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Interoperability in Healthcare: Benefits, Challenges and Resolutions

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ABSTRACT: Information and Communication Technologies (ICTs) play significant roles in the improvement of patient care and the reduction of healthcare cost by facilitating the seamless exchange of vital information among healthcare providers. Thus, clinicians can have easy access to patients' information in a timely manner, medical errors are reduced, and health related records are easily integrated. However, as beneficial as data interoperability is to healthcare, at present, it is largely an unreached goal. This is chiefly because electronic Health Information Systems used within the healthcare organizations have been developed independently with diverse and heterogeneous ICT tools, methods, processes and procedures which result in a large number of heterogeneous and distributed proprietary models for representing and recording patients' information. Consequently, the seamless, effective and meaningful exchange of patients' information is yet to be achieved across healthcare systems. This paper therefore appraises the concepts of interoperability in the context of healthcare, its benefits and its attendant challenges. The paper suggests that the adoption of a standardized healthcare terminology, education strategy, design of useable interfaces for ICT tools, privacy and security issues as well as the connection of legacy systems to the health network are ways of achieving complete interoperability of electronic based Health Information Systems in healthcare.

KEYWORDS: Interoperability, Information Communication Technologies, electronic Health Information System, healthcare, patient care.

1 INTRODUCTION

Since the 1990s, advances in Information and Communication Technologies (ICTs) in healthcare have created new ways of managing patients' information through the digitization of health-related information. The use of ICTs in healthcare has the potential of reducing medical errors, improving collaboration between healthcare providers, reducing the cost of healthcare and dramatically improving the delivery and quality of healthcare [1]. The enhancement of ICTs in healthcare has also led to the generation of huge amount of information relating to the diagnosis, testing, monitoring, treatment and health management of patients, billing for healthcare services and asset-management of healthcare resources [2]. These information are stored in heterogeneous distributed Health Information Systems, in different file formats which are mainly proprietary [3]. These information need to interact and be accessed by healthcare practitioners in a uniform and transparent way, anywhere and anytime, as required by the treatment path of the patients. For instance, healthcare providers need to exchange information, such as clinical notes, observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, allergies and letters, x-rays, and bills. However, these information may be heterogeneous in terminologies, schema, syntax, semantics, data types, data formats and data constraints. This heterogeneity often results in

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severe data interoperability problems [4]. Consequently, the healthcare system is characterized by increased costs, high error rate, and knowledge mismanagement. Thus, this could result in high rate of mortality.

Numerous solutions have been proposed to achieve total interoperability in the healthcare with degrees of success. These include the use of standards, archeytpes, web services, healthcare service bus, and interface engines and ontologies. However, in spite of these diverse solutions, interoperability within the healthcare domain is yet to be completely achieved [5]-[7]. Consequently, this paper discusses the concept of interoperability, the benefits and barriers of interoperability and also suggests ways in which complete interoperability can be achieved within the context of healthcare.

2 CONCEPT OF INTEROPERABILITY

In broad terms, interoperability is the ability of different information and communications technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently, and to use the information that has been exchanged [8]. Data interoperability is the ability to correctly interpret data across systems or organizational boundaries [9]. The key points are illustrated below in Figure 1. In the scenario below, it is assumed that the people on the left have information needed by the people on the right, and that data in one system is accessible to the other. Hence, interoperability will only be achieved if the receiving system and users properly understand the meaning of information they receive and they are able to use this information [10].

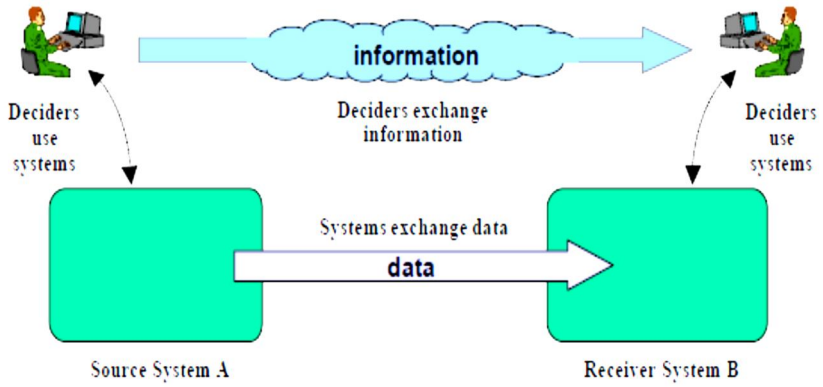

Fig. 1. Concept of Interoperability [1]

