Architecture Evaluation for the Implementation of a Regional Integrated Electronic Health Record

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Abstract

The interconnection between different healthcare information systems is not yet a trivial task. Solid communication infrastructures do exist, solid solutions for Health Information Systems (HIS) are installed, but, unfortunately, too many different solutions hinder the integration of HIS at a regional, national or European level.

In this paper we propose a solution and an implementation of an Integrated Electronic Health Record that is a composition of two distinct integration models – centralized and distributed. We exploit this solution against a set of predefined users and institutional requirements, at a regional level in two Portuguese regions. As a conclusion, an evaluation of the cost and inherent benefits is made involving the clinical, economical and organizational perspectives.

Keywords:
Regional Health Planning, Medical Record Linkage, EHR, Health Systems Plans, EPR

1. Introduction

Despite the massive introduction and wide usage of Health Information Systems during the last decade, several problems still exist in these scenarios, most of them related with the lack of integration.

With the evolution of the health information and communication systems, it is now the time for the implementation of systems that allow the unification of the existing Electronic Health Records (EHR). For that, and taking into account the existing architectures, it is necessary to perform an analysis of the architectural possibilities and optimize the mix between them, in order to maximize the benefit from the implementation of such systems.

The analysis scope must include, not only the necessary means required to unify the EHR’s, but also the required maintenance and support and, if possible, the creation of an archive that allows the integration of the already existing information, scattered and stored in the systems of the multiple players of the health care provision value chain.

In this paper, we define and describe four main models for the implementation of an Integrated Electronic Health Record (I-EHR), and, in order to perform the implementation analysis of each model, we identify the geographical region where it is to be implemented, identifying and quantifying the number of institutions and involved professionals, as well as the demographic status of the region. It is also presented a methodological evaluation framework that considers the technological, clinical and economic perspectives. Finally it is presented an application of the methodological framework to the proposed architecture and a qualitative cost-benefit analysis is made.
2. Materials

For the definition of concepts, we hereby present the formal definition of Integrated Electronic Health Record (I-EHR) and present four versions of architectures that can be adopted to support its implementation.

According to [1], an I-EHR is a collection of all of an individual’s lifetime health data in electronic form, generated during relevant interactions with the healthcare system. In addition to providing support for continuity of care, the I-EHR may prove to be a valuable tool in basic and clinical research, medical decision making, epidemiology, evidence-based medicine, and in formulating public health policy.

Multiple benefits, and associated effort, can arise from the implementation of such a system at a regional or national scale [2, 3]. The benefits can be identified among multiple dimensions, with the most relevant being the clinical and economical, but still with identifiable benefits in the scientific, technological and organizational dimensions.

3. Reference architectures for the implementation of an I-EHR

In what concerns the integration of autonomous and distributed systems, four approaches can be taken. The first, based on a message-based architecture, the second and third one based in the system federation architecture, which are be further subdivided into physically and virtually federated architectures, and finally the fourth one, an evolution of the virtually federated architecture, that is the virtually unique electronic health record (VUEHR) architecture. We briefly present the first three and then make a more detailed analysis of the fourth model in what concerns interoperability, modularity and scalability, migration, stability, management, maintenance, security and, finally, its cost effectiveness.

The message based architecture [4] is characterized by data communication between systems that rely on message communication protocols, with the data structures and message contents following a standardized structure.

The physically federated architecture is based on the existence of a centralized system that gathers all the information from the autonomous distributed systems into a centralized structure, where data is structured, indexed and normalized and further integrated with administrative and medical emergency data [5-8].

The virtually federated architecture is based on the integration of the clinical information components through the use of a set of structured pointers that reference the remote location of the patient data, geographically and physically scattered. This model also demands the existence of a centralized structure, as in the physically federated architecture, that has lower storage and communication requirements. The most simplistic implementation structure can be based in a server unit with a search engine that guarantees the federated structure [9].

