Electronic Health Records and Decision Support Local and Global Perspectives

JOSÉ NEVES[1], MANUEL SANTOS[2], JOSÉ MACHADO[1], ANTÓNIO ABELHA[1]
Departamento de Informática[1], Departamento de Sistemas de Informação[2]
Universidade do Minho
PORTUGAL
jneves@di.uminho. pt mfs@dsi.uminho.pt jmac@di.uminho.pt abelha@di.uminho.pt

SOLLARI ALLEGRO, MARIA SALAZAR
Centro Hospitalar do Porto, EPE
Porto
PORTUGAL
SollariAllegro.admn@hgsa.min-saude.pt msalazar@hgsa.min-saude.pt

Abstract – Safer, less expensive, and higher-quality health care can be achieved using clinical decision support (CDS), although the use of CDS often leads to disappointing results. Various problems and limitations can be pointed being the most frequently referred by the physicians the inadequate implementation of the clinical workflow. Electronic Health Records (EHR) and Patient Health Record Systems (PHRS) can play an important role in CDS mitigating those limitations and enabling the effective use of the archived information in the support of the clinical practice and generating the right knowledge to make decisions. The availability of such knowledge is crucial either, for the hospitals and for the government institutions. This brings new requirements for the EHR and PHRS conception and for the use of the information out of the boundaries of the hospitals and health centers. Interoperation and open models constitute the greater challenges that EHR enfaces in the very next future. This paper presents a survey on the design, development and implementation of PHRS in terms of organizational, regional, national and worldwide initiatives. Finally is presented the EHR implementation in the Hospital Geral de Santo António, EPE, one of the major hospitals in the North Region of Portugal.

Key Words - Electronic Health Records, Electronic Medical Records, Electronic Patient Record System, Interoperation, Terminologies

1 Introduction

In recent days Google launched in USA the Google Health service as a way to record and to make available personal medical information. Registered users can introduce and access to medical information in any place and at any time. On the other hand, health care providers can upload medical information and test results automatically. Unlike the USA, the Law in Portugal and in the Europe are more restrictive concerning the open access to medical or clinical data. Portugal is making a great effort in the area of information technologies (e.g. through the governmental technological program) that in turn has having a significant impact in the health care organizations like the hospitals and the regional health administrations. The electronic health record is receiving a great attention and various projects are on the ground. Nevertheless, some issues should be taken into account in order to enable, in the future, an effective interchange of health information among the different organizations and the government.

Patient and Health Record Systems (PHRS) which record detailed clinical or medical information that can be shared or joined electronically within and between a range of local organizations are the "holy grail" for the governmental and academic work groups [1]. PHRS can play a principal role in the National Health Service (NHS), enabling a more efficient and fast interchange of information, and consequently a better quality of patient care. In addition, they can support clinical decision making.

In Europe various organizational, institutional, governmental and private initiatives are in course, having the some common main proposes the standardization, the definition of functional models, minimal data sets and interoperability.

Electronic Health Records (EHR) depends on three areas:

– Terminology;
– Structure;
– Interoperability in Communication.

These three areas constitute the basic pillars on which organizational, regional, national or even worldwide EHR, should be designed and developed.

The semantic interoperability is becoming the top challenge to the implementation of the EHR. Some different and, in some aspects, divergent initiatives are in course to address interoperability issues:

- Information models (e.g. HL7 Reference Information Model RIM, CEN Continuity of care and EHRcom);
- Architectures (e.g. HL7 Common Document Architecture CDA, CEN EHRcom);
- Context (e.g. Templates or Archetypes) and the diversity of clinical terminologies (e.g., departmental, nacional).

Although the regional and national efforts, hospital (and other health care organizations) initiatives should be taken into account in order to gain momentum towards an effective EHR.

After this introduction, the paper contains a chapter dedicated to background concepts. In the chapter 3 the most important players on the area are presented. The chapter 4 summarizes the principal EHR initiatives. Chapter 5 is dedicated to the EHR implementation in the Hospital Geral de Santo António, EPE, one of the major hospitals in the North Region of Portugal. Finally, in the chapter 6, some conclusions are depicted.

