INFORMATION SYSTEMS HETEROGENEITY AND INTEROPERABILITY INSIDE HOSPITALS
A Survey

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Abstract: This paper presents a study of the heterogeneity and interoperability of Information Systems (IS) that exist in Northern Portuguese Hospitals. Structured interviews to each Hospital CIO were performed regarding their opinions, existing IS and integrations. The number of IS is exponentially related of the dimension of the hospital (number of beds), and the relation between the number of IS and the number of integrations follows an exponential model. The ratio between the number of effective integrations and the total possibilities is very low and follows a quadratic model, indicating that the energy spent grows rapidly with the increase of IS number and with poor results. Admission/discharge/transfer and drug related IS are installed more often, and therefore are better candidates for a regional network. Despite numerous efforts to develop standards, it seems that there is a large gap between their development and their applicability. Interoperability inside organizations is a crucial first step, looking for the goal of achieving regional and national EHR. Standardization is vital considering the number of IS and multitude of organizations involved.

1 INTRODUCTION

It is currently agreed that interoperability in healthcare is a matter of great importance, but also of great complexity. The major challenge is to find a way to allow interoperability between different Information Systems (IS) in order to share information and resources. Interoperability promises a positive effect in the quality of care and also economic advantages (Maldonado et al., 2003, Lenz and Reichert, 2005, Walker et al., 2005, Uslu and Stausberg, 2008).

Several solutions coexist with the aim of facilitating the integration of a growing volume of data, using different standards and technologies. After many years of development in IS, the majority of the healthcare organizations unfortunately are still far beyond achieving open architectures that would allow harmonious integration of computer applications. The creation of a cohesive and integrated Electronic Healthcare Record (EHR) is a more complicated task than initially expected with several obstacles (Zviran et al., 1998, Kitsiou et al., 2006). Consistently combining data from different sources takes a great deal of effort because the individual systems usually differ in several aspects, such as semantics, data representation, functionality, presentation and terminology (Lenz, Blaser et al. 1999; Lenz and Kuhn 2002; Kitsiou, Manthou et al. 2006). In addition, several architectural mismatches exists in the majority of the organizations, bringing additional problems (Land and Crnkovic, 2003).

Interoperability of EHR is on the agenda of the European Union (e.g. EPSOS and Calliope), of many national governments (e.g. MedCom at Denmark, RSEpt at Portugal) and regional initiatives (e.g. RTS at the region of Aveiro in Portugal (Cunha, 2007)). A summary of relevant patient data has been seen as the most appropriate approach for establishing EHR interoperability (Shabtai et al., 2007). Nevertheless, to obtain the full advantages of information sharing (either for patient care,

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management or research), it is necessary to share much more data than just a summary. The European Union in the January 2009 report says that achieving full interoperability across the entirety of healthcare would be a lengthy, expensive and possibly unattainable goal (Veli N. Stroetmann (Ed.) and Karl A. Stroetmann, 2009).

It is also known, that in order to obtain a regional or national patient record it is first crucial to achieve interoperability inside each healthcare organization (Cotter, 2007). The integration maturity model proposed by Schmidt includes four levels of integration (inexistent, point to point, processes and external); it should be noticed that only in this final step is interoperability among different institutions considered (Schmidt, 2000).

This paper describes the heterogeneity and interoperability of IS existing in Northern Portuguese Hospitals, aiming to foresee the integration difficulties in creating a complete regional or national patient record.

2 METHODS

2.1 Study Participants

The participants of this study are all hospitals in the northern region of Portugal (n=34). The hospitals are represented in this study by their Chief Information Officer (CIO).

In the scope of this study we have just considered clinical IS. We have not considered integrations with any medical device.

2.2 Design Study

This is a cross-sectional study representing the reality found in these Portuguese hospitals in the first semester of 2009.

2.3 Data Collection Methods

ARS Norte (Administração Regional de Saúde do Norte – Northern Regional Health Administration) was asked permission to facilitate data collection for the study. After their support it was sent a request for cooperation to each Hospital. Then, the authors sent an email to each hospital CIO involved in the study with the questionnaire attached.

