate service delivery. Most of the existing health information systems are developed by different vendors with different data structures. For these systems to work together towards a common goal of achieving continuity of care and quality service to patients, there is a need to exchange patient's medical record among each other in an interoperable way. The objective of this research is to study existing EHR interoperability standards, data exchange technologies and develop a prototype system by choosing what suits best for solving the problem.

To analyze the existing interoperable data exchange problem among hospitals using EMR in Ethiopia two sample EMRs were selected representing public and the private hospitals. One of the systems is SmartCare which is currently used by 12 public hospitals in different regions of the country, and the other is EMR used by Kadisco hospital in Addis Ababa.

We analyzed different EHR interoperability standards in the health care domain and also distributed data exchange technologies were analyzed. Based on the analysis performed on health care interoperability standards HL7's CDA was chosen for implementation and web service as a communication means for the interoperable data exchange.

A prototype system has been designed, implemented and tested. The result of this research showed that it is possible to use health care interoperability standards to solve the currently existing data exchange problems in Ethiopia.

Keywords: Interoperability; Standard; Health Care; Distributed Technology

1. Introduction

Medical record is a chronological written account of a patient's examination and treatment that includes the patient's medical history and complaints, the physician's physical findings, the results of diagnostic tests and procedures, and medications and therapeutic procedures. It is a medical document that allows, among other things, a complete understanding of the patient's health situation over many years, e.g., it is "longitudinal" and is therefore invaluable when making a complicated diagnosis or determining a long-term care plan [1].

Interoperability is defined as the ability of two or more systems or components to exchange information and use the information that has been exchanged. Interoperability depends on two significant components. One is syntactic (functional) interoperability which refers to the structure of a communication and can be thought of as equivalent to grammar rules in spoken languages. The other is semantic interoperability which holds the meaning of a communication, the equivalent of a dictionary. Without semantic interoperability, information may be interchanged but there is no certainty that the receiver can use or understand it [2].

Interoperability requires creation, acceptance and implementation of standards to ensure that data is available and retains its meaning and context through the various processes of clinical care, in any part of the health system.

Health-care standards implement rules that govern the way patient information is electronically stored and interchanged. Ideally, a single set of standards would provide efficient access to text, numeric and image data, allowing information to be shared appropriately by health professionals, administrators and consumers. Healthcare standards currently available address both components of interoperability mentioned above syntactic (functional) interoperability and semantic interoperability [3].

Currently existing health care standards which include Health Level Seven (HL7) [4], openEHR [5], [6] and Integrated Healthcare Enterprise (IHE) [7, 8] are discussed briefly.

1.1 HL7

Health Level Seven International is one of several American National Standards Institute (ANSI) accredited Standards Developing Organizations (SDOs) operating in the healthcare arena. The HL7 Version 2 Messaging Standard is the most widely implemented standard for healthcare information in the world. HL7 V3, like V2.x, is a standard for exchanging messages among information systems that implement healthcare applications. However, V3 strives to improve the V2 process and its outcomes. The development principles behind HL7 V3 led to a more robust, fully specified standard. The HL7 Clinical Document Architecture (CDA) is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange.

A CDA can contain any type of clinical content. Typical CDA documents would be a Discharge Summary, Imaging Report, Admission & Physical, and Pathology Report and so on. CDA uses XML, although it allows for a non-XML body (pdf, Word, jpg and so on) for simple implementations.

The goals of the CDA are:

- Give priority to delivery of patient care.
- Allow cost effective implementation across as wide a spectrum of systems as possible.
- Support exchange of human-readable documents and enable a wide range of post-exchange processing applications.
- Promote longevity of all information encoded according to this architecture.
- Be compatible with a wide range of document creation applications.
- Promote exchange that is independent of the underlying transfer or storage mechanism.
- Enable policy-makers to control their own information requirements without extension to this specification.