In general, there are seven basic levels of different levels of interoperability [11]. These levels include:

- Level 0 or No Interoperability: This is usually characterized by stand-alone systems which have no interoperability.
- Level 1 or Technical Interoperability: This level of interoperability involves the use of a communication protocol for the exchange of data between systems. Technical interoperability establishes harmonization at the plug and play, signal and protocol level.
- Level2 or Syntactic interoperability: This is the ability of two or more systems to exchange data and services using a common interoperability protocol such as the High Level Architecture (HLA).
- Level3 or Semantic Interoperability: Semantic interoperability refers to the ability of two or more systems to automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of the systems [12]. Semantic interoperability is also used in a more general sense to refer to the ability of two or more systems to exchange information with an unambiguous and shared meaning [13]. Semantic interoperability implies that the precise meaning of the exchanged information is understood by the communicating systems. Hence, the systems are able to recognize and process semantically equivalent information homogeneously, even if their instances are heterogeneously represented, that is, if they are differently structured, and/or using different terminology or different natural language [7]. Semantic interoperability can thus be said to be distinct from the other levels of interoperability because it ensures that the receiving system understands the meaning of the exchange information, even when the algorithms used by the receiving system are unknown to the sending system.

- Pragmatic Interoperability: This level of interoperability is achieved when the interoperating systems are aware of the methods and procedures that each other are employing. This implies that the use of the data or the context of its application is understood by the participating systems.
- Dynamic Interoperability: Two or more systems are said to have attained dynamic interoperability when they are able to comprehend the state changes that occur in the assumptions and constraints that they are making over time, and they are able to take advantage of those changes.
- Conceptual Interoperability: Conceptual interoperability is reached if the assumptions and constraints of the meaningful abstraction of reality are aligned.

However, in the context of healthcare, there is no standard definition of interoperability [14]. Nevertheless, the National Alliance for Health Information Technology defined interoperability in the context of healthcare as the ability of different information technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently, and to use the information that has been exchanged [14]. Interoperability in healthcare can be investigated in different categories such as the interoperability of the messages (information) exchanged between healthcare applications, interoperability of Electronic Healthcare Records (EHRs), interoperability of patient identifiers, coding terms, clinical guidelines and healthcare business processes. However, all these categories of interoperability can be classified in two major layers which are syntactic interoperability layer and the semantic interoperability layer [8]. Syntactic interoperability also referred to as the messaging layer involves the ability of two or more systems to exchange information.

Syntactic interoperability in e-health involves several layers which include the following:

- Network layer: The network layer provides the functional and procedural means of transferring variable length data sequences from a source host on one network to a destination host on a different network while maintaining the quality of service requested by the transport layer.
- Transport layer: The successful exchange of health-related information amongst healthcare applications requires the transport protocols, such as Internet. At present, the Transport Communication Protocol /Internet Protocol (Internet) is the de-facto communication standard for the exchange of health-related messages.
- Application protocol layer: This layer supports application and end-user processes. The functions of this layer typically include the identification of communicating systems, user authentication and privacy. This layer also identifies any constraints on data syntax. It also provides application services for file transfers and e-mail. Example of protocols at this layer is the File Transfer Protocol.
- Message protocol and messaging format layer: The message layer defines the structure and format for the messages that are exchanged between end-points. An example of a protocol used at this layer is the Simple Object Access Protocol (SOAP).
- Sequencing of the messages: There is a need to standardize the sequencing of the messages in healthcare. For example, in Health Level 7 standards, when "I05 RQC Request Clinical Information" message is sent, the expected return message is "I05 RCI Return Clinical Information". There are also different types of messages. These messages could be a message with the intent of action or an acknowledgment message indicating the successful exchange of a message or an error message. However, for the message content to be processed correctly by the receiving application, the message content structure and the data items in the message must be standardized [8].