After the CIO returned the questionnaire a process of double validation of the results was performed: (1) the first author of this work, made a phone interview with CIO to confirm the answers given; (2) then the data was sent by e-mail to every CIO so that the results of each interview were validated by them.

2.4 Variable Description

The main variables of the questionnaire can be grouped into CIOs opinions and the reality existing inside their institutions. Variables about opinions:

- How important is interoperability between IS
- What plans for interoperability exist for your institution
- Do you trust the security of the already existing integrations regarding information confidentiality, integrity and availability
- Are there monitoring mechanisms to detect integration errors
- Does the hospital have a plan regarding IS
- If a plan exists, how does it refer to interoperability issues
- Is it better to buy most of IS to one single vendor, or to buy best-of-breed departmental IS from multiple vendors
- Should there be regulation and certification to the IS market regarding integration issues
- Between which stakeholders (e.g. different hospital departments, hospital and social institutions, hospital and primary care) should data exchange be a priority

Variables about reality inside hospitals:

- What IS exist in the hospital
- For each IS:
  - What is the scope (Global or Departmental; the classification of the departmental systems was made based on the list of medical specialties of the National Board of Physicians);
  - Supplier;
  - Relational database management system (RDBMS);
  - Compliance with Architecture Standards. Classification Adapted from (Blobel, 2006)
  - Terminology and Ontology Standards. Classification Adapted from (Blobel, 2006)
- What integrations exist between IS
- For each integration:

I1. The level of the integration. Classification adapted from (Schmidt 2000)
I2. Type of integration;
I3. Type of error detection (none, log, log and automatic alert);
I4. Communication Standards. Classification Adapted from (Blobel, 2006).

Four matrixes were built per hospital (one for each variable regarding each integration, from I1 to I4). Data from all arrays were stored in a relational database, built on MS Access. Finally, we grouped all the matrixes of all hospitals. An example of such matrixes is illustrated in Table 1. Then some data was exported to SPSS for statistical analysis.

Table 1: Example of possible integration matrix between 5 different systems (A to E) regarding variable I1. The letter "d" means integration at the data level; "p" means integration at the presentation level and "l" integration at the logical level.

	A	B	C	D	E
A					
B	d				
C	l	d			
D	-	-	-		
E	d	-	p	-	

3 RESULTS

In this region there are 34 hospitals, most of them are grouped in centers with financial autonomy (24 hospitals are grouped in 9 centers). As for the others, 7 are alone and 3 are grouped in 2 local units of care (local units of care include hospitals and primary care centers). The 7 ungrouped hospitals are either very small or specialized hospitals. To our analysis the number of different institutions considered is 18 (9 centers + 7 individual hospitals + 2 local units of care). The number of beds per hospital varies between 50 and 1083, with a median of 428 beds.

3.1 CIO Opinions

All CIOs (n=18) believe that interoperability is a big issue in the future (72.2% of the responsible state it is a very important issue and of urgent resolution, responding the remaining 27.8% this is a very important issue but not priority at the moment).

Most responsible for the IS have answered they already have projects being implemented or plans to soon begin interventions in IS integration (66.6%).

Most CIO (61.1%) stated that the hospital has a plan for IS. The percentage of respondents who said that the plan addresses the integration of IS in a superficial way is 54.5% other 45.5% respond that the issue is discussed in detail, with definition of the requirements for interoperability.

The vast majority of respondents (72.2%) believe that regarding the architecture of hospital IS the best policy is to have multiple suppliers even with the need for integrating them. The remaining 27.8% of respondents argue that the best policy is to have a single provider that includes all clinical areas thus ensuring a simple integration between all modules. As for those responsible for hospitals with 500 beds or more none advocate that the best policy is to have a single supplier.

The vast majority of CIO's (88.9%) believe that there should be regulation and certification of software because without that interoperability will hardly be effective, though the organizations should be autonomous in the choices they make. The percentage of those who argues that the Ministry of Health should impose the solutions to organizations is only 11.1%.