In V3, CDA documents can be exchanged in any message that can exchange documents (such as the HL7 V3 Medical Records messages).

A conformant CDA document is one that at a minimum validates against the CDA Schema, and that restricts its use of coded vocabulary to values allowable within the specified vocabulary domains.

1.2 OpenEHR

OpenEHR is a virtual community working on interoperability and computability in e-health. Its main focus is electronic patient records (EHRs) and systems. The openEHR Foundation has published a set of specifications defining a health information reference model, a language for building clinical models or archetypes, which are separate from the software, and a query language. The architecture is designed to make use of external health terminologies, such as SNOMED CT, LOINC and ICDx. Components and systems conforming to openEHR are open in terms of data (they obey the published openEHR XML Schemas), models (they are driven by archetypes, written in the published ADL formalism) and APIs. They share the key openEHR innovation of adaptability, due to the archetypes being external to the software, and significant parts of the software being machine-derived from the archetypes. The essential outcome is systems and tools for computing with health information at a semantic level, thus enabling true analytic functions like decision support, and research querying.

1.3 Integrated Healthcare Enterprise (IHE)

IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE uses a concept called Integration Profiles to describe clinical information management use cases and specify how to use existing standards (HL7, DICOM, etc.) to address them. Systems that implement integration profiles solve interoperability problems. For equipment vendors, Integration Profiles are implementation guides. For healthcare providers, Integration Profiles are shorthand for integration requirements in purchasing documents.

IHE Profiles supported by a specific release of a specific product are made available to customers by using IHE Integration Statements. IHE Integration Statements are documents prepared and published by vendors to describe the intended conformance of their products with the IHE Technical Framework. Integration Statements tell consumers the specific IHE capabilities a given product is designed to support in terms of the key concepts of IHE: Actors and Integration Profiles. The IHE Product Registry is a Web-based database of Integration Statements. Implementers can create, manage and publish Integration Statements for their commercial and open source healthcare IT systems. Users can decide what Actors and Profiles are needed in their enterprise and then browse for systems that meet those conformance requirements.

IHE Technical Frameworks are the documents that specify the Integration Profiles and the associated systems (actors) and transactions. Each IHE Domain publishes a Technical Framework used by engineers to implement IHE functionality. IHE is organized into Domains which each address problems in one area of healthcare.

1.4 Distributed Computing Technologies

The use of distributed computing technologies for problem solving has been around for many years. The early paradigm of distributed computing has been that of remote procedure calls (RPC). However, in recent years, this paradigm has shifted to the use of remote objects due to the acceptance of object oriented programming practices. Three specific middleware standards for distributed computing, namely: the Common Object Request Broker Architecture (CORBA), Java's Remote Method Invocation (RMI), and the more recent web services technology, frequently based on XML data encoding and SOAP based messaging protocols are briefly discussed and summarized below [9].

The three middleware standards all have certain commonalities. All are based around the concept of a client application using the services available on a remote machine, or server.

1.5 Medical Record Exchange in Ethiopia

In broader terms the health care delivery system in Ethiopia can be categorized as Public and Private. The private sector's role in the delivery of health services in Ethiopia has increased during the last decade. Based on the National Health Accounts report, it is estimated that the private health sector accounts for more than 40 percent of the curative and rehabilitative services in the country. Private health care delivery is divided into private for-profit and private not-for-profit organizations. The private health sector also includes clinics (primary, medium, and higher), General hospitals and specialized hospitals.

In Ethiopia electronic medical record usage is in its infancy stage, for the public health care facilities it is only less than a decade. Currently many public hospitals in Ethiopia use electronic medical record system to facilitate health care service. The private health care sector also uses different health information systems to facilitate the services they provide. The systems include Laboratory Information Systems (LIS), Electronic Medical Record Systems (EMR), Pharmacy Management Systems, etc. Most of these health information systems are developed by many different vendors, except for the public health care facilities, which use the same Electronic Medical Record System supplied by the Federal Ministry of Health (FMOH).