2 Background

2.1 Definitions

The data representation methodologies, recording and diffusion of medical and clinical data have being object of various studies, and it can be found a great number of projects and initiatives around the world. The stakeholders and shareholders fluctuate from the governmental and academic institutions to Information Technologies (IT) enterprises. Moreover, a great number of vocabularies and semantic issues can be found to designate similar concepts, and in some cases, the same term is assigned to different things. Below are presented some of those terms in alphabetic order:

CCR Continuity of Care Record;
CMR Computerized Medical Record;
CPR Computer-based Patient Record;
DMR Digital Medical Record;
EHR Electronic Health Record;
EHRS Electronic Health Record System;
EMR Electronic Medical Record;
ePHR Electronic Personal Medical Record;
EPR Electronic Patient Record;
HIE Health Information Exchange;
ICRS Integrated Care Record Services;
LHII Local Health Information Infrastructure for EHRs;
PCR Patient-carried (Card-based) Patient Record;
PER Patient Electronic Record;
PHR Personal Health Record;
PMR Patient Medical Record;
PMRI Patient Medical Record Information;
RHIO Regional Health Information Organization.

Some works are in course to generate consensus in this matter [3][4]. In order to establish a referential, the most important terms where defined by the National Alliance for Health Information Technology [8], which divided the terms into two categories: health information technology terms and health network terms.

2.2. Health Information Technology Terms

Electronic Medical Record (EMR) - An electronic record of health-related information on an individual that is created, gathered, managed, and consulted by licensed clinicians and staff from a single organization who are involved on the individual's health and care.In contrast to what is found in an EHR, data in an EMR do not have to be incorporated electronically via interoperable protocols from sources not affiliated with a provider organization.
An EMR may include:

- Past and present clinical information on an individual, resulting from care rendered by a single provider organization;
- Observations and clinical findings noted by a physician, physician's assistant, nurse, or other clinician during an ambulatory care encounter;
- Test results arising out of such care providing procedure;
- Information arising from patient-provider contact that happens outside of the clinical setting, such as information that may be transmitted by telephone or email;
- Information and data resulting from care outside of the organization that is requested or ordered by the clinician of record and is manually entered by the organization's staff.

- The data in an EMR are:
- Recorded by clinicians and staff in a single organizational setting;
- Updated as new information becomes available;
- Accessible according to applicable federal, state and organization rules and regulations governing care of individuals.

Electronic Health Record (EHR) - An aggregate electronic record of health-related information on an individual that is created and gathered cumulatively across more than one health care organization and is managed and consulted by licensed clinicians and staff involved in the individual's health and care.

In addition to the information provided in an EMR, an EHR may also include:

- Past and present clinical information incorporated electronically from all organizations that have been engaged in an individual's care or health maintenance;
- Administrative information pertinent to making clinical judgments and cost-sensitive decisions. Examples include an individual's DNR (do not resuscitate) order, or a living will/power of attorney for health care;
- Population-based data from sources such as disease registries and initiatives to detect disease outbreaks;
- Information to facilitate optimal management and coordination of an individual's care across multiple settings and providers. (e.g. ontact information for family management);
- Information that can be interjected into a clinical situation or used to interpret data on an individual to support and improve clinical decisions. (e.g. drug/drug interactions);
- Information on evidence based medicine, scientific research studies, or environmental situations;
- Information from remote monitoring devices, which capture real time data on vital signs, namely cardiac or respiratory status, lab data.

The data in an EHR are envisioned to be:

- Updated regularly to reflect the most recent data and information available in order to provide an accurate record of an individual's care;
- Capable of being accessed at the point of care; providers retain the decision over how to execute this capability within the confines of legal accessibility requirements;
- Capable of secure, authenticated, and authorized remote access.

EHR vs. EMR

These definitions launched a deep discussion on the effective differences between EMR and EHR. The authors, like Tom Trabin (HL7 EHR Technical Committee), based on the collected experience of EMR/EHR systems implementations on various institutions, argue that EMR is more an historical perspective than a definition. A future view should deprecate the narrow term EMR keeping the broader term EHR.

Electronic Health Record System (EHRS)

The IOM's 1991 report, The Computer-Based Patient Record: An Essential Technology, and updated in 1997 (Dick, R.S, Steen, E.B., & Detmer, D.E. (Editors), National Academy Press: Washington, DC) defined an EHR System as:

> The set of components that form the mechanism by which patient records are created, used, stored, and retrieved.
>
> A patient record system is usually located within a health care provider setting. It includes people, data, rules and procedures, processing and storage devices (e.g. paper and pen, hardware and software), and communication and support facilities.

