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The Electronic Health Record and its Contribution to Healthcare Information Systems Interoperability

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Abstract

One of the main advantages of using computational systems in the health care activity comes from their ability to provide useful information for decision making to health professionals. Thus, their main purpose is to increment the quality and efficiency of healthcare delivery. In order to achieve these purposes, Health Information Systems must fulfill interoperability standards, quality, security, scalability, reliability and timeliness in data storage and processing terms. One of the main existing problems in this area is the fact that informatics applications do not share information, or share it in a very low level. When communication between different Health Information Systems exists, it is mainly achieved through proprietary integration solutions. In this paper is made a survey of the main advantages of Electronic Health Records and presented a proposal of some general guidelines for building them and promote the integration of different information resources.

Keywords: Information System; Interoperability; Electronic Health Record; Integration; HL7; DICOM

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1. Introduction

Medical Informatics relates cognitive activities, information processing, and communication tasks of medical practice, education, and research including the information science and the technology that support these tasks [27]. Health informatics tools include not only the physical components, but also the definition of clinical protocols, formal medical terminologies, and information and communication systems [4].

The activity of providing health care is a complex task, which stems from several factors, among which we can highlight the complexity of the information flow, particularly in clinical processes, the wide variety and different clinical data formats, the ambiguity of the concepts used, the inherent uncertainty in medical diagnosis, the large structural variability of medical records and organizational and clinical practice cultures of the different institutions [3].

Generally, in a health care organization we have large amounts of data production. These data, which may be of different types, shapes and nature, are stored in several databases with different management platforms and often differing in the architectural levels, both regarding the organization of the data as well as in terms of the way they are visualized. The complex nature of this kind of organizations, coupled with the costs often underestimated, increases the probability of failure of software projects initially planned. In fact, there are many projects that aim the implementation of Information and Communication Technologies in Health whose objectives are not reach on time, budget and defined expectations, which is mainly due to the increasing complexity, both in the scientific, technological and normative of health informatics as in the field of national and international clinical protocols. The different information systems that healthcare organizations have are the result of the natural process of development over the years. These systems were developed based on various technological platforms and different programming languages, coexisting in the same organization with a large number of heterogeneous and spread systems, developed to support specific needs of certain services or sectors [19]. This reality is one of the reasons why interoperability of current information systems in health care units is still very weak and one of the main reasons why development projects of global information systems in this sector are difficult to implement [9, 11].

Despite these difficulties, it is clear the growing interconnection between the practice of medicine and the Information Technology and Communication regarding the collection, storage, processing and communication of clinical data. As in other sectors, in the exercise of their activities, health professionals make decisions for which, beyond the competence and knowledge, access to information is extremely important related to the patient and activity, which should be available in appropriate time and place, and shall ensure the fulfillment of safety levels and consistency of data that constitute it. One of the main advantages of using computational systems in healthcare activity arises from the ability to provide useful information for decision making to health professionals. However, it is important to note that given the large number of systems in production in this sector, which are mostly independent, with no interoperability or integration within a Global Information System. Information extracted from them is sometimes contradictory having lower levels of reliability than the required to address the relevance and the kind of decisions that are supposed to be taken. Note that in most healthcare organizations nationwide different information systems have their own storage structures, which leads to data duplication. There are several cases where information extracted from different systems based on the same data do not match. To be able to use information systems in decision support, it is essential to act in order to get encoded data in a standard form, validating the quality of electronic data, optimizing their presentation and exploration, and implementing the necessary algorithms so they can be applied at the patient point of care [14].

In this paper is made a survey of the main advantages of Electronic Health Records and presented a proposal of some general guidelines for building them and promote the integration of different information resources.

This paper is organized as follows: In section 2 are presented the main features and objectives of Health Information Systems (HIS), as well as their relevance for the promotion of healthcare. In this section is also addressed the issue of HIS interoperability and its importance in building an health global information system. In section 2 are also presented the standards to use in order to ensure the necessary systems interoperability and facilitate its integration. In section 3 is made a survey of the main advantages of Electronic Health Records and proposed some general guidelines for building their supporting Health Information System. In section 4 are presented some conclusion and future work to develop in this area.

2. Health Information Systems

Progress in information technology is a real and unavoidable fact, it plays an important role in the health care sector regarding its final goal – health care. In this sector, his scope of action covers various areas such as the Health Information Systems, Telemedicine, Biological Signal Processing (in which is included the Medical Image Processing), Security Health Informatics, etc.