Syntactic interoperability only ensures that the message is received by the receiving system. It does not guarantee that the content of the received information will be processable by the receiving system. Hence, it can be said that without syntactic interoperability, data and information cannot be handled properly with regards to its formats, encodings, properties, values and data types. Therefore, to guarantee total interoperability in healthcare, semantic interoperability must be provided. Semantic interoperability is the ability for information shared by systems to be understood at the level of formally defined domain concepts [15]. Semantic interoperability can also be defined as the ability of two or more computer systems to exchange information in such a way that the meaning of that information can be automatically interpreted by the receiving system accurately enough to produce useful results to the end users of both systems [16]. From the definition above, it can be deduced that semantic interoperability is yet to be achieved in healthcare. This is because 'being useful to end users' in the definition refers to end users who are human beings and who have the capacity to make sense of the data exchanged even when it is incomplete, contains errors, redundant, full of duplications, ambiguous and lack adequate formalization. Computers, however, do not such capacity. This is because the computer does not capture the semantics of information and it has no pre-existing repository of contexts, but instead requires a semantic representation that is simpler and more precise [17]. In recent times, the challenge of semantic interoperability is to ensure that information exchanged are understood not only by the human beings on both ends of the ICT communication channel, but also, the exchanged information must be understood by the computer systems and their associated software. Hence, it can be said that, without

semantic interoperability, the meaning of the used language, terminology and metadata values cannot be negotiated or correctly understood. The levels of semantic interoperability in healthcare according to [7] include:

- Full semantic interoperability: This level of interoperability also referred to as co-operability is the highest level of semantic interoperability. It is reached if users of system B are able to use information acquired automatically from system A with equivalent meaning to its local data, and the information can be processed homogenously with data captured natively within System B, as if they were entered by a user B directly into system. At this level, neither language nor technological differences prevent the system to seamlessly integrate the received information.
- Partial semantic interoperability: In partial semantic interoperability, the users of system B are able to access the information from system A and are able to detect, interpret and meaningfully present to the information to the attending physician.

3 THE CRITICAL NEEDS FOR INTEROPERABILITY IN HEALTHCARE

The healthcare domain currently is undergoing a fundamental change in its approach to delivering care as ICTs is becoming an indispensible component of healthcare. However, with the rising cost of healthcare, incessant inefficiencies and healthcare quality failures experienced by healthcare providers and patients, there is a need to understand the critical role that interoperability plays in data sharing and re-use among disparate healthcare applications and devices, reduction of healthcare costs and the improvement in the quality of care. Thus, this section critically appraises the benefits of complete interoperability in healthcare.

3.1 EASY ACCESS TO PATIENTS RECORDS

Patients usually get care from a wide range of care givers (such as hospitals, laboratory, pharmacy, urgent care centers, physician group, solo physicians and nurses, school clinics, and public health sites) based on their proximity, bedside manner, quality of care received and cultural attitude [18]. This has led to the fragmentation of the patients' information in proprietary heterogeneous systems across healthcare organizations. Consequently, vital information stored in these systems cannot be easily accessed to present a clear and complete picture of the patient. For instance, a study in an outpatient clinic found that pertinent patient data were unavailable in 81% of cases, with an average of four missing items per case. The entire medical record was unavailable 5% of the time [19]. In addition, the patients' information are often in a non-standard, non-structured and non-coded (text) form which makes the exchange of information a challenge [20]. Hence, the healthcare's current fragmented state results in injury, wasted resources, and loss of lives. In addition, avoidable deaths and injuries occur because of poor communication between healthcare practitioners annually. In spite of these challenges, healthcare practitioners are required to have access to the detailed and complete records of their patients across heterogeneous systems in order to manage the safe and effective delivery of healthcare services. However, through healthcare information exchange and interoperability, clinicians can have access to longitudinal patients' records stored in proprietary heterogeneous systems in a timely manner. This will improve healthcare processes by giving care providers the patient-specific information they need to effectively consult on a case. Also, with complete interoperability in healthcare, patients can also have full access to fragmented medical records maintained by each of their healthcare providers which will enable to better manage their health. Thus, interoperability establishes a seamless continuum of healthcare. The major benefit of interoperability in healthcare is to facilitate the easy access to health-related information that are stored in heterogeneous systems irrespective of the geographical locations of the healthcare providers as well as the patients. This concept is depicted in Figure 2.