The 2003 IOM Letter Report, Key Capabilities of an Electronic Health Record System, defined the EHR System as counting:

> Longitudinal collection of electronic health information for and about persons, where health information is defined as information pertaining to the health of an individual or health care provided to an individual immediate electronic access to person- and population-level information by authorized, and only authorized, users provision of knowledge and decision-support that enhance the quality, safety, and efficiency of patient care; and support of efficient processes for health care delivery.

The 2003 ISO/TS 18308 references the IOM 1991 definition above as well as CEN 13606, 2000:

> A system for recording, retrieving and manipulating information in electronic health records.

Electronic Personal Health Record (ePHR) - An electronic, cumulative record of health-related information on an individual, drawn from multiple sources, that is created, gathered, and managed by the individual. The integrity of the data in the ePHR and control of access to it are the responsibility of the individual. Sources may include, but are not limited to:

- Health care providers;
- Health care clinicians;
- Medical devices;
- Wellness promoters;
- Individuals;
- Health insurers;
- Public health services;
- Research institutions.

2.3 Health Network Terms

Health Information Exchange (HIE)

The electronic movement of health-related data and information among organizations according to agreed standards, protocols, and other criteria.

Regional Health Information Organization (RHIO)

An organization that brings together health care stakeholders within a defined geographic area and governs the electronic exchange of health-related information among them for the purpose of improving health and care.

Can arrange for the provision of additional technical and operational services supporting its primary purpose. Such services may vary based on stakeholder needs and a range of environmental factors. It includes:

- The technology and support for physicians to create and use electronic records, delivered to their places of work through Internet connections by application service providers (ASPs);
- Electronic exchange of messages in a secure format to report and distribute medical test results;
- Data on specific patients to first responders in a community; for example, whether a patient has signed a DNR (do not resuscitate) directive;
- Coordinated electronic health record and personal health record platforms for the region;
- The "regional" in RHIO defines a variable area that is less than national but can be broader than legislative boundaries (e.g. state lines, city limits). This latitude allows the determination of geographic boundaries logical to a set of stakeholders seeking to pursue the objectives of a RHIO. A RHIO can be organized to support a community, groups of communities, a statewide area or a region crossing state boundaries.

3 Players

Several organizations are involved in a standardization work in order to promote the interoperability and a unified model of EHR. Table 1 presents a list of the principal players and their contributions.

Table 1 – Players

Players	Contribution
HL7	EHR System Functional Model and Interoperability; Interoperability Model and Lifecycle Model.
EUROREC Institute and PROREC (Ireland)	EHRs certification development, testing and assessment by defining functional and other criteria.
CEN – European Committee for Standardization, CENELEC - European Committee for Electrotechnical Standardization, and ETSI - European Telecommunications Standards Institute	'eHEALTH-INTEROP', which will address the requirements of the European Commission mandate on standardization in the field of e-health
ISO	ISO EHR Standards openEHR ISO 18308 - 2009Requirements for an Electronic Health Record Reference Architecture2009 ISO/DTR 20514 – Electronic Health Record Definition, Scope and Context
CCHIT - Certification Commission for Healthcare Information Techno	Certification of EHR Systems
NAHIT - National Alliance for Health Inf. Technology	Terms definition

4 EHR Initiatives

Table 2 synthesizes the EHR initiatives among various countries, identifying the projects and the correspondent stakeholders and shareholders. The financial means are also referred to [2].