Information and Communication Technologies increased use in healthcare organizations presents a pattern that is similar to what happened in major companies that rely in a well developed IT infrastructure. The use of web technologies, database systems, and network infrastructures are some initiatives that affect both the practice and management of healthcare market.

Regarding the evolution of information and communication technologies in healthcare organizations, there is a strong resistance to the adoption of e-health systems - the use of the so-called Electronic Medical Records (EMR). With the use of patient data information systems, information goes from a paper record to electronic format in the form of files, thus allowing easier and more effective management. However, it is interesting to note the tendency of users to learn and actively participate in the promotion, prevention and health care, along with the rights and legislated standards, have a real impact in the development of the information systems, which take these factors into account.

The concept of Health Information System emerges from Health Information and Communication Technologies, constituting one of the three main lines along which they are organized [29]. Health Information Systems are frequently described as the interaction between individuals, processes and technology in order to support fundamental information operations, management and availability, so that healthcare services can be improved [5]. Similarly to other sectors, the nature of the health sector has changed over time from a relatively stable activity to a dynamic backdrop. Health Information Systems whose evolution is based on several different technologies, can be described as those who, through data processing, provide information and enhance the knowledge creation in health care environments [17]. Giving more detail to this definition we can say that an Health Information System can be defined as a mechanism for storing, processing, analyzing and transmitting information required for planning, organization, execution and evaluation of health services.

The main goal of Health Information Systems is to contribute to an efficient and high quality healthcare [5]. These systems should also promote the development, rationalization and improvement of its management. So that these objectives can be achieved, Health Information Systems must fulfill interoperability standards, quality, security, scalability, reliability and timeliness in data storage and processing terms [29]. They should ensure efficiency and security of information flows, eliminating actions duplication, namely diagnoses, and simultaneously enhance the speed, efficiency and proximity of health systems. Also note that these systems should have not only clinical features, as well as management ones, which should be linked through the integration of different information systems used, allowing:

- access to data needed for performance monitoring and correlation of the ones needed for economic evaluation studies;
- case-mix consolidation and data mining to support the providers procurement;

- health planning;
- greater accountability, better decision-making and evidence-based policies;
- reorganization of logistics and supply flows.

There are growing needs for information at point of care, intended to be complete, homogeneous, accurate, current and of interest to clinical decision [7]. Several studies show that information systems can cause a positive effect on quality of care [20], as well as being presently unquestionable their potential economic benefits [24].

In Portugal it is clear that there are many computing systems and applications in use, recently deployed in different healthcare units, particularly in specialized healthcare units (hospitals). Looking at the report published by the Portuguese National Statistics Institute in 2012, that as regards the use of Information Technologies and Communication, based on the responses of a survey made to a universe of 229 Portuguese hospitals (122 public hospitals and 107 private), we can observe that 96% of the surveyed hospitals use broadband Internet and 30.1% practice telemedicine activities, particularly in the areas of teleradiology and teleconsultation [30]. Still according to the same report, inpatient processes are computerized in 90% of the inquired hospitals, outpatient processes in 84.3% and surgery rooms processes in 65.9% of them. Electronic Medical Record is used in 76.9% of the surveyed hospitals. However, despite this information, the notorious technological advancement of computer technology and its high accessibility for the community, its effective implementation in healthcare is still far from what is desired. This reality is partly a consequence of the fears and insecurities of the different professionals who must operate with it, which results in a constant resistance to the use of new technologies in this sector.

A Hospital Information System is an instance of Health Information Systems, where the Hospital Unit is both the environment and the healthcare institution. These systems have undergone deep changes since the 90s, reflecting the evolution of technology, which is accompanied by the growth of the environment complexity and the increasing pressure regarding the need for timely access to information by a great number of different professionals. On the other hand, there is greater awareness by the governing bodies of healthcare units of the benefits introduced by the new technologies in this sector [26].

Table 1. Benefits of clinical information coding and areas of application [1].

Application Areas	Benefits of Clinical Data Coding
1. Healthcare;	Decreased amount of data to be recorded;
2. Quality control through:	Normalization of concepts and the resulting increase
2.1 Presentation results standardization;	in the recording quality;
2.2 Information comparability between health units;	Research and statistical development support;
2.3 Action protocols application;	Application of clinical and management decision
2.4 Increased knowledge in clinical decision support.	support systems;
3. Scientific investigation (Epidemiology, etc.);	Operational and technical assistance management
4. Planning and management.	support;
	Planning support.