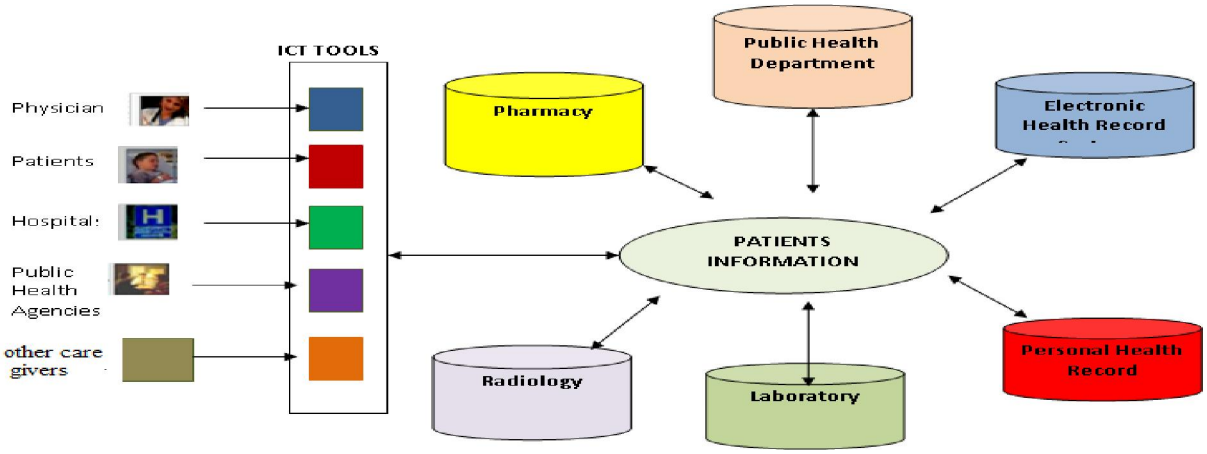

Fig. 2. Easy Access to Patients Information

3.2 EASY COMPREHENSION OF MEDICAL TERMS

The application of interoperability in the healthcare domain will provide care givers with the ability to better understand terms and concepts as data is transmitted from one system to another, while preserving the meaning of the content. Thus, interoperability will contribute to the improvement of healthcare because it ensures that the right meanings of medical terminology are delivered to communicating systems. Hence, physicians can easily analyze data from all collaborating systems for diagnosis and decision making.

3.3 REDUCTION OF MEDICAL ERRORS

The delivery of healthcare often involves moving the locus of care among diverse sites and providers. Hence, patients' records are scattered across several physicians' offices, laboratories and hospitals. This process is usually fraught with errors as a result of lack of interoperability among healthcare systems. For instance, a study conducted in an inpatient setting estimated that 18% of medical errors that result in an adverse drug event were due to inadequate availability of patients' information [19]. Thus, medical errors are of great concern to healthcare because they are the sixth leading cause of death in hospitals [2]. Also, it was reported in [2] that at least 44,000 and perhaps as many as 98,000 Americans die in hospitals each year as a result of medical errors, which results in considerable loss of life. Also, more than one million patients are injured each year as a result of broken health care processes and system failures [19]. One of the ways of avoiding medical errors is to ensure complete interoperability in healthcare by ensuring that health related data are formatted in a way that allows disparate computer systems to understand both the structure and content of the exchanged information.

3.4 REDUCED HEALTHCARE COST

One of the major challenges that the healthcare industry is facing is increasing costs [2]. For instance it was estimated that healthcare costs in the United States of America were about 14.9 % of the Gross Domestic Product, which accounted for $1.6 trillion in 2002, and $1.9 trillion in 2005 [2]. Furthermore, healthcare is projected to rise to $3.6 trillion by 2014 in the United States of America [2]. Interoperability among healthcare ICT systems would deliver a national savings of $77.8 billion dollars every year [2]. Hence, the effective sharing and communication of data, information, and knowledge among various stakeholders in the healthcare network is an essential factor for reducing healthcare cost.

3.5 INTEGRATION OF HEALTH-RELATED RECORDS

The healthcare system is an information-intensive activity that produces enormous data from its diverse sub systems such as laboratories, wards, operating theatres, primary care organizations, and from wearable and wireless devices. However, integrating information from autonomously developed applications is a difficult task, as individual applications usually are not designed to cooperate and they often based on differing conceptualizations [21]. Nevertheless, the management of information across healthcare systems and organizations requires collaboration, portability and data integration. Interoperability ensures that disparate applications within diverse healthcare facility "talk to and understand" one another. With this benefit of interoperability, healthcare organizations can integrate the information in disparate applications such as

registration systems, laboratory systems, core measure tracking and surgical software suites. In addition, interoperability allows a healthcare system to seamlessly integrate with other healthcare vendors, organizations, providers and national level organizations.