Finally, the virtually unique electronic health record (VUEHR) architecture, a model we have developed and proposed in [10, 11] and that has been refined since, provides access to integrated patient information scattered among different systems inside the health provision network. It is based on a smart card containing card-owner information, as well as structured references to its electronic records. The card securely supports the reference structured data set, and the implementation of Public Keys Cryptography and Crypto Smart Cards unequivocally provides a way to securely store, transport and access the card-owner information. It also grants the user full control over the access to its data, through a PIN and/or biometric registration and also allows the card-owner to entitle information access levels to other users such as the healthcare professionals. The main benefits can be characterized by highly scattered geographical storage requirements; a scalable architecture with great flexibility in the addition of new healthcare providers systems to the federation with no impact in the existing systems, guaranteeing an implementation phased approach. It is also a highly reliable model, due to its simplicity and operational and functional independence from any type of centralized unit. The model empowers of patient user,
enabling the discretionary access to data, when crossed with the healthcare professional card, and allows open access to the medical emergency data. The system is technology independent and its only requirement is that the institutions provide Web access to patient information and support authentication with digital certificates. The information duplication problem is therefore reduced and the anonymization of data is intrinsic to the system.

4. Methods

We now proceed into describing the region where the I-EHR is to be implemented, in demographic and health care current status, and presenting the users that will be subject to the implementation of such a system. We will then present the evaluation framework that will help us perform the evaluation of the architecture mix that supports implementation.

Region geographical and health care characterization

The region to be analyzed is located in the central sea side of Portugal and is constituted by two NUTS III regions (Baixo Vouga and Entre Douro e Vouga) [12] that are made up of 17 Local Administrative Units (municipalities), scattered by 2.264 square kilometers and comprising 662.536 inhabitants [13].

There are 17 health centers (primary care units), one per municipality, that have 128 local extensions to the small villages. These units employ 1.520 persons, of which 463 are doctors and 314 are nurses.

The region has 8 hospitals (secondary care units) comprising 22 medical and 37 surgical services, 6 intensive care units, 13 clinical pathological services and 19 imaging services [14]. The total staff comprises 3.470 employees, of which, 578 are doctors and 1163 are nurses. It also has 3 privately owned hospitals for which no data is available.

It comprises 169 pharmacies that employ 399 workers, of which 302 are pharmacists.

5. Evaluation framework

The proposed architecture will be a mix of the previously described federated architectures and that will have to comply with the following evaluation framework items [15-17]:

Technical compatibility with other systems and existing legacy systems, including issues such as upgradeability, maintenance, data consistency and adaptability to changing requirements, as well as security and user identification aspects, with these aspects being the fundamental key issues to be considered;

Professional and patient user acceptance, including addressing professional clinical and business needs as well as structural process related impact and impacts in the quality of care provided, aligning these issues with the technical ones but not making them fundamental;

Economical viability of the proposed solution, with calculation of upfront investment and operational costs, as well as cost effectiveness and benefits, thus generating the return on the investment made will be an important aspect of the evaluation, that is heavily related to the technical options made early in the project;

Other aspects such as the social consequences of the implementation of such a system are considered as out of scope from this paper.

6. Results and Discussion

Taking into consideration the previously presented geographical and health specifications of the region under analysis, we now discuss the task of finding the optimal architecture for the system in order to implement the regional I-EHR.

On a top down approach, we would select as the main architecture that would gather all the institutions and participants, the virtually unique electronic health record architecture. It was selected since it provides maximum flexibility in the integration of the different, heterogeneous institutions and at the same time is scalable enough in order to be extensible to other regions that would adopt this architecture with minimum cost. On the down side, it
will demand the issuance of new health cards, powerful enough to retain the references created in each interaction with the health institutions, and will demand the integration of the existing software into “institutional data centres”.