Table 2 – EHR Initiatives

Country	Initiative	Stakeholders / Shareholders	Funding
Australia	Health Connect	National E-Health Transition Authority (NEHTA)	$160AUD
Canada	Health Infoway. Canada has created a national framework to guide the development of an interoperable EHR across its jurisdictions, with each one determining its own implementation strategy	Federal, provincial and territorial governments	$1.2 billion 2003 $1 billion 2007
England	Government-centered EHR The National Care Record Service Program began implementation via a nationwide procurement process that resulted in one National Application Service Provider (NASP) and five Local Service Providers (LSPs). The EHR information model is based on HL7 v3 RIM, updated and queried through HL7 v3 messaging.	National Health Service (NHS)	
Finland	Finland's national objective is to secure the access to information for those involved in care regardless of time or place. The means used to achieve that objective have include: • a comprehensive digitalization of patient data • development of the semantic and technical compatibility of the electronic patient record systems in regard to the entire content of a record • development of the national health care infrastructure and • information network solutions, identification and verification solutions and electronic signature • maintaining of information that supports decision making on the net.	National Insurance Institution, the National Authority for Medico Legal Affairs, the association of Finnish Local and Regional Authorities, HL7 Finland,, the University of Kuopio, Duodecim, the Office of the Data Protection Ombudsman and the Ministry of the Interior's Municipality IT Unit.	Regional implementation projects - about 20 million Euros/year 2004-2007, 50 % funding by the ministry.
Israel	A national program does not exist however, EHR implementations are widespread in both the public and private sectors. A survey was conducted within Israel to evaluate the status of electronic		

Country	Initiative	Stakeholders / Shareholders	Funding
	medical record (EMR) systems in all major general hospitals in terms of the applications used and the patterns of use. Of the 26 general hospitals, 21 (91.3%) use EMR systems.		
Japan	Currently does not have a government-centered EHR however, some local, regional and single hospitals have installed digital patient records sharing data between hospitals, clinics and patients.		
Norway	Is conducting research that is expected to lead to a national EHR program		Research Council of Norway awarded Norwegian University of Science and Technology (NTNU) a contract to establish The Norwegian Electronic Health Record Research Centre (NSEP). The center receives annual funding of NOK 5 million to strengthen and develop an interdisciplinary research group with competence in health research, ICT and social sciences.
Portugal	A 10 years program was establish in 2007 that includes the promotion of the communication among the systems. No particular attention was given to the EHR problematic.	Governmental – Health System Central Administration (ACSS)	299 205 307 Euros
South Africa Sweden Germany France Netherlands	Government-centered EHR		All are providing government funding to support committees that are developing EHR strategies for a national system. Sweden, France and South Africa have already moved towards a government-funded national system, while Germany and the Netherlands have not yet formally committed to this model.
USA	is still working towards developing standards. This is complicated by the fact that there are so many vendors to choose from when compared to other nations. This tends to widen the gap in interoperability.	Federal government	Although the federal government has introduced some legislation to support the implementation of EHRs, unlike most other countries it has not mandated its use nor provided adequate funding sources for nationwide implementations.

5 EHR in Hospital Geral de Santo António

Hospital Geral de Santo António (HGSA) integrates the Oporto Hospitals Centre in the North Region of Portugal. The HGSA's mission is to deliver an health care humanized, be competitive and a reference, promoting their linkage with the other partners in the system, the recovery of pre-and post-graduate education and training; promotion and encouragement of scientific research and development in health.

5.1 Motivation

Because the internal requirements for the Electronic Health Record were not compatible with the existing software in the market, the HGSA board of directors decided to develop a specific solution establishing cooperation with the University of Minho, in the North Region of Portugal.

5.2 Goals

The main goals of the EHR can be summarized as follows:

- To provide a secure, reliable, efficient, clear and structured way to register all the data collected about the patient, the pathologies and therapies;
- To reproduce and to complement the information registration processes as well its dissemination;
- To register the patient clinical situation and corresponding assessments by the health professionals;
- To support the actions taken related to the clinical practice and patient treatment;
- To support preventing actions and health promotion;
- To support the health care services continuity;
- To provide explicit evidence of health care services;
- To satisfy legal and professional requirements.

5.3 Results

The principal results attained can be, in turn, enumerated as follows:

- The increase of the rigour and reliability of the data registered in the clinical process;
- The decrease of the storage and logistic costs of the documents;
- Drastically decrease of the number and gravity of errors, omissions and ambiguities;
- The ubiquity of the processes, ever-present in the network;
- The increase of the security of information storage and handling;
- The time saving in handling the patient information (e.g. therapies, exams, prescriptions);
- The support for the "business continuity" among different professionals;
- The incremental migration from the paper based process to the electronic based one (towards to a paper free hospital).