The three most frequently mentioned reasons, by the eighteen respondents, to justify the lack of interoperability that exists in the IS are: (1) existing solutions are obsolete (66.7%), (2) the services tend to behave as "islands" (61.1%) and (3) IS architecture is poorly defined (50.0%).

Table 2 presents the results given, when asked to choose from three options, as for between which stakeholders should data exchange be a priority,

Although most respondents believe that the integration between different IS is sufficiently secure, they expressed some distrust in the three areas under review (confidentiality of information exchanged, data integrity and availability).

Table 2: Opinions of CIOs (n=18) regarding the question about between which stakeholders should data exchange be a priority.

Type of data exchange	**N**	**%**
Between each hospital department	18	100
Between hospital and primary care	18	100
Between hospital and patient	8	44
Between hospital and pharmacies	5	28
Between hospital and social security	4	22
Between hospital and private hospitals	1	6
Between hospital and insurance companies	0	0
Between hospital and patient transportation companies	0	0

3.2 Reality Inside Hospitals

3.2.1 Existing Information Systems

We found a total of 416 different installations resulting in 127 different IS (ratio 3.3). There are organizations that sometimes have the same IS installed more than once, usually as a result of the creation of Hospital Health Centres, thus without complete consolidation of all its IS to date. There are three organizations in this situation (40 installations).

Table 3 shows the number of installations, number of different existing systems and their ratio grouped by the types of installed IS.

Table 3: Type of installed IS, number of installations, number of different existing systems and their ratio. The Departmental type IS are subdivided in subgroups.

Type of IS	Installations		Different IS	Ratio
	N	%	N	%
ADT or EPR	67	16	8	8.4
Departmental	349	84	119	2.9
Laboratory IS	*58*	*14*	*22*	*2.6*
Imaging (RIS and PACS)	*41*	*10*	*17*	*2.4*
Prescribing and dispensing drugs	*34*	*8*	*6*	*5.7*
Others	*216*	*52*	*74*	*2.9*
Total	**416**		**127**	**3.3**

In terms of distribution of suppliers of IS by country of origin, the country with the highest expression is Portugal (58.3%). For the other supplier countries, it is also worth mentioning, Spain (12.5%) and the United States of America (10.4%), other five countries represent the remaining 18.8%. For the RDBMS used, the vast majority of facilities use Oracle (77.9%) followed by SQL Server (10.3%) and in 11.8% others.

The number of IS by organization follow a normal distribution. The majority of organizations (66.7%) have up to twenty two distinct IS. The average of IS per Hospital is 20.9 (SD 9.1) with a minimum 7 and maximum 41. If we consider the total number of installations (including repetitions) the average hospital installations rises up to 23.1.

No IS found follows any standard of information architectures.

As for terminologies, 67.7% of IS don't use any specific terminology, LOINC is used by 11.02%; ICD by 9.45%; SNOMED by 7.87% and others in 3.94%.

The analysis of the relationship between the variables: number of IS (IS Nº) and number of beds (Nº Beds); number of IS and number of effective integrations (Nº Integrations) and number of possible (Pi) and effective integrations, was tested in three models (linear, quadratic an exponential) to search for the model that best fit the data. The quality of the adjustment was analyzed with the F test.

There is a high positive association between the number of beds and the number of IS (R^2= 0.65). The exponential equation better relates the number of IS with the number of beds. The equation is as follows:

$$\text{IS Nº} = 10.78 \times e^{0.001 \times \text{Nº Beds}}$$

3.2.2 Existing Integrations

In the total 18 organizations (34 hospitals) we found 629 integrations. The number of integrations per organization does not follow a normal distribution. The median is 27.5 (minimum 7 and maximum 88 integrations).

There is a high positive association between the number of IS and the number of integrations (R^2= 0.66). In this case, 66% of the variation in the number of integrations (Nº integrations) is explained by the number of IS (IS Nº). The equation that better represents the relationship is exponential. The equation is as follows:

$$\text{Nº Integrations} = 9.15 \times e^{0.06 \times \text{IS Nº}}$$

The total possibilities of integration (Pi), based on the number of existing systems (IS Nº), is as follows:

$$\text{Pi= IS Nº } [(\text{IS Nº}/2)-(1/2)]$$

The mean percentage of effective integrations (existing integrations) versus the number of total possible integrations is 15.8% (SD 7.6).