For different computer systems to share a patient's information, the information needs to be transferred from one system to another. In Ethiopia currently there is no any data exchange infrastructure among health care facilities which follow the rules of interoperability standards.

2. Related Work

In this section experiences on CDA use by Turkey [12] and Australia [13] are discussed briefly.

Turkey uses a modified version of HL7 CDA R2 as the local Electronic Health Record (EHR) format, which is termed as "Transmission Schemas". Turkey's National Health Information System supports the exchange of EHRs, called the Transmission Schema instances, at the national level. The content of the Transmission Schemas are defined within the National Health Data Dictionary that is developed to enable the parties to share the same meaning of data, and use them for the same purpose. Transmission Schemas are composed of Minimum Health Data Sets which are composed of data elements from the national health data dictionary. The data elements are mostly coded with coding systems and all these coding systems are available at the Health Coding Reference Server.

They implemented HL7 Web Services Profile for the transportation of Transmission Schema instances. There is a Web Service for each Transmission Schema defined in the national health data dictionary. These services support insertion, update, deletion and querying operations. For security, WS-Security Username Token Profile over Secure Sockets Layer (SSL) is used.

Even though Turkey adopted HL7 CDA as the EHR standard, in order to meet all national requirements directly at the schema level, many changes have been made on the original CDA Schema that broke the conformity of local "Transmission Schemas" to CDA. The generated schemas are completely HL7 v3 and CDA R-MIM conformant but not CDA conformant.

There are 25 different CDA based Transmission Schemas and in order to enable conformity of the messages to the original CDA, first they made an extensive analysis of all the incompatible changes and then developed an adaptor based on XSLT to automatically generate CDA conformant EHR documents from the "Transmission Schema" instances. There were 14 major categories of inconsistencies identified. The inconsistencies are mostly renaming of the XML elements in a CDA document, while some others are removing a mandatory element or ignoring the HL7 data type of an element. The inconsistencies exist both at the CDA header and body levels.

The other experience discussed in this paper is experience by Australia. Australia has been in the process of designing and implementing a national eHealth system for a number of years. A core component of this design has been the selection of HL7's CDA as the basis of the Australian EHR. This incorporates CDA into both the Electronic Health Record and for document exchange point-to-point. CDA was chosen partly for its ability to address issues of governance and consistency in a national environment that does not have definitive oversight or a single decision making body. Developing long and complex implementation guides has been assisted by good design of a super schema to include the Australian extensions, together with a framework for extensive conformance checking. Australia has created a multi level conformance framework which currently supports mainly Level 2 CDA architecture yet provides a transition path way to future full interoperability. One area of contention around the Australian solution, however, is a debate over content presentation and data content using CDA. The Australian implementation has had considerable debate around the technical and governance infrastructure for controlling the rendering of the documents. Other challenges have arisen in the selection of transport standards, sourcing of CDA experts and in relation to the need for local extensions to CDA. Local extensions to CDA have been modeled using the HL7 development paradigm (based on the HL7 RIM) as permitted by the CDA standard, and submitted for inclusion in HL7 CDA Release 3.

3. The Proposed Solution

To analyze the existing interoperable data exchange problem among hospitals using EMR in Ethiopia two sample systems were selected representing public and private hospitals. One of the systems is SmartCare which is currently deployed in 12 public hospitals, the other is EMR used by Kadisco hospital in Addis Ababa.

Currently an effort has been made by FMOH in collaboration with development partners to use Electronic Medical Records (EMR) to facilitate the health care delivery process in Ethiopia. The implementation of this EMR is through software called SmartCare which is developed by Tulane International in partnership with Tulane University in US, CDC and FMOH. SmartCare is deployed in 12 hospitals throughout the different regions of the country. There is also a plan to use it for all public hospitals in the country.

