Integration of Healthcare Information Systems:
Improving Data Quality in a Diagnostic Imaging Department

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Abstract—**The existence of multiple information systems in the healthcare environment causes data integrity issues when the information flow architecture is not implemented considering the specificities of each department, the multiple data sources and the data input does not follow the systems requirements. This paper presents a case-study of a diagnostic imaging department information flow analyses and optimization, using the DICOM standard embedded on most equipment, to improve data integrity, availability and structure. The existing patient data structure was redefined and the existing information flow was re-engineered in accordance with the DICOM and IHE guidelines. This study focuses in a diagnostic imaging department and resulted in the identification of a new information flow that permits a significant and positive reduction of information inconsistencies, thus improving data quality.**

Keywords- Healthcare Information Systems; Information Flow Re-engineering; Medical Records; Data Quality

I. INTRODUCTION

The development of information technologies (IT) has made available, namely to healthcare providers (HcP), a better flow and processing of information that supports the clinical activity. The clinical activity has been brought closer to the inherent administrative and financial actions increasing the capacity to plan, monitor and evaluate the performed activities which has a positive impact in the financial management, production capacity and in the provided services quality [1].

Patient information is spread through several information systems (IS) that gather different kinds of data, such as demographic, medical, financial or managerial, each system having its own idiosyncrasies. In radiology departments, the IS comprised in the information flow are the Hospital Information System (HIS), Radiology Information System (RIS) and the Picture Archiving and Communication System (PACS). HIS is a management system that has three main functions: i) support clinical and medical care actions; ii) administer the hospital operation such as financial, resources scheduling and patient admissions; and iii) evaluate the hospital performance. A radiology department has specific operational requirements and, therefore, requires its own management system, acting under the umbrella of HIS. Such management systems need separate information which has to be integrated with the data from HIS, this being the role of RIS. PACS is the image management system, it acts as an archiving server which receives studies/images from the acquisition gateway, inserts/appends the study information to a database and stores the images. Together, these systems allow the HcP to manage the information flow and share it using different communication protocols in order to handle their heterogeneity.

The existence of multiple IS may cause data integrity issues when the information flow architecture is not implemented considering the specificities of each department, the multiple data sources and the input data does not follow the IS requirements.

A. Digital Imaging and Communications in Medicine

The Health Level 7 (HL7) [2]and the Digital Imaging and Communications in Medicine (DICOM) [3] are the most common communication Standards used to interface the healthcare IS in order to collect and integrate information from different sources and types facilitating its distribution and availability where it is needed.

The development of the DICOM Standard dates back to 1982 to a joint committee of the American College of Radiology (ACR) and the National Electrical Manufacturers (NEMA) [2]. Such cooperation intended to create the possibility of data transfer in healthcare regardless of the

manufacturer's Standards. The first version of the DICOM Standard, at the time denominated ACR-NEMA Standards Publication No. 300-1985, was published in 1985 and revised by version 2.0 in 1988. The first version named DICOM was in 1993 (v.3.0), and was the foremost to include services beyond data transfer [3].

The current DICOM Standard is structured in parts, each layer being used to define different services and objects. An implementation of the DICOM Standard does not have to use all of its parts. Implementations may use the parts of DICOM, such as Service-Object Pair (SOP) classes, media storage profiles and attributes, necessary to support the designed architecture, as Conformance Statements refer to a specific implementation.

DICOM SOP classes and associated Information Object Definitions (IODs) are used to convey specific medical imaging information at the Data Format Layer. IODs are sets of Attributes that comprise a type of data element identified by tags [4]. Attributes are classified in three types: Type 1: Mandatory data elements. When classified as 1C, the mandatory character of data elements is dependent of the specified conditions; Type 2: Required data element but its value may be unknown. When classified as 2C, the data elements are required under the specified conditions; Type 3: Optional data elements.