5.4 Modus Operandi

The process to collect data comes from Problem Oriented Medical Record (POMR) method. This is a format for clinical recording consisting of a problem list, a database including the patient history with physical examination and clinical findings, diagnostic, therapeutic and educational plans and a daily SOAP (Subjective, Objective, Assessment and Plan) progress note, based on the quality of information being processed. The problem list serves as an index for the reader, each problem being followed through until resolution. This system widely influences note keeping by recognizing the five different phases of the decision making process, i.e. data collection, problem specification, devising a management plan, reviewing the situation and revising the plan if necessary [10][11]. The complete live cycle is depicted in Fig. 1.

5.4 The Computational Model

With respect to the computational paradigm it were considered extended logic programs with two kinds of negation, classical negation, $\neg$, and default negation, not. Intuitively, not p is true whenever there is no reason to believe p (close world assumption), whereas $\neg$ p requires a proof of the negated literal.

An extended logic program (program, for short) is a finite collection of rules and integrity constraints, standing for all their ground instances, and is given in the form:

$$p \leftarrow p_1 \wedge \ldots \wedge p_n \wedge \text{not } q_1 \wedge \ldots \wedge \text{not } q_m; \text{ and}$$
$$? \; p_1 \wedge \ldots \wedge p_n \wedge \text{not } q_1 \wedge \ldots \wedge \text{not } q_m, \; (n,m \geq 0)$$

where ? is a domain atom denoting falsity, the p_i, q_j, and p are classical ground literals, i.e. either positive atoms or atoms preceded by the classical negation sign $\neg$. Every program is associated with a set of abducibles. Abducibles can be seen as hypotheses that provide possible solutions or explanations of

given queries, being given here in the form of exceptions to the extensions of the predicates that make the program.

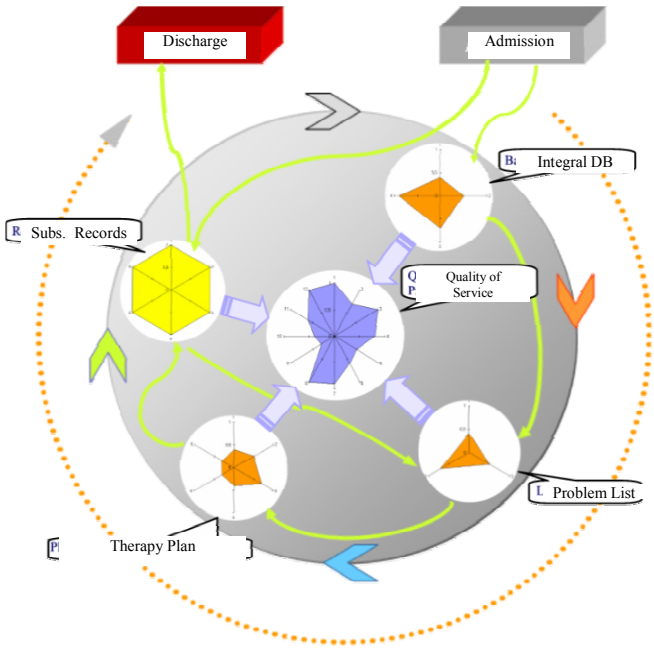

Fig. 1 – EHR Life Cycle

Indeed, in our approach, we will not get a solution to a particular problem, but rather a logic representation (or program) of the universe of discourse. On the other hand, logic programming enables an evolving program to predict in advance its possible future states and to make a preference. This computational paradigm is particularly advantageous since it can be used to predict a program evolution employing the methodologies for problem solving that benefit from abducibles, in order to make and preserve abductive hypotheses. It is on the preservation of the abductive hypotheses that our approach will be based to present a solution to the problems posted by the EHR Life Cycle (Fig. 1).
Selecting an abstract and general logical representation or program, performance metrics are clearly difficult to devise. Programs have to be tested on their ability to adapt to a changing environment, to make deductions and draw inferences, and to choose the most appropriate course of action from a wide range of alternatives. Above all they have to learn how to do these things on their own, not by implementing specific instructions given to them by a programmer, but by continuously responding to positive and negative environmental feedback.

