Electronic Health Record Architecture: A Systematic Review

Maryam Jahanbakhsh, Reza Rabiei, Farkhondeh Asadi, Hamid Moghaddasi*

Department of Health Information Technology and Management, School of Allied Medical Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

*Corresponding Author: Email address: moghaddasi@sbmu.ac.ir (H. Moghaddasi)

ABSTRACT

Numerous advantages are derived from the electronic health record (EHR). Though achieving such advantages depends on its architecture, at present no unique understanding of the architecture dimensions and specifications is available. Therefore, the aim of the present study is a systematic review of architecture perception of the electronic health record. The authors searched the literature in Science Direct, Scopus, PubMed and Proudest Databases (2000 to Jun 2015). Data extraction was done by 2 reviewers on content, structure, content/structure relationship, confidentiality and security of the EHR. Subsequent to refining the 87 retrieved studies, 25 studies were finally included in the study. In the studies and paradigms so far proposed for the EHR, a unique comprehensive architecture model from the viewpoint of research criteria has not been investigated and it has been considered only from some dimensions. Hence, we provide a new definition of the EHR architecture.

Key Words*:* Electronic health record; content and structure; security; architecture

INTRODUCTION

Researches conducted up to 2011 indicated that during the future 20 to 30 years, the electronic health record will be the information source for health of citizens in most of the health environments [1] and will have a considerable effect on their health[2]. For this same reason, at present at least 23 countries all around the world are planning to establish electronic health records[3]. Experience of such countries however, indicates that establishing electronic health record at national level is faced with such problems as expansion and content variability of record data, difficulty in providing a specified and standard structure for the record due to variation and structure multiplicity, lack of common medical terminology, and challenges relative to privacy [1, 4-7] Providing answers to such problems is very important [6-8] and involves type of designing (architecture) of the electronic health record[9]. In fact, establishing a framework for successful implementation of the electronic government in the health sector requires architecture of the electronic record[10]. Study of definitions presented on architecture in various fields like software and information system indicate that architecture is the science of study and identifying components of a phenomenon, their interrelations and also the relationship among the set of components with the environment [11-16]. Architecture of the electronic health record as well is an example of data architecture and as one of the crucial types of architecture of applied schedule and technologies relative to the electronic health record[17, 18].

Maldonado et al. stated that different international bodies have worked on the definition of architecture of the electronic health record, the result of which attempts has been the establishment of such architecture standards as CDA HL7, openEHR and ISO EN 13606. Likewise, the HL7 organization through establishment of the CDA standard defines the structure and semantic of the clinical documents[19] . ASTM too, has proposed the E1384 standard for planning the electronic health record especially the lifelong health record [20]

which is mainly focused on the content of the electronic health record [8, 21].

Of course this architecture approach is focused on the generic structure of the medical documentation and is not necessarily centered on content and semantic which is required for integration of the level of data [22]. In other words, CDA has been established with the objective of providing suggestions for the structure and limitedly points out to the content of the electronic record[23]. The technical committee 251 (health informatics) in CEN in the section of the standard 13606 has provided a reference model for exchange of the electronic record[19] which is focused on such dimensions as structure and security of the electronic health record in relation with architecture[17, 23]; it, however, has no allusion to the record content. Additionally, though in relation to the terminology issue it has been deemed necessary that the record content should be named, no particular terminology has been proposed here [23]. Finally, the openEHR consortium which is considered the architecture of the lifelong health record, and is shared with and focused on patients[19], is centered on the record structure [24]. In this manner, in spite of maturity of the electronic health record architecture following over 15 years of endeavors and researches of such institutions, there are still problems in this regard, indicating that on the subject of the vital role of architecture of the electronic health record, its defining and focusing on this issue is vital [19]. Therefore, the objective of the present study is the precise definition of the electronic health record architecture.

METHOD

Literature review was done through the foreign databases of Science Direct, Scopus, PubMed and Proquest databases. The criterion for entry into the research study was the focus of researches on architecture of the electronic health record and cases which are concerned with the architecture of the system generating the electronic health record while cases which are concerned with record, were eliminated from the study. The search for keywords included 87 information sources, one of which being without abstract, three cases being out of the research temporal limit, two cases were indexes of papers and two cases were books. Therefore, 79 studies including papers and dissertations were enrolled into the research amongst which only 41 studies possessed the required criteria to be enrolled into the research and 16 studies in 4 databases overlapped from the viewpoint of title and were repetitive and after their elimination, 25 studies were finally enrolled into the research.