A DICOM tag is a unique identifier of an Attribute, and corresponding data element, defined by a pair of numbers represented as (gggg,eeee), where gggg denotes the Group Number and eeee the Element Number. Group Numbers were given a meaning in the ACR-NEMA Standards Publication No. 300-1985 and ACR-NEMA Standards Publication No. 300-1988, known as version 1.0 and 2.0. For example, Group (0008,xxxx) was denoted by *Identifying Information*. In DICOM version 3.0 the Group's names are not mentioned, as new Attributes are now being assigned to Groups based on their similarity to the existing ones.

An architecture that implements the information flow aiming the optimization of the service provided to the patient was defined by the Integrating the Healthcare Enterprise (IHE). As the IHE architecture was developed for the specific healthcare environment based on communication standards, it provides a set of profiles to ensure communication between different systems, which use different communication protocols, allowing the information to flow through the hospital and become available where it is needed [5].

This paper presents a case-study of a diagnostic imaging department information flow analyses and optimization, using the DICOM standard embedded on most equipment, to improve data integrity, availability and structure.

II. RELATED WORK

Data integrity is a known problem in healthcare, being the object of multiple studies in recent years. Arellano et al. [6] studied the problem of integrating multiple master person indexes (MPI) into a single enterprise person index (EPI). The authors evidenced the importance of standardization when filling in MPI files and the existence of a unique patient identifier. Cruz-Correia et al. [7] used three

approaches, working simultaneously, to monitor data quality in a Portuguese public hospital where a Virtual Electronic Patient Record (VEPR) had been implemented. On the first approach a third party network monitoring application was implemented and configured to generate alerts on abnormal report retrieval and visualization rates. On a second approach patient identification inconsistencies were monitored by crossing data from the departmental IS and the administrative database. On a third stage data integrity was monitored through the verification of the physician digital signature on clinical records delivered by the VEPR. The first solution presented a large number of false alerts, and non-trigged alerts, due to the inactivity of some departments on the weekends. Nevertheless, achieved a significant reduction on the number of inconsistencies and increased data integrity. The data quality in healthcare was approached by Bates et al. [8] by inferring on the influence that information technologies (IT) have on data errors. The authors proposed a framework on recommendations using ITs to reduce errors in healthcare, divided in two categories: i) general recommendations; and ii) domain specific recommendations. The first category included recommendations such as the use of standards for data and systems and the communication between systems. The second category suggested the use of identification standards of consumables and the use of ITs to communicate asynchronous data.

III. CASE STUDY DESCRIPTION

The case study described in this section is based on the data structure and information flow of a diagnostic imaging department; the name will not be mentioned for ethical reasons.

The studied HcP provides diagnostic imaging services on the modalities: computed tomography (1), mammography (1), conventional radiology (1), ortopantomography (1), densitometry (1), magnetic resonance (1), stereotaxy (1) and ultrasound scanning (5).

According to the language standard, the HcP information flow can be divided into three modules: i) Management, ii) RIS, iii) Imaging, as shown in Figure 1.

The Management module is the input point for the patient demographic and clinical data. Usually, the patient demographic data and exam information is inserted in the database upon an exam request made by the patient, the majority of the times made through a phone contact. This information is confirmed and updated on the front desk in the presence of the patient on the exam day. This module also manages the financial information taking into account the existing public and private conventions. Public conventions enclose entities such as the National Health Service (SNS, from the Portuguese Serviço Nacional de Saúde), the public officials assistance (ADSE, from the Portuguese Assistência na Doença aos Servidores do Estado), and the Public Security Police insurance, (PSP, from the Portuguese Polícia de Segurança Pública). Private conventions include the health insurances that have established a protocol with the clinic. Each one of these conventions has its own
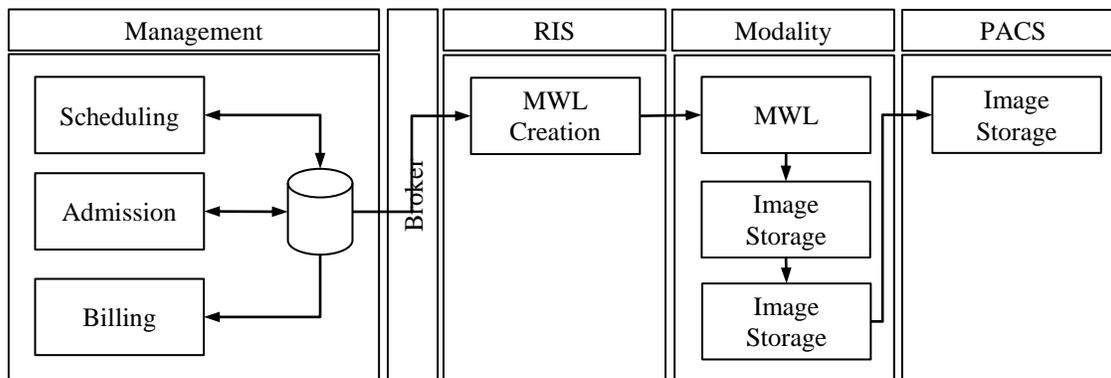
Figure 1 Illustration of the information flow at the studied HcP.