SmartCare is developed using c#.Net as a development language and SQL server at the backend database. It includes modules for Outpatient, Inpatient, Laboratory, Pharmacy, Reports, etc.

SmartCare uses smart card to transport patient's data to other facilities that are using smart care. Entire EMR is stored on card (64-100 pages), Card data is compressed and encrypted. Card can't be read by other systems, requires specialized card driver and code logic to read the data from the smart card. System is password driven, with a role based security model (RBS); databases are linked via a virtual network for data communication/synchronization, driven by the patient.

Currently hospitals using SmartCare exchange patient medical data using smart card. Smart card stores the entire EMR on card to transport patient data to other facilities that are using smart care. Smart card can't be read by other systems since it requires specialized card driver and code logic. For other hospitals, using other EMR software, to exchange patient medical record with SmartCare both exchanging parties need to have a common reference framework or standardized format of exchange. If both parties are able to use standard format to exchange, semantic interoperability will be achieved.

For Hospitals which are not using SmartCare it shares patient data only in a form of patient summary which include patient demographic information, diagnosis, investigations, procedures, treatments, etc. Patient summary is provided to the patient in printed format, using CD or through Email to the Health facility that requested the document. Since the patient summary doesn't follow any standard format, other EMRs can't read and use the data. The only way the EMRs use the data is by re-entering the data manually which can cause human error (typing), unable to understand some abbreviations and also can be incomplete since doesn't have any standardized format.

There are many reasons to transfer patient's complete medical record to another hospital. One could be patients' own reason like relocating to other country or town for his/her own reason or it could be due to medical reasons, like service provider transfer to other health care provider for further investigation or intervention. One example could be patient traveling abroad to medical service.

Patient summary from SmartCare is generated by collecting all patient related data starting from patients first visit up to the date patient summary is generated. This can include patient demographic information, outpatient visits, diagnosis, investigations, medications, inpatient admissions, procedures like surgeries, length of stay in the hospital, treating physicians, nurses, laboratory technicians, etc

The other sample EMR chosen was EMR used by Kadisco Hospital. Kadisco hospital is a privately owned general hospital. This EMR is a web based system developed by a local software company called Ingenious Computer Systems. This system generates patient summary report up on transfer of patient, or up on patient request. It uses printed paper format to exchange patient record to other hospitals, in a form of patient summary. This EMR also doesn't use any standard format to exchange patient data with other EMRs. If we try to compare the two patient summaries generated by SmartCare and by the EMR from Kadisco hospital they both differ in many aspects including the data elements, vocabularies they use to refer the same term, etc.

Semantic interoperability takes advantage of both the structuring of the data exchange and the codification of the data including vocabulary so that the exchanging information systems can interpret and use the data. For the two EMR systems to be semantically interoperable, they need to follow some standardized data format that agrees both systems on what to expect and how to interpret. EHR Standards (eHealth standards) are building blocks for health information exchange which provide a common reference framework, promoting uniformity in the definition and identification of health system components including messaging and data interchange standards which allow for consistent data flow among systems and organizations, specifying format, data elements and structure. They include terminology standards which provide specific codes for clinical concepts such as diseases, problem lists, allergies, medications, diagnoses, etc. They enhance data quality, reduce medical errors and reduce the need for customization of IT solutions across the health care system [12].

Analysis of three existing EHR standards were performed to help us see the different approaches by each based on content structure, content access, security features, and market relevance [11]. Table 1 summarizes the result of the analysis.

To understand different options to use as means of interoperable medical record exchange different distributed computing technologies were analyzed [10]. Table 2 summarizes the result of the analysis.

The result showed that the EHR currently used by public hospitals in Ethiopia (SmartCare) can exchange patient's medical record with other EMRs from private hospitals up on request (need) by making available patients records in standardized formats (CDA R2) through a web service. EMRs form private hospitals only need to locate the WSDL file from SmartCare and generate a proxy class to the Smart Care's web service which enables them to request patient's record using patient's unique identification. The EMRs from the private sectors also need to add a code implementation to automatically read the exchanged CDA document and also to save the document to own system.