3.6 ENHANCED SUPPORT FOR THE MANAGEMENT OF CHRONIC DISEASES

The treatment of chronic diseases often involves multiple physicians and healthcare providers. In recent times, half the U.S. population lives with chronic disease [19]. An interoperable healthcare system however, will make it easier for patients to find information to help them prevent such conditions, since many chronic illnesses are preventable. Thus, individuals can improve their lifestyle to avoid chronic diseases.

4 BARRIERS TO INTEROPERABILITY IN HEALTHCARE

There is no doubt that interoperability has a major positive impact on healthcare. However, the lack of interoperability in healthcare systems and services has long been identified as one of the major challenges in healthcare. For instance, a practitioner in a private practice may have difficulty obtaining complete information about a patient who is currently being hospitalized; also a practitioner may repeat tests and procedures because he or she does not have prior information about the patient. Consequently, this section appraises the barriers impeding interoperability in healthcare.

4.1 COMPLEXITY OF THE HEALTHCARE DOMAIN

The healthcare domain is a very complex one because it involves a lot of actors such as doctors, radiologists, nurses, pharmacists, laboratory technicians who collaboratively participate in the treatment of patients. Each of these actors generates information that is needed by one another. The information in the healthcare domain is also enormously complex, because it covers different types of data such as patient administration, organizational information, clinical data and laboratory/pathology data [4]. However, safe and effective healthcare relies heavily on the ability to exchange data from one software to another, and from one person to another, and also on the ability to understand that information so that it can be used. However, care givers may be unwilling to share health-related information, but even when they are in agreement to share information, individual entities may have their customized or vendor-driven software that is incompatible and not interoperable with other systems.

4.2 STANDARDIZATION PROBLEMS IN HEALTHCARE

The operational goal of standardization is to provide sets of consistent specifications called “standards” to be shared by all parties manufacturing the same products, or providing the same services [17]. Standards are agreed-upon specifications that allow independently manufactured products, whether physical or digital, to work together, or in other words, to be interoperable. The major goal of standards in the healthcare domain is to improve patient care by allowing interoperability among disparate systems. However, standards are often too general and subject to local interpretation and implementation. For instance, there is a “standard” that every patient admitted to a U.S. hospital undergoes nursing assessment processes which are not uniform or standardized from one hospital to the other. A serious error or omission in this process can lead to the untimely death of a patient [19]. In addition, abbreviations are barely standardized within the healthcare domain. Moreover, there are a lot of standards used in healthcare. These include the Health level 7 standards, OpenEHR, Digital imaging and communications in medicine (Dicom), CEN/ISO EN13606, International Classification of Disease etc. Healthcare institutes however do not conform to a single standard, and the use of multiple standards breeds confusion [20]. Thus, the pursuit of high patient care and safety is futile in the absence of uniformity or standardization of the basic means of communication.

4.3 USE OF INCOMPATIBLE CLINICAL ONTOLOGIES/TERMINOLOGIES

Existing efforts aimed at achieving semantic interoperability within the healthcare domain rely on agreements about the understanding concepts stored in terminology systems such as nomenclatures, vocabularies, thesauri, or ontologies. This is based on the fact that all computer systems would understand one another perfectly if they use the same terminology or ontologies, or mutually compatible ones [17]. However, the growth of incompatible terminologies and ontologies within the healthcare domain is exponential. Thus, the use of incompatible and heterogeneous terminology and ontologies in healthcare contribute to the problem of interoperability. This is because heterogeneous terminologies and ontologies consist of multiple representations for the same clinical concept.

4.4 LEGACY SYSTEMS

Legacy systems (usually electronic medical record systems) with limited interoperability capabilities are those systems implemented prior to the introduction of common national standards. These systems are still in use today. Their data storage, input, and inventory of data items are unique and often proprietary. The problem associated with legacy systems is that they are designed for a particular task or facility. Moreover, many of these systems are designed to prevent interoperability with other vendors' applications to protect market share and to encourage purchases by hospitals or clinic chains .

4.5 RESISTANCE TO CHANGE

The healthcare industry unlike most industries (e.g. banking industry) still relies on piles of papers/ handwritten notes (paper records) for patients care. This is because most healthcare providers are resistant to change from their traditional paper based system to electronic health system because of the following reasons which were emphasized in [22].