RESULTS

As a whole, during the study of the relevant keywords, 87 studies had been published from 2000 to 2015, 79 cases of which were investigated and following reviewing their abstract or complete texts and eliminating the repetitive cases only 25 studies were selected (table 1).

EHR architecture from the viewpoint of content

Four studies have considered the architecture of the electronic health record from the viewpoint of content as follows:

Bergman et al. have considered the architecture of the shared electronic health record from various dimensions including the content and the information paradigm [33].

Jing et al. in the study of architecture of the genetic data have considered the data content and have proposed this architecture in the framework of the CCR standard [34].

Tortosa Menargnes and Fernandez-Breis in the study of the electronic health record architecture have alluded to the dual openEHR model and deem it as being central on archetypes and terminology [32].

Duftschmid et al. have introduced the ISO/EN 13606 standard for the architecture of the electronic health record. This standard has made possible the semantic interoperable interchanges in the electronic health record and points to the importance of such archetypes which define the structure and semantic content of the electronic health record [27].

EHR architecture from the viewpoint of structure

The following 5 studies have considered architecture of the electronic health record from the structural point of view.

Blobel et al. believe that for the semantic interoperability, definition and uniform implementation of architecture is obligatory and that architecture is the structure and performances of the components constituting a system. They

have introduced the openEHR, CEN EN 13606 and HL7 v3 as the advanced architecture approaches and in this direction consider HL7 v3 with sufficient maturity for semantic interoperability compared with other approaches [31].Warren et al. emphasize on architecture of the health record and the effect of data architecture on the record structure and in this connection rely on the openEHR and HL7 as structural models of the record[30].

Hanzlicek et al. reckon development of modern architecture of the electronic health record in Europe as being centered on the existing European standard and projects. They consider the architecture of the electronic health record as equal to the abbreviation MUDR or the distributed multimedia record and emphasize on structure of the medical concepts. This architecture itself is established using architecture in the three layers of the databases, applied programs and the user interface [35].

Gordan regards guidelines of the CEN TC 251 in Europe as the cause of progress and maturity of the architecture standards and proposes guidelines of this committee as the agent for establishment of format and the required structure for the content of the electronic health record [36].

Maldonado et al. regards the architecture of the electronic health record as relying on the openEHR and ISO 13606 emphasis on structure[26].

EHR architecture from the viewpoint of content and structure

In 10 cases of the electronic health record architecture, both aspects of content and structure have been considered.

Xu et al. introduce the dimensions which are considered in architecture of China's electronic health record as data structure, clinical information data and data group and data element standard. Data structure includes 4 organized hierarchical levels which are from the lowest to the highest level: data elements, data groups, section and clinical documentations respectively. In this architecture, the clinical information data which leads to establishment of a framework for data structure and relationships amongst the clinical information, much corresponding with the E1384 ASTM standard and planning of clinical documents has been done though the HL7CDA philosophy[20]. Lopez et al. believe that pioneer organizations like HL7 and openEHR emphasize on content and structure dimensions and ISO is also centered on data structure and security [28].

In architecture of the electronic health record, Kim focuses on the information model i.e. contents, and their semantic relation within the information structure. He introduces the requisite for clear representation of content and concepts as paraphrases in the form of short and worth writing SNOMED CT statements[37].With regard to architecture, Maldonado et al. consider definitions of medical concepts in the framework of archetype and regards the architecture of the electronic health record as being based on ISO 13606. In this dual model, content and structure of data is connected to the terminology systems[25].Hamilton introduces architecture of the electronic dental health record as including the architecture of content, structure and dental naming systems[38].Acharya in his dissertation in the field of establishing the electronic record, points to the information model and in fact identification of various data required for documenting by dentist and the method for structuring data, and that the information to be included in the record and manner of stretchering are considered as two major challenges toward implementing EDR or the electronic dental record [39].Harrell et al. in their study introduce the ANSI/ADA N1000 as the informatics standards in the field of dentistry and based on it enumerate the electronic dental record architecture in the framework of content and structure of the record. They believe that so far standards in the field of electronic dental record architecture have not covered the required content and need modification or expansion of the existing architecture in the fields of structure, format and relationships amongst the information elements[40].Paterson introduces the terminology systems such as ICD, CCI, SNOMED, and UMLS and also the information architecture standards like HL7 CDA at two peer subjects in the information architecture [29].Krogh and Naden deem establishment of the electronic medical record documentation model as requiring the record architecture; this architecture is based on the information model (structure and format, nucleus data and appropriate terminology) [41] .