The graphic (scattered plot Figure 1) shows the results regarding the number of effective integrations and total possible integrations using the 3 models (linear, exponential and polynomial).

After analyzing the three models, we conclude that the quadratic is the more adequate. The equation that demonstrates this relation is as follows:

$$\text{Nº Integrations}=16{,}59+0{,}02 \times \text{Nº Pi}+(7 \times 10^{-5}) \times \text{Nº Pi}^2$$

The number of integrations for application layer (data, logic, presentation) is as follows: data (83.8%), presentation (14.9%) and logic (1.3%). In the data layer most common integrations types are: DB Link (35.0%) and Shared Database (30%). The use of FTP is used asynchronously at 4.1% of cases. In only 3.5% of cases messages are used via sockets directly by applications. Message Oriented Middleware (MOM) is used in 11% of cases (Biztalk 60%; Iguana 14.3%; Mirth 7.1%; Ensemble 5.7%; Apache Service Mix 4.3%, Merge 4.3%, Mitra 2.9% and Hermes 1.4%).

When MOM is used, the same IS uses the same MOM in the totality of the cases. In some cases in the same single integration is used more than one MOM.

In the logic layer, Web Services is the only method used. In the presentation layer all integrations are Web based.

In the majority of the integrations no semantic protocol is used (87.1%). In the remaining (12.9%) the only used is HL7 V2.X. Where HL7 is used, in 80.2% cases, MOM is used in the integration.

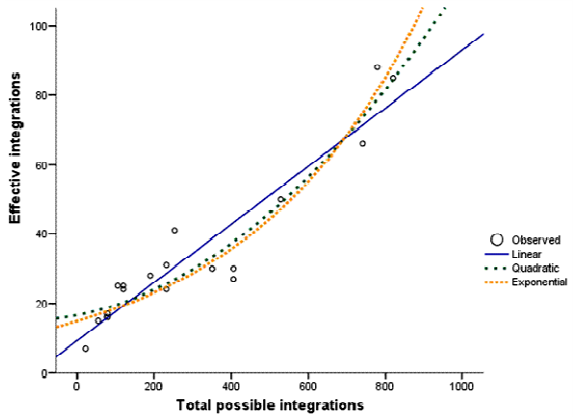

Figure 1: Number of effective integrations versus number of total possible integrations.

In most cases there is no mechanism for detecting errors (51.5%). In 33.7% there is only log record, and in only 14.8% of cases there are record and alarm mechanisms for abnormal situations.

4 DISCUSSION

Numerous authors point to interoperability as crucial for achieving gains in health, by improving the quality of care, allowing greater convenience, cost reduction, improvements in research, public health and decision support, among many others. Our results show that the CIO's of the studied hospitals somehow support these points of view as they attribute great importance to interoperability.

The vast majority of CIO's believe that it is not possible to build an EHR using just a single supplier, and so there is the need of interoperability between existing solutions. In our opinion, this reinforces the need for governmental regulation agencies to facilitate the interoperability between stakeholders.

Our study concludes that there is a multiplicity of IS, probably too many. Some are very specialized and so very difficult to become part of a single monolithic IS. In addition to the hospital wide IS, the most prevalent are those related to the laboratories, medical imaging, and drugs prescribing and dispensing.

The number of different IS versus the number of installations show us that global systems have the best ratio (8.4 installations per IS), followed by drug related IS (5.7 installations per IS). In our opinion these are the best candidates for early multi-institution integrations as the existing heterogeneity is lower. The remaining IS types (Laboratory, Imaging and others) have very similar ratios (2.6, 2.4 and 2.9 respectively) and so are more difficult to be integrated as more different IS have to be included.

The number of IS per organization is closely related to the hospital dimension (number of beds), following an exponential relationship.

The number of integrations per hospital is closely related to the number of IS, following an exponential relationship.