In order to accomplish such goal, i.e., to model the universe of discourse in a changing environment, the breeding and executable computer programs will be ordered in terms of the quality-of-information that stems out of them, when subject to a process of conceptual blending. In blending, the structure or extension of two or more predicates is projected to a separate blended space, which inherits a partial structure from the inputs, and has an emergent structure of its own. Meaning is not compositional in the usual sense, and blending operates to produce understandings of composite functions or predicates, the conceptual domain, i.e., a conceptual domain has a basic structure of entities and relations at a high level of generality (e.g., the conceptual domain for journey has roles for traveler, path, origin, destination). In our work we will follow the normal view of conceptual metaphor, i.e., metaphor will carry structure from one conceptual domain (the source) to another (the target) directly.

Therefore, let i ($i \in \{1,\ldots,m\}$) denote the predicates whose extensions make an extended logic program that model the universe of discourse, and j ($j \in \{1,\ldots,n\}$) the attributes for those predicates. Let $xj \in [minj, maxj]$ be a value for attribute j. To each predicate it is also associated a scoring function $Vij\ [minj, maxj] \rightarrow 0\ldots1$, that gives the score predicate i assigns to a value of attribute j in the range of its acceptable values, i.e., its domain (for the sake of simplicity, scores are kept in the interval 0…1), here given in the form:

all(attribute_exception_list, sub_expression, invariants)

This states that sub_expression should hold for each combination of the exceptions of the extensions of the predicates that denote the attributes in the attribute_exception_list and the invariants. This is further translated by introducing three new predicates. The first predicate creates a list of all possible exception combinations (e.g., pairs, triples) as a list of sets determined by the domain size (and the invariants). The second predicate recurses through this list, and makes a call to the third predicate for each exception combination.The third predicate denotes sub_expression, given for each predicate, as a result, the respective a score function. The Quality of the Information (QI) with respect to a generic predicate K is therefore given by QIK=1/Card, where Card denotes the cardinality of the exception set for K, if the exception set is not disjoint. If the exception set is disjoint, the quality of information is given by:

$$Q_K = \frac{1}{C_1^{Card} + \ldots + C_{card}^{card}}$$

where C_{card}^{card} is a card-combination subset, with card elements. The next element of the model to be considered, it is the relative importance that a predicate assigns to each of its attributes under observation; wij stands for the relevance of attribute j for predicate i (it is also assumed that the weights of all predicates are normalized, i.e. [7]:

$$\sum_{1 \le j \le n} \text{wij} = 1, \text{ for all i.}$$

It is now possible to define a predicate's scoring function, i.e., for a value x = (x1,…,xn) in the multi-dimensional space defined by the attributes domains, which is given in the form:

$$\text{Vi}(x) = \sum_{1 \le j \le n} \text{wij Vij}(xj).$$

It is now possible to measure the QI that stems from a logic program, by posting the Vi(x) values into a multi-dimensional space and projecting it onto a two dimensional one. Under this procedure, it is defined a circle, as the one given in Fig. 2. Here, the dashed n-parts of the circle (in this case built on the extensions of 5 (five) predicates, named as p1…p5) denote the QI that is associated with each of the predicate extensions that make the logic program P. It works out the most promising extended logic programs or theories to model the universe of discourse that make the optimal solution, subject to formal proof, to the problem.
It is now possible to return to the case referred to above, where we had a series of data that is produced according to a set of patient attributes, being got all time along (Fig. 2).

5.5 State-of-art

The EHR is now in use in the services of the hospital covering the work settings:

- In-patient;
- Out-patient;
- Day Hospital;
- Operative Block.

All the information systems (e.g. Labs Software, PACS, RIS, HIS) of the hospital interoperate through the AIDA platform supporting the exchange of information into and from the EHR [4] [5] [6] [9].

Some adoption of EHR indexes are presented in Table 3 and 4. The first one shows the internal impact in terms of the use of the EHRS. The second one shows the external impact in terms of the absolute number of patients covered.