Liu et al. consider establishment of electronic health record in China as requiring to determine the requisite information items, categorization and inserting them within a hierarchical structure of an information model and then defining characteristics of these data elements[42].

EHR architecture from the viewpoint of confidentiality and security

Seven cases of studies as follows define the confidentiality and security as part of the electronic health record architecture.

Blobel has considered information security as part of architectural principles of the electronic record and believes the establishment of shared care must be assured by secure and sharable HER architecture [43].

Linden et al. describe the electronic health record as a set of the patient's health information which during his/her life is saved in various systems and is used in an environment broadly accessible; hence, he believes paying attention to privacy and security is one of the requirements of architecture of the electronic health record [44].

Gunter and Terry, regarding architecture of the electronic health record at national level emphasize on various approaches such as patient's autonomy, privacy and confidentiality [45].

Steele et al. consider secure and confidential management of data as requirement of the electronic health record architecture[46].

Regarding China's electronic health record architecture, Xu et al., in addition to the data groups and their structure, have focused on the confidentiality and security mechanism [20].

Ghazvini and Shukur have considered security, access and privacy as impediments of the personal electronic record and consider record's architecture as a dependent factor on their solution[6].

Pharow and Blobel consider security as one of the crucial exigencies of the electronic health record architecture [47].

DISCUSSION

Regarding architecture of the electronic health record, answers are sought to determine how, by whom and in which structure the data should be collected, to whom they should be accessible and how access of others should be limited [48]. In other words, in order to establish the electronic health record, all the information required to establish the record content should be identified and defined and their structure must be specified and standardized [42] and that privacy and security of data should be considered as important issues [49]. At present, however, the issues of content, structure, confidentiality and security have not been considered comprehensively and due to the lack of a uniform viewpoint and definition for architecture of the electronic health record, we are faced with variation of approaches in this regard.

Content of the electronic health record includes the sum of its constituents[20]; the focal point of the electronic record is health [50] since semantic interoperability and understanding the meanings of data requires sharing data models which are dependent on shared data elements and in fact the content [51]. As the good paper health record depends on its contents and documents, a good electronic health record as well depends on its data content [52]. Sixteen percent of the reviewed studies have considered content as one of the architectural dimensions of the record.

Data structure indicates configuration, relationships and content of data[53]. In fact, structure as a section of the electronic health record architecture indicates configuration and relationships within the electronic health record. Not only efficient collection of data depends on understanding the concepts of data structure and its relevant standard [54], but continuous and interoperability exchange of health information requires common structures for the information which is transferred within the health information systems [55] and accordingly the electronic health record is one of the effective factors on interoperability [56] . Therefore, the content of any medical record calls for a standard structure and movement from paper record to computerized record, and requires effective determination of its structure [57]. Graschew et al. in connection with the patient's medical record architecture emphasize on data structure [58]. About 20 percent of the reviewed studies point to record structure as an inseparable section of its architecture.

About 40 percent of studies emphasize on both content and structure as architecture of the electronic health record. Ingram in his study has

stated that CHIME (a center for multi-professional and informatics of health education in UCL which is active at international level) has conducted numerous researches which have resulted in achievements in the framework of such successful projects as GEHR, Synapses, Synex and Medicate, health care record standards CEN TC 251 and ISO TC 215, and finally the openEHR organization. CHIME has introduced content, terminology and information source model as components of the health record architecture [59]. Duftschmid et al. too, consider structure and appropriate terminology as necessary for content of the electronic health record for semantic operability and architecture of the record and mention ISO 13606, HL7 and openEHR as the most important architecture standards of the electronic record [60].