A high ratio between the real and the possible number of integrations is more easily achieved in small hospitals. In larger hospitals this is more difficult to achieve since the number of IS is higher, and although the number of integrations rise, the total proportion is lower, because the number of possible integrations grows faster. This means that the energy to integrate the existing systems rises very fast when the dimension of the hospital rises with poor results.

We have witnessed in the last 15 years a change of paradigm of IS "data-aware" to "process-aware", where organizations are increasingly focusing on the business processes (Van der Aalst et al., 2007). SOA and BPM promise making systems flexible and agile. For this reasons, SOA is the "state of the art" technology in the sector (Kuhn et al., 2007). The adoption of SOA in health is the natural course, this new approach will force us to rethink architecture and how we developed the IS for the health sector (Mykkänen et al., 2007). However, our results show that almost all the integrations are in the data and presentation layer, not sharing functionalities and not taking advantage of the potential of SOA and BPM technologies. This can possibly be explained either by the age of these technologies, younger than the age of the existing IS, or by the resistance to change that sometimes characterizes the health sector.

Despite numerous efforts to develop standards, it seems that there is a large gap between their development and their application in these hospitals. No IS follows a standard information architecture, and in 12.9% of cases the only standard of communication found was HL7 v2.x. Interesting fact is that HL7 is used almost always in association with middleware (80.2%), leading us to conclude that the IS that implement HL7 directly is very low. HL7 v2.x is the most widely implemented standard in the world today (Cruz-Correia et al., 2007). However, the fact that an IS is compliant with HL7 version 2, does not imply direct interoperability between applications, since this version has no precisely defined underlying information model, allowing vague definitions with a multitude of optional data

models. In this context, although there is great flexibility, it is necessary bilateral agreements between the parties involved to be able to achieve interoperability. To solve this problem a new version of HL7 (version 3) is developing based on a reference model called Reference Information Model (RIM) (Eichelberg et al., 2005). For this reason, in the totality of the cases we studied it is necessary bilateral agreements, even when HL7 is used.

From a management perspective integration is not valued as a global centralized activity. Our results show that it is possible to find in the same hospital technological overlapping approaches. Also, the same IS uses the same MOM everywhere, and therefore we conclude that the MOM is imposed by the supplier, probably because is much faster and easier to build the integrations with the same product everywhere.

The construction of regional or national EHR, are in the centre of attention today, by the potential benefits involved. However, to make this possible, first there must be local interoperability at each health organization so that patient data can be seen in a comprehensive way when it is accessed from other institution. Interoperability inside hospitals is weak, for the reasons presented above, thus undermining the project of regional and national EHR, as well as creating enormous obstacles within organizations.

Our results also show that CIOs are reluctant regarding the safety of the exchanged data, as in the majority of cases (51.5%) there is no control mechanism for the integration.

In the scope of this study we have just considered clinical IS, and we have not considered integrations with medical devices. If the analysis is extended the complexity of the problem is even greater.

A limitation of our study is the inexistence of other similar studies for comparison. However it is our impression that this reality will be identical in many other regions.

Another important finding relates to the difficulty on getting the data, due to the lack of documentation regarding existing systems and their integrations. In the majority of the cases getting the data from the healthcare was hard. We have reasons to believe that being the main author of the paper also a CIO and therefore a colleague of the interviewed has helped gathering the data.

5 CONCLUSIONS

Our study concludes that there is a multiplicity of IS, probably too many. The number of IS per organization is closely related to the hospital dimension and the number of integrations is exponentially related with the number of IS. The energy necessary to integrate the existing systems grows rapidly when the dimension of the hospital increases, with poor results.

Almost all integrations are in the data and presentation layer, not sharing functionalities and not taking advantage of the potential of SOA and BPM technologies

Despite numerous efforts to develop standards, it seems that there is a large gap between their development and their application in these hospitals.

To our knowledge, the situation in Portugal seems even worse as not many (if any) people work in international standards bodies. We intend to present these results to national institutions aiming at raising global awareness on our current situation.

Interoperability inside hospitals is weak, thus undermining the project of regional and national EHR, as well as creating enormous obstacles within organizations.

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