particularities concerning the invoicing exam description and rules.

The Broker receives the patient and exam information in HL7 from the Management Module, converting it to the DICOM standard before sending it to RIS.

RIS is in charge of creating a bridge between the Management and the Imaging modules. RIS receives the necessary patient and the exam information to create the Modality Work List (MWL) at the Modality request.

The Modality and the PACS together constitute the Imaging Module. The Modality issues the MWL requests to RIS, making the patient and the exam information available to the technicians at the exam room. After image acquisition and processing, at the demand of the technicians, these are sent for storage in PACS.

The aim of the work presented herein is to improve the information flow in between the described modules, in order to identify and resolve actions that can incur in information incoherence, to provide accurate information when and wherever it is needed.

IV. METHODS

A holistic approach was used to determine the existing information flow. As the Management Module is a non-commercial system, during this phase the existing IS were identified and characterized according to the communication standard supported and data available. In a second phase the data consistency was verified, by crossing information from the ISs, outlined in the first phase, and the problems identified. The identified problems can be classified in two categories based upon the type of data in which they are related to: i) Patient data or ii) HcP internal data.

The identified problems related to patient data are as follows:

a) *Internal identifiers are attributed upon the request* – in case of patient no-shows, or late-cancellations; patient records with no data are sent to RIS for the MWL creation, causing empty entries on the modality;

b) *Absence of a unique patient identifier (UID)* – in the absence of an UID, when a patient returns to the clinic it is impossible to unequivocally identify him/her and multiple internal identifiers could be generated to the same patient. This patient misidentification leads to the existence of multiple records for the same patient being impossible to

make his/her clinical history available to the clinical staff. Additionally, the propagation of this problem through the other systems could not be controlled or avoided;

c) *Creation of a new patient registry without cancelling the previous* - this action occurred when mistakes were found in the primary registry, causing not only multiple patient registries for the same exam but also a double patient billing registry that had to be filtered afterwards by the accounting staff.

d) *Consumables were registered as exams* – This occurred because the information generated by the Modality was not being returned to the billing system. As this information arrives at the Modality it reveals MWL inconsistencies, exams without data or associated images and, furthermore, inaccurate data passed forward to the billing system;

e) *Patients registered and their demographic data changed manually at the Modality* – this caused inconsistencies between the patient demographics and exam data existing in the Management Module and the real operational activities. Therefore, patients may not appear in the billing system or the existing information could be incorrect.

The identified problems relating to the HcP internal information comprises:

a) *Incorrect attribution of Accession Number* – Accession Number represents the request identifier for the Modality. As this identifier was attributed by Modality, different exams were attributed with the same Accession Number. In practice this means that if a patient is scheduled to perform more than one exam at the same Modality they would all be attributed the same Accession Number and, when sent to PACS they would be stored as a single exam;

b) *Patient request not matching the referring doctor prescription* – Different conventions have different exam descriptions and require to be billed according to different rules. Therefore, upon the patient request the information was inserted on the database according to the patient convention exam description and rules. Thus, the same patient had multiple requests for the same exam and the data sent to the modality was not correct;

c) *Inexistence of information on the MWL* – The exam description was not identified on the MWL message sent to the Modality by the RIS. This lack of information made it

impossible for the technician to be acquainted of which exam was going to be performed by the patient until the paper copy of the referring doctor's prescription was delivered by the auxiliary staff.