- Large number of physicians in individual or small group practices with very limited administrative support for IT and related practice changes;
- The lack of uniformity and interoperability of IT systems from different vendors;
- Regulatory limitations on hospital funding of IT for physicians;
- Lack of trust and other legal concerns with respect to joint IT solutions; and
- Privacy and security concerns

Thus, the transition from a paper-based system to an electronic interoperable system in healthcare still remains a challenge for healthcare providers. The paper based process is inherently error-prone, as the multiple actors involved in the patients care may not communicate complicated results appropriately, leading to medical errors. The paper based system also adversely affects the management of medical information and the secure sharing of information across the continuum of care.

5 THE WAYS FORWARD

The achievement of a fully interoperable healthcare delivery system is a daunting task that is characterized by numerous barriers. However, the following solutions can be adapted to achieve complete interoperability in healthcare.

5.1 ADOPTION OF A STANDARDIZED TERMINOLOGY IN HEALTHCARE

The establishment and adoption of a standard terminology/vocabulary, that is, a common language for the description and exchange of data is essential for the achievement of complete interoperability in healthcare. This is because interoperability in healthcare requires standardization of the format and content of health-related data so that they can be understandable to computer programs as well as to the patients and care givers.

5.2 CONNECTION OF LEGACY SYSTEMS TO HEALTH NETWORK

The connection of legacy systems to the healthcare network, either temporarily or permanently is one of the solutions to complete interoperability in healthcare. This is because legacy systems are critical to medicine and thus they cannot be shut down from interoperable systems. Interoperating legacy systems with the healthcare network can be achieved via the use of a middleware software or hardware which translates the input and output of the system so it can interact with other connected healthcare systems.

5.3 EDUCATION STRATEGY

Healthcare providers should be taught the use of ICT tools in healthcare and their importance. Healthcare providers should be made to acquire the technical skills and knowledge needed to make full use of electronic systems in healthcare. Healthcare providers should be made to realize that adopting interoperable electronic healthcare information is in their best interest in terms of time and professional convenience. In addition, opportunities for health informatics training and introductory virtual courses on topics such as standards, application development and eHealth are essential for healthcare providers.

5.4 PRIVACY AND SECURITY POLICIES

Privacy and security policies should be considered as a part of design of an interoperable healthcare system. Healthcare Policies must be widely agreed by patients and practitioners on the terms and conditions for access to and dissemination of patient data. Adequate protection for the privacy of health information should also be considered in the development of interoperable healthcare system. Legislation and regulation should be frequently considered to reevaluate emerging technologies and capabilities. Also, authentication techniques such as passwords, fingerprints, retina scans and biometric devices such as fingerprint readers and voice-scanning systems should be used to help ensure data and networks are secure.

5.5 USABILITY ISSUES

The ability of care givers to use ICTs successfully depends on how well the technologies have been designed at the level of human-computer interaction (i.e. the user interface). The display of health-related information in a disorderly, illogical, or confusing manner leads to decreased user performance and satisfaction. Moreover, a poorly designed user interface contributes to medical errors. Addressing user interface issues requires greater attention to the cognitive and social factors influencing clinicians in their daily workflow and interaction with technologies

6 CONCLUSION

The major goal of interoperability in healthcare is to facilitate the seamless exchange of health-related information amongst caregivers and patients for clinical decision making. However, interoperability within the context of healthcare is yet to be realized. Thus, the lack of interoperability amongst healthcare systems further strengthens the information silos that exist in today's paper-based medical files, which results in proprietary control over health information. This has resulted in increased healthcare cost, declining quality of patients care, and the inability to integrate patients' information across healthcare systems. Consequently, this paper appraised the concepts of interoperability and its relevance to healthcare and attendant challenges. The paper also suggests solutions to achieving interoperability in healthcare.

REFERENCES

[1] Institute for Alternative Futures, "Health Information Systems 2015," Background Report for Biomonitoring Futures Project., Institute for Alternative Futures, Alexandria, pp. 1-15, March, 2006.

[2] C. Bock, L. Carnahan, S. Fenves, M. Gruninger, V. Kashyap, B. Lide, J. Nell, R. Raman and R. Sriram, "Healthcare Strategic Focus Area: Clinical Informatics," National Institute of Standards and Technology, Technology Administration, Department of Commerce, United States of America, pp.1-33, September, 2005.