In Portugal, among the several information systems in health units we can highlight, either by relevance or by the number of institutions in which they are installed, the Administrative Management System of Patients (SONHO – Differentiated Healthcare Units; SINUS – Primary Healthcare Units), the Medical Support System (SAM), the Nursing Practice Support System (SAPE), the Picture Archiving and Communication System, the Electronic Prescription System, the Referencing System between Differentiated and Primary Healthcare Units,

and the Laboratory Management System. In general, each of these systems has its own data repository, which results in recurrence. On the other hand, the integration of these systems is poor, and when this occurs it is achieved through the implementation of various integration engines (usually the manufacturers proprietary). This fact entails, beyond the increased cost inherent to the frequent changes of information systems, great difficulties concerning the extraction of reliable information, capable of supporting decisions of different actors leading to knowledge creation.

2.1. Health Information Systems Interoperability

On health, interoperability is the ability of heterogeneous health information systems, and computer applications to communicate and exchange data accurately, effectively, consistently and use the information that has been exchanged [22]. This is a key concept in relation to electronic health records, in that it measures the ability of communication and cooperation between different entities in the health sector, enabling information sharing through Electronic Health Records and other medical systems [22, 25, 6]. However there are notorious difficulties in health information systems integration, either by the large number of suppliers of systems and technologies, either because there are many clinical and administrative sharing information apps between applications within the same organization, and also by the fact that each application can support multiple communication interfaces that need constant modifications maintenance. Achieve interoperability between heterogeneous health information systems is very important as it will reduce health associated costs and contribute to more effective patients treatment.

Between the different levels of integration considered by National Alliance for Health Information Technology (NAHIT), is the automatic transfer of complementary diagnostic procedures results for electronic medical record systems, which should be accessible by other information systems without need for translation or additional semantics translation.

The interoperability between health information systems is only possible through the definition of standard messages, which must be adopted by all manufacturers of this type of technology, in order not to put into question the effective functioning of these systems [2]. Among the different standards used should be highlighted by its features the HL7 (Health Level Seven) and the DICOM (Digital Imaging and Communication in Medicine) [22, 25].

The protocol for electronic data exchange, HL7 version 2.x, is the industry standard used to convey clinical and administrative information between heterogeneous health applications, which is based in a context of application-application messaging exchange. Regarding the protocol HL7 v2.x, HL7 version 3 (HL7 v3) adopts an object-oriented approach, using the principles of the Unified Modeling Language (UML), which are based on a data model called the Reference Information Model (RIM). HL7 messages are XML documents that can be validated against the XML schemas derived from the conceptual model, which is suitable for data transportation between heterogeneous systems, allowing structured information encoding, separating content from formatting. HL7 Reference Information Model is a static model representing the domain of medical information. The process of developing the standard HL7 v3 defines the rules used in the implementation and drift specific domain information models from RIM, generating in the end XML schema definitions associated with a particular message type. The standard HL7 RIM provides a significant level of functionality in messaging exchange between applications, structuring envelopes that support the exchange of messages between applications.

The definition of standard clinical document architecture (CDA) ensures the structure consistency in order to allow their interpretation by both computer systems and by its end users. This standard contributes to the approach of the production systems industry to design a generic model of common clinical records, walking towards the definition of a universal model of centralized medical records [16].

3. Electronic Health Record – A proposal

The medical record is a dynamic informational entity that enables continuous monitoring of the health condition of a patient, which aggregates all the information from the clinical history and treatments, to the considerations and findings resulting from additional performed diagnostic tests. It is understood by Electronic Health Record (EHR) of a patient the chronological agglomeration of clinical information resulting from the care he has received, cataloged by place of performance and professionals engaged in the provided acts. Besides allowing better information management and flexibility when compared to paper records, these systems present as great advantage the quickly access to useful information needed for decision-making at the point of care [12]. Beyond these, we can also highlight other advantages such as its ability to allow simultaneous consultation and edition of the information relating to a patient by different health professionals, space savings over the growing number of clinical records, the data security and confidentiality promotion, the integration of different information resources (complementary diagnostic tests results (laboratory tests, medical images, etc..), centralization and constantly updated information, the information structuring according to medical standards and the promotion of statistical control and optimization services [21, 18, 15]. Despite the numerous advantages of EHR adoption, reality shows a low rate of implementation of these systems [13], being the main reasons the large initial investment and maintenance costs, the privacy and trust of potential users, the interoperability, the migration of old records, and social organizational and legal barriers [18, 15, 8, 23].

3.1. Features to integrate

The system designed for the Electronic Health Record creation and maintenance should be the core of the patient's information (single repository) and should be accessed by other modules through a set of functions and validations to ensure the confidentiality of this information.