To propose improvement changes to the information flow that would tackle the problems presented above with the minimum possible impact on the HcP workflow, it was essential to be acquainted with the existing workflows [9-11] and to know the Portuguese and International guidelines, protocols and best practices [5, 12-16]. This knowledge supported the information flow re-engineering and presents the fundamental issues, such as process interactions and information requirements and structure.

V. RESULTS AND DISCUSSION

The patient data structure, shown in Figure 2, was defined in accordance with the DICOM Standard requirements and the existing database architecture, in order to minimize the changes to the last once the existing records could not be changed given the linkage to PACS and to avoid further inconsistencies. In this sense, was created a new identifier of the patient visit, *Episode ID*, which is attributed to all the exams performed on the same visit independently of the modality in which they ought to be performed. This identifier would replace the previous Accession Number. The *Accession Number* was kept in the structure but it is now attributed by exam requested and not by Modality. The *Accession Number* identifies a scheduled procedure, by HIS request, and it is duplicated to the *Study ID* by the Modality to identify the performed procedure. Each series, which denotes a set of acquired images, is identified by the Modality with a *Series ID* according to the nomenclature defined by the DICOM Standard.

The temporary registry data stores the patient requests. These patients have made a request and are scheduled for the day but, as they have not yet been admitted they are given no identifiers, unless they already exist in the database. This avoids the creation of empty patient records and registries from patients that have not yet been admitted are sent to the Modality through the MWL.

At the moment of admission it was made mandatory to fill the patient VAT number to tackle the patient misidentification. The VAT number is personal and allows the univocal identification of the patient. It was evidenced

that, during admission, the creation of a new patient registry, when the original contained errors, is bad practice. However, such action cannot be controlled by the IS. To avoid several denominations for the same exam a look-up table was created based on the protocol lists existing in the modalities. Furthermore, and also in admission, the patients' requests are now registered according to the referring doctor's prescription and not to the patient convention rules. Thus, an interface was implemented to treat the patient request information according to the patient convention rules and create a list of provided services to be billed to the patient and stored in a financial information database, independent of the clinical information. In this sense, the consumables also no longer register as exams being managed by the Modality through the Modality Performed Procedure Step (MPPS) DICOM service. The MPPS is a complementary service to the MWL that enables the Modality to report on the performed exams. It is included in the MPPS message information relating: i) the patient demographics and IDs; ii) the exam performance, such as beginning and ending time of image acquisition, parameters used in the configuration of Modality protocols, number of series acquired, list of objects generated during acquisition; iii) the dose delivered to the patient; and iv) the consumables used during the exam such as contrast, anesthesia and number of film sheets used to print the exam [17]. The MPPS message is generated in three different study states: i) On patient registry at the Modality, taking the value IN-PROGRESS, acknowledging the moment in which the exam has started; ii) When the patient study is closed, taking the value COMPLETED, referring the moment when the exam has finished and reporting all the information regarding the performed exam; and iii) when, for some reason, the exam is discarded, taking the value CANCELLED. The activation of this DICOM service allows the modules prior to the Modality on the information flow, RIS and Management module, to return on the information sent to the Modality and be acquainted with the actual status of the operations.

These changes in the Management module facilitate better management of the MWL creation by RIS. The full information regarding the patient and the scheduled exam are now sent to RIS allowing both the patient and exam to be fully characterized by the Modality. This fact is of extreme importance as it not only avoids the information to be passed from the admission to the control room on paper, but also enables the Modality to create a DICOM structure making any previous exams of the same patient available to the technician. Furthermore, as RIS receives MPPS message from the Modality it is able to control the MWL according to the information sent.

Thus, patients are removed from the MWL if the status is COMPLETED or CANCELLED and maintained in queue if the status takes the value IN-PROGRESS.