Privacy, confidentiality and security of health data have been considered as very crucial issues in operability of health data among different systems [61] and is considered as an inseparable part of the electronic health architecture [62]. High sensitivity of health data and their relation to the surrounding environment through information interchanges have led to emphasis on strict observation of confidentiality and security as an inseparable section of the electronic health record. About 28 percent of the reviewed studies also conform to such issues.

CONCLUSION

Although there are numerous standards and models in the field of electronic health record architecture, it seems that so far no comprehensive architecture model in the framework of content, structure, confidentiality and security of the electronic health record has been provided and only some dimensions have been considered. Therefore, regarding the performed studies, the electronic health record architecture can be defined as the science of study and characterizing its components (content and structure), relationship among components (content should be standardized by terminology, it should be placed within the structure, and structure should be indicative of configuration, relations and content of data), and the relationship between the set of components and the environment (confidentiality and security).

Table1. Frequency of retrieved sources in the studies source databases

Sources Databases	**Frequency of Retrieved Sources**			
	Total sources	**Irrelevant Sources***	**Relevant Sources**	**Similar & Repetitive Sources**
Pubmed	9	2	7	6
Scopus	20	7	13	6
Sciencedirect	34	19	15	4
Proquest	16	10	6	0
Total	79	38	41	16

* Irrelevant cases pointed out to the architecture of the electronic record system.

ACKNOWLEDGMENT

The current study is part of the Ph.D. thesis in Shahid Beheshti University of Medical Sciences.

DISCLOSURE

The authors report no conflicts of interest in this work.

REFERENCES

1.Borycki E, Joe RS, Armstrong B, Bellwood P, Campbell R. Educating Health Professionals about the Electronic Health Record (EHR): Removing the Barriers to Adoption. Knowledge Management & E-Learning. 2011;3(1).

2.Dorda W, Duftschmid G, Gerhold L, Gall W, Gambal J. Austria's path toward nationwide electronic health records. Methods of information in medicine. 2008;47(2):117-23.

3.Hodge T. National Electronic Health Record Initiatives – the 2011 Who's Who. February 7, 2011

4.Deutsch E, Duftschmid G, Dorda W. Critical areas of national electronic health record programs-is our focus correct? Int J Med Inform. 2010;79(3):211-22.