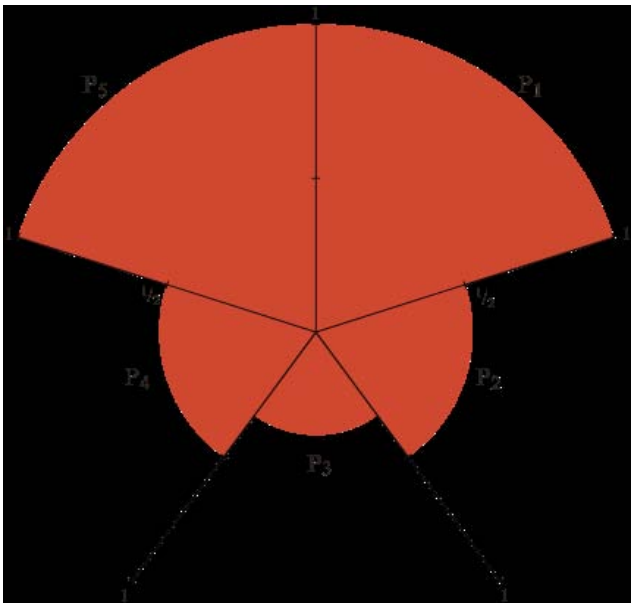

Fig. 2 - A measure of the quality-of-information for logic program or theory P

Table 3 - Internal Impact

Functionality	Services	Number of Professionals
Global EHR	38/38 = 100%	610/763 = 80%
Admission	29/38 = 76%	311/763 = 41%
Discharge	26/38 = 68%	297/763 = 39%
Test Results	38/38 = 100%	1044/1044 = 100%

Table 4 - External Impact

Number of EHRs	Number of Tests
28092	264763

6 Conclusions

Several counties and countries around the World are promoting projects towards an effective interchange of health records among institutions. This paper made a snapshot of the ongoing initiatives and the way they are being coordinated and financed.
In Portugal we do not recognize a formal governmental initiative to deploy a national,

interoperable EHR system. Looking for successful projects is highly recommended in order to avoid some mistakes. The evidence shows that we should start setting standards, finding adequate funding and establishing good communications with consistent messages. Some implementations like the presented in Hospital Geral de Santo António should be used as a starting point, once it not only presents a formal model, subject to proof, to address the problem, but also an implementation.

Acknowledgements

Financial support for this study was received from the FCT project PTDC/EIA/72819/2006 and from the Algoritmi research center

References:

[1] House of Commons of London - Health Committee, *The Electronic Patient Record, Sixth Report of Session* 2006 –07 Volume Report, September, 2007.

[2] Steve Arnold, Joseph Wagner, Susan J Hyatt, Gary M. Klein, and the Global EHR Task Force Members, *Electronic Health Records: A Global Perspective Overview*, 2007.

[3] Office of the National Coordinator of USA, *Defining Key Health Information Technology Terms,* Draft report prepared for the second public comment period March 24 – April 8, 2008.

[4] Abelha, A., Machado, J., Santos, M., Sollari, A., Rua, F., Paiva, M., Neves, J. *Agency for Integration, Diffusion and Archive of Medical Information*, Proceedings of Third IASTED International Conference on Artificial Intelligence and Applications, Malaga, Spain, September, 2003.

[5] Machado J., Abelha A., Santos M. and Neves J., *Multi-agent Based Problem Solving in Medical Decision Support Systems*, in Proceedings of the 2nd International Conference on Knowledge Engineering and Decision Support, Lisbon, 2006.

[6] Machado J., Abelha A., Neves J., and Santos M.. *Ambient intelligence in medicine*, In Proceedings of the IEEE-Biocas 2006, Biomedical Circuits and Systems Conference, Healthcare Technology, Imperial College, London, UK, 2006.

[7] Neves, J. C., *A Logic Interpreter to Handle Time and Negation in Logic Data Bases*, Proceedings of ACM 1984 Annual Conference, San Francisco, October 24-27, U.S.A., 1984.

[8] http://www.nahit.org/cms/images/docs/hittermsfinalreport_051508.pdf (Consulted in 30th May 2008).

[9] Alves V., Machado J., Abelha A. e Neves J., Agent Driven Diagnosis in Medicine, in proceedings of the 6th WSEAS International Conference on Mathematics and Computers in Biology and Chemistry (MCBC 05), Buenos Aires, Argentina, 2005.

[10] Alves V., Machado J., Abelha A. e Neves J., Agent Based Decision Support Systems in Medicine, in WSEAS on Biology and Biomedicine, Issue 2, Volume 2, 2005.

[11] Abelha A., Machado J., Alves V. e Neves J., Health Data Management in the Medical Arena, in WSEAS Transactions on Computers, Issue 6, Volume 3, ISSN 1109-2750, 2004.