The activation of the MPPS service implies some changes on the technicians' workflow. Consumables have now to be registered by the technician on the MPSS and studies have to be set to the COMPLETED status after image acquisition.
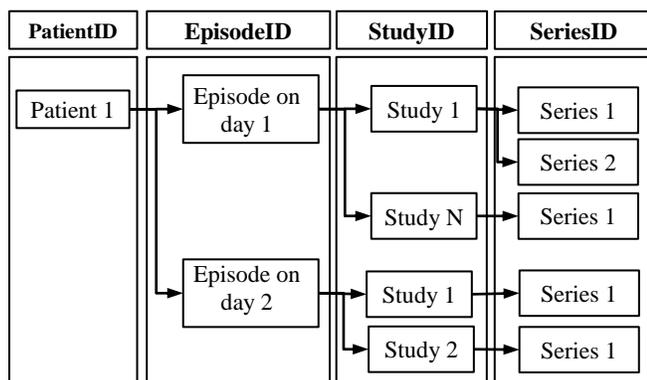

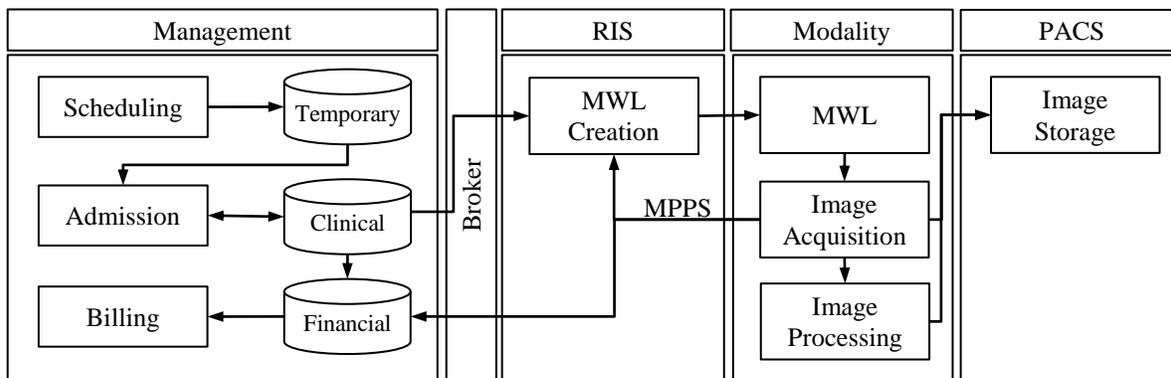**Figure 2** Illustration of the defined patient data structure.

Figure 3 Illustration of the re-engineered information flow.

This action can either be performed automatically in the moment another patient is registered on the Modality, or manually by the technician when the acquisition is terminated. The activation of this service also requires that patients cannot be registered, or their demographic data changed manually on the Modality, as the MPPS message will only be sent for patients created by the MWL. The principle behind this fact is that the MPPS message will only be sent if there is a correspondence between the RIS and the Modality data, which does not happen with manual inputs. To avoid this from happening, the implementation of a management terminal on the control was suggested. As such, the technician can perform these actions without disturbing the information flow. The re-engineered information flow is shown in Figure 3.

VI.   CONCLUSIONS AND FUTURE WORK

It was demonstrated that the implementation of information flows that apply the DICOM and the IHE guidelines can significantly reduce problems that affect data quality. The re-engineered information flow proposed herein significantly reduced the information problems at the studied HcP.

The implementation of the re-engineered workflow also facilitated an easier access to patients' previous examinations and minimized the number of duplicated records. The information flow has a clear and more efficient architecture, evolving towards the recommended paperless flow that minimizes human errors.

In the future it would be interesting to digitalize the referring doctor's prescription in order to make it possible to store it in PACS along with the study, as well as make it available on time to any clinical resource that has the need to consult it. Additionally, the creation of DICOM structured reports should be considered, that enable semantic queries to PACS based in fields such as the examined body region and evidenced pathologies.

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