5.ASTM. Standard Guide for Content ans Structre of the Electronic Health Record: ASTM EMR. . Annual Book of ASTM Standards 2000;14.
6.Ghazvini A, Shukur Z. Security Challenges and Success Factors of Electronic Healthcare System. Procedia Technology. 2013;11:212-9.
7.Van de Velde R, Degoulet P. Clinical information systems: a component-based approach: Springer Science & Business Media; 2003.
8.ASTM. Standard Practice for Content and Structure of the Electronic Health Record (EHR). 2013.
9.Maharaja A. Use of the Electronic Health Record in Private Medical Practices: ProQuest; 2009.
10.Goel S, Dwivedi R, Sherry A. Critical factors for successful implementation of E-governance programs: a case study of HUDA. Global Journal of Flexible Systems Management. 2012;13(4):233-44.
11.OP'T LAND M, PROPER E, WAAGE M, CLOO J, STEGHUIS C, 2009 PwssM. Enterprise Architecture: Creating Value by Informed Governance. Published wwwsocialstyrelsense. May Springer 2009.
12.Blogged G. Defining Architecture [Online]. Agust 6 2012.
13.Platt M. Microsoft Archtecture Owerviwe[Online].
14.Blobel B, editor Standards and solutions for architecture based, ontology driven and individualized pervasive health. PHealth 2012: Proceedings of the 9th International Conference on Wearable Micro and Nano Technologies for Personalized Health, June 26-28, 2012, Porto, Portugal; 2012: IOS Press.
15. Architecture [Online]. [Internet]. [cited 2014/2/22].Available from: thttp://www.rgoarchitects.com/Files/Architecture.ppt
16.Wozak F. Medical Data Grids as a Base-Architecture for Interregional Shared Electronic Health Records. Institute for Health Information Systems, University for Health Sciences, Medical Informatics and Technology (UMIT), Doctoral thesis. 2007.
17.Eichelberg M, Aden T, Riesmeier J, Dogac A, Laleci GB, editors. Electronic health record standards–a brief overview. Proceedings of the 4th IEEE International Conference on Information and Communications Technology (ICICT 2006); 2006: Citeseer.
18.Spewak SH, Hill SC. Enterprise architecture planning: developing a blueprint for data, applications and technology. QED Information Sciences, Inc.; 1993.
19.Maldonado JA, Costa CM, Moner D, Menárguez-Tortosa M, Boscá D, Giménez JAM, et al. Using the ResearchEHR platform to facilitate the practical application of the EHR standards. Journal of biomedical informatics. 2012;45(4):746-62.
20.Xu W, Guan Z, Cao H, Zhang H, Lu M, Li T. Analysis and evaluation of the Electronic Health Record standard in China: A comparison with the American national standard ASTM E 1384. International Journal of Medical Informatics. 2011;80(8):555-61.
21.Lincoln M. Standards for Structure and Content of Electronic Health Records [2013/5/5]. Available from: https://www.hl7.org/documentcenter/public_temp_57D9FE6C-1C23-BA17-0CD82F370D8E5C31/wg/vocab/Structure_and_Content_May_00_Cleveland.ppt.
22.Pannu PS. Fact-of-death data exchange using clinical document architecture: University of California, Davis; 2010.
23.Cohen S, Shabo A. Electronic health record (EHR) standards survey. Retrieved June. 2001;29:2007.
24.Schloeffel P, Beale T, Hayworth G, Heard S, Leslie H. The relationship between CEN 13606, HL7, and openEHR. HIC 2006 and HINZ 2006: Proceedings. 2006:24.
25.Maldonado J, Moner D, Bosca D, Fernández JT, Angulo C, Robles M, editors. Semantic upgrade and normalization of existing EHR extracts. Engineering in Medicine and Biology Society, 2008 EMBS 2008 30th Annual International Conference of the IEEE; 2008: IEEE.
26.Maldonado JA, Moner D, Boscá D, Fernández-Breis JT, Angulo C, Robles M. LinkEHR-Ed: A multi-reference model archetype editor based on formal semantics. International journal of medical informatics. 2009;78(8):559-70.