Within the definition of its functional requirements, the EHR should contain, for each patient, all information resulting from their interaction with different health professionals, in order to facilitate an integrated vision of patient data and serve as clinical decision support. Additionally, the EHR should allow the recorded information to be analyzed under the encounter concept, according to the institution used criteria.

The main needs to be covered will be:

1. Definition of a flexible data structure to accommodate the information in the profile of each patient and clinical history of patients;
2. Clinical information registry concerning subsequent consultations and prescriptions;
3. Repository of all medical history individualized and complete.

The several professional groups involved in healthcare have already developed methodologies that reflect the process engineering associated to a clinical act, which can be organized in three phases:

1. Observation: Initial stage where the professional collects information from the patient or other professionals (e.g. patient in loco contact, analysis of his medical history, analysis of complementary diagnosis tests and therapy results, analysis of other clinical opinions, etc.). which can have a subjective or objective nature;
2. Decision: Stage where the professional, based on the knowledge acquired in the previous phase, uses his scientific knowledge and professional experience to establish a diagnosis (probable or definite);
3. Intervention plan: Last stage where, given the elaborated diagnosis and the patient profile, the health professional defines the application of a particular Intervention Plan (e.g. surgical therapy, drug therapy, referentiation, etc.).

This process should not be viewed in a detached way, being in many circumstances a recurrent procedure (e.g. patients on Inpatient).

With the creation of classifications, it is recommended the definition of normalization rules that are based on this concept, in the use of ratings and the definition of action guidelines. In that sense, fall under the following examples:

1. The SOAP logic (Subjective, Objective, Assessment, Plan), used by physicians;
2. The ICPC (International Classification of Primary Care), ICD (International Classification of Diseases), ICD-CM (International Classification of Diseases-Clinical Modification), SNOMED (Systematized Nomenclature of Medicine) for Reasons, Diagnostics and Action Plans registration;
3. The classifications associated with Drug Administration and Complementary Diagnosis Tests and Therapy, for prescriptions registry (e.g. ATC Norm (Anatomic Therapeutic Chemical Code), MedDRA Terminology (Medical Dictionary for Regulatory Activities), WHO-ART for adverse reaction, etc.);
4. The parameters recorded and validated by Laboratory Technicians (e.g. ranges of numeric values, Boolean values, descriptive values, ranking lists, image and video), with the completion of Complementary Diagnosis Tests and Therapy;
5. The ICNP classification (International Classification for Nursing Practice) for Phenomena and Nursing Interventions registration;
6. The classifications for specific areas (e.g. Histology for Neoplasms, Maratka for Gastroenterology, etc.);
7. The Graffard, Duvall and Mitchel classification for the support of the registration of Diagnosis Social Intervention performed by Social Service Technicians.

It is understood that the Electronic Health Record should, therefore, allow the following set of features:

1. Templates parameterization (normalized) to fill clinical information, specific to each profile of activity;
2. Templates customization for analysis of the information of the Clinical Process and extraction of information leading to the creation of knowledge;
3. Templates parameterization for updating and processing of information after the act performed (Clinical Management File);
4. Integration of information from different sources and in different formats (should be used the protocols HL7 and DICOM as exchange information formats between coexisting systems applications);
5. Guarantee of privacy, security and confidentiality of information about each patient.

4. Conclusions and Future Work

Despite the difficulties of implementation and diffusion of information and communication technologies in the health sector, due to its own complexity, it is remarkable and growing the interconnection between medical practice and these technologies. Health Information Systems promotes the interaction between individuals, processes and technology in order to support operations, management and delivery of essential information in order to improve healthcare services, increasing their quality and efficiency. To make this possible, these systems must obey to interoperability standards, quality, security, scalability and reliability and timeliness to the level of the stored data and its processing. Due to the high heterogeneity of information systems implemented in healthcare organizations nationwide, this is a reality far from reach. The Electronic Health Record can be seen as a Health Information System in the context of globalization, since it enhances the interoperability between different systems having as one of its main features the integration of different information resources. These systems have several advantages among which we can highlight the rapid access to useful information needed for decision-making at the care point, safety and data confidentiality promotion, centralization and constantly updated information, the information structuring according with medical standards and the promotion of statistical control and performance optimization.

As future work we intend to develop a pilot project (of symbolic dimension), in order to test and validate the proposal presented in this paper. It will be developed a module of an EHR, in which it will be integrated different information sources related to it. For this we intend to develop Application Programming Interfaces (API), according to a strict definition of the data type, operations and data transfer semantics, pre-conditions, post-conditions, handling errors or exceptions, and syntax error messages to show at the interface of the application systems.

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