[3] A. Kokkinaki, I. Chouvarda and N, Maglaveras, "Integrating SCP-ECG files and Patient Records: An Ontology Based Approach," The Medical School, Aristotle University of Thessaloniki, Greece, pp. 1-7, July, 2006.

[4] A. Ryan, "Towards Semantic Interoperability in Healthcare: Ontology Mapping from SNOMED-CT to HL7 version 3"., Conferences in Research and Practice in Information Technology (CRPIT)," vol. 72, pp.1-6, 2006 .

[5] T. Beale and M. D Heard, "An Ontology-based Model of Clinical Information," MEINFO 2007, pp.760-766, 2007.

[6] C.G. McLeod, "Interface Engines for Healthcare: 21st Century Trends, " McLeod C.G., USA, pp. 1-14, March 2006.

[7] Semantic Health Report "Semantic Interoperability for Better Health and Safer Healthcare," European Commission, Information Society and Media, pp. 1-34, January, 2009.

[8] D. Asuman, N. Tuncay, O. Alper, L. Gokce, K. Yildiray and E Marco, "Key Issues of Technical Interoperability Solutions in eHealth and the RIDE Project," Software Research and Development Center, Department of Computer Engineering, Middle East Technical University, Ankara, Turkey" pp. 1-11, 2006.

[9] S.A. Renner, "A Community of Interest Approach to Data Interoperability," Federal Database Colloquium San Diego, pp. 1-7, August 2001.

[10] Trans Atlantic Consumer Dialogue, "Resolution on Software Interoperability and Open Standards", Trans Atlantic Consumer Dialogue, pp. 1-6, July, 2008.

[11] A. Tolk, Y. Saikou and D.T Charles, "Support of Integratability, Interoperability, and Composability for System-of-Systems Engineering," Journal of Systemic, Cybernetics and Informatics, vol.5, n°. 5, pp. 65-74, 2007.

[12] Institute of Electrical and Electronics Engineers Standard Computer Dictionary," A Compilation of IEEE Standard Computer Glossaries, Institute of Electrical and Electronics Engineers, USA," 1999.

[13] A.S. Gregory, R.B. Kushel and Y. William, "Supporting Interoperability Using the Discrete-Event Modeling Ontology (Demo)," Proceedings of The 2009 Winter Simulation Conference M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin And R. G. Ingalls, Eds, pp.1399-1410, 2009.

[14] K. Heubusch, "Interoperability: What it Means, Why it Matters," Journal of AHIMA, vol.77, n°. 1, pp. 26-30, January, 2006.
[15] B. Veli, B.L. Gokce, D. Asuman and K. Yildiray, "Artemis Message Exchange Framework: Semantic Interoperability of Exchanged Messages in the Healthcare Domain", Software Research and Development Center, Middle East Technical University (METU), Ankara Turkiye, pp. 1-3, 2006.
[16] W. Ceusters and B. Smith," Semantic Interoperability in Healthcare State of the Art in the US", New York State Center of Excellence in Bioinformatics and Life Sciences Ontology Research Group", pp.1-33, March 2010.
[17] P. Groen and M. Wine,"Medical Semantics, Ontologies, Open Solutions and EHR Systems", Computer & Information Science Department, Shepherd University, West Virginia, August 2009.
[18] T. Thompson, D. Brailer, "The decade of health information technology: delivering consumer-centric and information-rich health care: framework for strategic action," Department of Health and Human Services, National Coordinator for Health Information Technology," 2004.
[19] E. Pan, D. Johnston, J. Walker, J. Adler-Milstein, D. W. Bates and B. Middleton, "The Value of Healthcare Information Exchange and Interoperability," Center for Information Technology Leadership, Wellesley, pp. 1-176,2004.
[20] L. M. Lau, S. Shakib, "Towards Data Interoperability: Practical Issues in Terminology Implementation and Mapping", 77th AHIMA Convention and Exhibit, October 2005.
[21] R. Lenz, M. Beyer, and A. Kuhn, "Semantic Integration in Healthcare Networks", Connecting Medical Informatics and Bio-Informatics", pp. 385-390, 2005.
[22] K. Rosati, M. Lamar, "The Quest For Interoperable Electronic Health Records: A Guide to Legal Issues in Establishing Health Information Networks," American Health Lawyers Association, pp. 1-107, July 2005.