27.Duftschmid G, Wrba T, Rinner C. Extraction of standardized archetyped data from Electronic Health Record systems based on the Entity-Attribute-Value Model. International Journal of Medical Informatics. 2010;79(8):585-97.
28.López-Nores M, Blanco-Fernández Y, Pazos-Arias JJ, García-Duque J. The iCabiNET system: Harnessing Electronic Health Record standards from domestic and mobile devices to support better medication adherence. Computer Standards & Interfaces. 2012;34(1):109-16.
29.Paterson GI. Boundary infostructures for chronic disease. 2007.
30.Warren JR, Frankel HK, Noone JT. Supporting special-purpose health care models via adaptive interfaces to the web. Interacting with Computers. 2002;14(3):251-67.
31.Blobel BG1 EK, Pharow P. Semantic interoperability--HL7 Version 3 compared to advanced architecture standards. Methods of information in medicine. 2006;45(4):343-53.
32.Menárguez-Tortosa M, Fernández-Breis JT. Validation of the openEHR archetype library by using OWL reasoning. Studies in Health Technology and Informatics. 2010;169:789-93.
33.Bergmann J, Bott OJ, Pretschner DP, Haux R. An e-consent-based shared EHR system architecture for integrated healthcare networks. international journal of medical informatics. 2007;76(2):130-6.
34.Jing X, Kay S, Marley T, Hardiker NR, Cimino JJ. Incorporating personalized gene sequence variants, molecular genetics knowledge, and health knowledge into an EHR prototype based on the Continuity of Care Record standard. Journal of biomedical informatics. 2012;45(1):82-92.
35.Hanzlicek P, Spidlen J, Heroutova H, Nagy M. User interface of MUDR electronic health record. International Journal of Medical Informatics. 2005;74(2–4):221-7.
36.Gordon C, Muir Gray, J.A., Toth, B., Veloso, M. . Systems of evidence-based healthcare and personalised health information: Some international and national trends Studies in Health Technology and Informatics. 2000;77:23-8.
37.Kim H. Exploring data reusability: Standardized representation of domain contents and feasibility testing University of Minnesota; 2005.
38.Hamilton J. Is the paperless practice possible? The Journal of the American Dental Association. 2005;136(2):161-2.
39.Acharya A.DEVELOPIN AN ELECTRONIC DENTAL RECORD INFORMATION MODEL FOR GENERAL DENTISTRY: University of Medicine and Dentistry of New Jersey; April 2010.
40.Harrell WE, Stanford S, Bralower P. ADA initiates development of orthodontic informatics standards. American journal of orthodontics and dentofacial orthopedics. 2005;128(2):153-6.
41.Von Krogh G, Nåden D. A Nursing-Specific Model of EPR Documentation: Organizational and Professional Requirements. Journal of Nursing Scholarship. 2008;40(1):68-75.
42.Liu D, Wang X, Pan F, Yang P, Xu Y, Tang X, et al. Harmonization of health data at national level: A pilot study in China. International Journal of Medical Informatics. 2010;79(6):450-8.
43.BlobelB. Advanced and secure architectural EHR approaches. International Journal of Medical Informatics 2006; 75(3-4):185-90.
44.van der Linden H, Kalra D, Hasman A, Talmon J. Inter-organizational future proof EHR systems: A review of the security and privacy related issues. International Journal of Medical Informatics. 2009;78(3):141-60.
45.Gunter TD, Terry NP. The emergence of national electronic health record architectures in the United States and Australia: models, costs, and questions. Journal of Medical Internet Research. 2005;7(1).
46.Steele R, Min K. Role-based Access To Portable Personal Electronic Health Records.
47.Pharow P, Blobel B. Electronic signatures for long-lasting storage purposes in electronic archives. International Journal of Medical Informatics. 2005;74(2–4):279-87.
48.Maharaja A. Use of the Electronic Health Record in Private Medical Practices. : Duquesne University; 2009.
49.Fernández-Alemán JL, Señor IC, Lozoya PÁO, Toval A. Security and privacy in electronic health records: A systematic literature review. Journal of biomedical informatics. 2013;46(3):541-62.
50.Meier A. EDemocracy & EGovernment: Stages of a Democratic Knowledge Society: Springer Science & Business Media; 2012.

51.Gliklich R, Dreyer N. Registries for Evaluating Patient Outcomes: A User's Guide. Rockville (MD): Agency for Healthcare Research and Quality (US). 2010.
52.Carol Adam ea. Data Standard Time: Data Content Standardization and the HIM Role. AHIMA 2006;2:26-32.
53.Brackett M. Data Architecture and DataStructure. June 4 2013.
54.Health Data Structure,Collection, andStandards. McGraw-Hill Companies; 2012.
55.COMMUNITIES COTE. Regular ReportonTurkey'sprogress towards accession. 2004.
56.Giokas D. InteroperabilityStrategies and Trends. Healthcare IT Standards Technology Officer Conference; SingaporeOctober 17, 2011.
57.Sharda P, Das AK, Cohen TA, Patel V. Customizing clinical narratives for the electronic medical record interface using cognitive methods. international journal of medical informatics. 2006;75(5):346-68.58.Graschew G, Roelofs TA, Rakowsky S, Schlag PM. Digital medicine in the virtual hospital of the future. Int J CARS. 2006;1:119–35.59.Ingram D, Murphy J, Griffith S, Southgate L. Educational implications of the development of a common health record architecture for Europe--the Good European Health Record project. Postgraduate medical journal. 1993;69:S97.60.Duftschmid G, Chaloupka J, Rinner C. Towards plug-and-play integration of archetypes into legacy electronic health record systems: the ArchiMed experience. BMC medical informatics and decision making. 2013;13(1):11.61.NHS. NHS Summary Care Record - Guide for GP Practice Staff October 2012. Available from: https://www.networks.nhs.uk/nhs-networks/nhs-cumbria-ccg/it/summary-care-records/SCRGuideGPPractice_v1.pdf/show_all_similar_networks.62.Blobel B. Architectural approach to eHealth for enabling paradigm changes in health. Methods of information in medicine. 2010;49(2):123.