Analysing the involved institutions, we start with the health centres and its extensions. Since they share similar processes and users, and taking into consideration that they are scattered in relatively small geographical areas, with good coverage of telecommunication services, we propose the interconnection of the health centre to the extensions using the physically federated architecture with the integration and storage of the data to be placed in the main health centre. All the data placed in the data centre, as a result of consultations, prescriptions and other clinical and/or administrative actions, would be referenced to the upper integration level according to the procedures described in the virtually unique electronic health record (VUEHR), with the information stored in the data centre and with a reference placed in the patient health card [18].

The implementation of this option, in what regards the health centers, can be phased over time, starting from the smaller to the bigger ones, with the main requirement being that the health center and its extensions are treated as a single unit and integrated in a one shot basis. Due to the similar nature of the software to be integrated, the experiences and the work performed can be replicated in the subsequent integration efforts, lowering the integration costs and efforts.

In what concerns the hospitals, the architectural option to be taken must allow that the involved services (medical, surgical, intensive care, pathological and imaging) are treated as different units, being able to phase the integration effort of its legacy systems into the main hospital data center according to their own schedule. As in the case of the health centers, it must be noticed that, since the same services, in different hospitals, share the same applications, the integration effort can be replicated among them, thus diminishing the economical integration effort.

The providers of external diagnosis services, that perform clinical exams externally to the hospitals and health centres can, with the implementation of this model, improve their workflow efficiency, with integrated exam scheduling and with online availability of the examinations performed.

The pharmacies that belong to the network only need to access the information regarding the medicines prescribed by the physicians in the health center or the hospital. However, since they all share similar management information systems, there is also the option of integrating this system into the network.

![General Architecture for a Regional Integrated EHR](image-url)
7. Conclusion

The results obtained in this study show us that there is no single architecture that can provide all users of the system with maximum results. This objective can only be achieved with the development of a “best of breed” architecture that gathers the best features and adapts them to the local needs and processes. It is shown that some of the units of the system (hospitals and health centres) need to have a preliminary, internal integration using the physically federated architecture in order to gather information from all the underlying units, which then interconnect into a network where the architecture is the virtually unique electronic health record (VUEHR) and that allows the access of all users to all the information, no matter what is the internal architecture adopted by them. The same applies to the remaining institutions where, independently of their size, they can with little integration effort, enter the network and access information provided by all parties. The architecture main components are shown in Figure 1.

Analysing the process in more detail, as mentioned previously, the implementation of this system requires three major activities to be performed concurrently.

First, the implementation of a regional high capacity communications infrastructure that is able to interconnect all the participant institutions.

Secondly, the need to integrate all the existing information systems in health institutions data centers, although it is possible to reuse some of the integration effort since they share similar applications from a reduced universe of sellers.

Thirdly, and the most demanding effort of them all, it is necessary to issue new health cards into the universe of 662,536 inhabitants and 5,389 health professionals employed in the health centers, hospitals and pharmacies of the region.

From a technical point of view, this approach can be implemented with the integration of the existing legacy systems with the new data center structure, thus maximizing the use of the existing software infrastructure and guaranteeing the backwards compatibility of the existing data. The maintenance effort of the central structure is almost inexistent, with the core of the maintenance effort taking place in the institutional health centers. On the security side, it is guaranteed that the clinical data can only be accessed with consent from the patient and, on the other hand, the data physical storage always remains under supervision of the health center. The security tunnelling would also be established automatically between the data center and the access point through the use of digital certificates. The professionals belonging to these institutions would also be able to maximize their requirements, having access to an I-EHR that complies with the requirements previously exposed.

The economical evaluation, at this stage, needs to be performed qualitatively since quantitative data are still not available. However, we can say that the integration effort is probably the main technical and economical difficulty, with the main advantage of having little maintenance requirements of the central system, although there are maintenance costs in the local data centres. This benefit can be annulled by the fact that there is the need to issue new cards for the universe of patients and professionals involved.

In a very preliminary benefit study performed using the TEC methodology developed by NCSU [19], we estimated that the implementation of this architecture could signify a yearly savings of 9,23 € per capita, which could mean a total yearly savings of 6,1 million euros in the region considered.

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9. References


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