Table 1: Summary of the Result of Analysis

	OpenEHR	*HL7 CDA*	*IHE XDS*
EHR Scope			
EHR content structure	Yes	Yes	No
EHR access services	Yes	No	No
Market Relevance	Yes	Yes	Yes
EHR content structure			
Contains persistent documents	Yes	Yes	N/A
Contains multimedia data	Yes	Yes	N/A

	OpenEHR	*HL7 CDA*	*IHE XDS*
Contains references to multimedia data	Yes	Yes	N/A
Structured content suitable for processing	Yes	Yes	N/A
Supports archetypes /templates	Yes	Yes	N/A
Specifies library of archetypes/Templates	Yes	Yes	N/A
Specifies distribution rules	Yes	No	N/A
Standard covers visualization	No	Yes	N/A
Supports digital signatures on documents	No	No	N/A
EHR access services			
Service for querying EHR content	Yes	N/A	Yes
Service for retrieving HER Content	Yes	N/A	Yes
Service for submitting EHR Content	Yes	N/A	Yes
Document-Centric storage/retrieval	No	N/A	Yes
Content format agnostic	No	N/A	Yes
EHR security features			
Supports transport level encryption	Yes	N/A	Yes
Protocol allows to transmit user Credentials	Yes	N/A	Yes
Protocol enforces access rules	Yes	N/A	Yes

Table 2: Web Services versus RMI

No	*Feature*	*Web Services*	*Java RMI*
1.	Synchronous operations	Yes	Yes
2.	Asynchronous operations	Yes	No
3.	Document oriented	Yes	No
4.	One-way operations	Yes	No
5.	Distributed garbage collection	No	Yes
6.	Platform independent	Yes	No
7.	Interoperable over heterogeneous platforms	Yes	Partial
8.	Language independent object/service description	Yes	No
9.	Location of objects/services	UUDI	Registry
10.	Remote object/service activation	No	Yes
11.	Security	Web Services Security	SSL
12.	Development cost	low	reasonable
13.	Overhead	OOP+HTTP	XML+HTTP

4. Discussion

As can be seen from the related experiences of Turkey and Australia each face different challenges when implementing CDA as EHR standard. The major challenge in both was extension of the CDA standards to accommodate local vocabularies which are not addressed by the current CDA version. These challenges faced by these experiences are also expected in our scenario, which can be remedied by following the same steps followed by them. For example, Australia was able to add some extensions to the CDA R2 standard to accommodate local use and suggest inclusions of these extensions in next version of CDA standard. The other challenge faced by Australia was in the area of expertise to the CDA standards which also can be a major challenge to us since we are beginners in these areas.

5. Conclusion

Effective communication requires that information senders and receivers share a common "reference framework" that enables all interactions to be unambiguously understood. Standards provide this common framework, promoting uniformity in the definition and identification of health system components, whether they are objects, diagnosis, people, interventions, etc.

In Ethiopia EHR can be broadly categorized as Public EMR (SmartCare) and Private EMR. For these EMRs to share data among each other, it is mandatory that they share common reference framework so that the sender and receiver EMRs will understand each other. In this paper we tried to discuss and analyze some of Electronic Health Records (EHR) standards and distributed communication technologies. Using the results of the analysis sample prototype implementations of the selected standards were developed and tested.

The result of this research showed that the prototype can be adopted and used in Ethiopia. Using this standard solution, the involved parties will be able to understand each other unambiguously when sending and receiving patient Medical record among each other.

We recommend FMOH to put these recommended solutions into action since it is one of the steps to be taken to improve quality of health care service in particular and health of the population in general. We are not suggesting that these are the only choices of interoperability standards to this problem, other researchers can come up with other different choices based on their own parameters by using international standards.

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