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OpenEHR modelling applied to Complementary Diagnostics Requests

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Abstract

Complementary Diagnostic Requests (CDRs) are required for disease identification, monitoring, and prognosis. Diagnostic tests misuse, on the other hand, can lead to negative health outcomes as well as additional costs. Inappropriate diagnostic test requests are primarily the result of a lack of interoperability between Healthcare Information Systems (HIS). On one hand, clinicians can be mislead into which test is the best option for each clinical case, on the other hand missing previous results, leads to duplication or unnecessary tests. HIS is increasingly relying on standards based on dual architecture to promote interoperability as well as the structuring and consistency of clinical and demographic data. The OpenEHR standard's duo-based architecture allows for concise modelling of archetypes and templates for a given clinical case, which was used in this study. As a result, the purpose of this research was to build an openEHR template for the CDR registration as well as the architecture of a Data Warehouse (DW) system capable of storing all of the information needed for the diagnostic test request process. Afterwards, Business Intelligence (BI) indicators was developed in order to answers the needs for test registration and execution.

Keywords: Complementary Diagnostic Request; Archetypes; Templates; OpenEHR; Interoperability; Data Warehouse; Business Intelligence

1. Introduction

Diagnostic tests, such as laboratory and imaging tests, are now considered indispensable in clinical settings because they can be used for a variety of purposes, including diagnosis confirmation or exclusion, clinical monitoring, screening, treatment triage, and disease progression stage assessment [15]. In clinical practise, appropriately identifying the most appropriate complementary diagnostic test for a patient's illness diagnosis is critical to minimising unfavourable effects [2].

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In primary care, CDRs can be both overused and underused. On one hand, the underuse of tests or failure to request a complementary test when one is required, can lead to diagnostic errors, such as incorrect or delayed diagnosis, which can result in potential risks and harm to patients, as well as increased costs for the healthcare system. On the other hand, the CDRs overuse also exhausts limited healthcare funds, diverting them away from potentially more valuable tests and treatments [13]. In both situations, patients are exposed to direct risks as well as potential unfavourable outcomes, incidental findings, and overdiagnosis when CDRs are performed without obvious benefit or when the potential harms outweigh the potential benefits.

The thousands of clinical records produced daily present themselves constantly with distinct and complex structures and meanings, which is why the data standardisation and the exchange and sharing of information between different HIS is becoming increasingly relevant. HIS can play an essential role in organising and monitoring the CDR requisitions, providing the basis for rising healthcare interoperability, enabling more effective information sharing, and presenting a more complete and consistent patients' Electronic Health Record (EHR), resulting in better and more accurate clinical decisions [4, 7]. Significant EHR expansion and more robust interoperability standards use will further boost health systems' ability to improve data availability, accuracy, and comprehensiveness, leading to advances in benchmarking and disease surveillance and prevention capacities [8].

Interoperability in HIS is increasingly becoming a must rather than a choice. For this, it's important that systems communicate to each other correctly and effectively, with data moving between systems and being understood correctly [9]. The openEHR standard, which operates at the most diverse levels of interoperability, is one of the solutions that is increasingly accepted and recognised globally. The use of archetypes as a foundation unit allows for the development of novel linkages between information models and data structures [12, 11]. Its open and comprehensive specifications, clinical models, and software components can be used to create an interoperable HIS and to collect structured and valuable clinical data [5]. Its Reference Model (RM) includes a dependable and rigorous framework with the EHR's logical structures and defines the structures and attributes required to describe its data instances. The RM, on the other hand, supports the Archetype Model (AOM), which is made up of archetypes and templates. Archetypes are portrayed as formal and semantic artefacts that aid doctors and medical informatics professionals in representing, storing, and communicating clinical data. Their key benefit is their reusability for many applications, which helps to promote semantic interoperability between different HIS. Archetypes are assembled and arranged in templates to represent certain use cases, with the option of referring to external terminology [10].

Sá et al. discovered that laboratory tests are the most frequently ordered tests in Portugal, that there is a trend toward over-testing, and that requests for diagnostic tests vary widely geographically and organizationally in Portuguese primary care practises, implying that there is potential room for test request rationalisation. O'Sullivan et al. discovered significant heterogeneity in the rates of diagnostic test under- and overutilization in many primary care settings around the world. Echocardiography is underutilised in some clinical contexts, such as the confirmation of a heart failure diagnosis, but overutilized in others, such as postoperative assessment. Given these issues, the primary purpose of this research is to determine the best technique for constructing a long-lasting and intelligent solution capable of dealing with CDR request issues, hence increasing the efficacy rate of Clinical Decision Support Systems (CDSS). As a result, an openEHR modelling methodology was developed, which was followed by the development of an Extract, Transform, and Load (ETL) process to create a DW, which was then followed by its BI component.

2. Related Work

Currently, although there are still some barriers to the applicability of the interoperability concept in health institutions, there are already several hospital information systems around the world whose insertion of this theme has proven successful. Currently in Portugal, HIS are supported by the National Healthcare System (SNS in Portuguese) prevail, among which the *SClínico*. The *SClínico Hospitalar* is an evolving information system that emerged from the experience with two previous systems, SAM (Sistema de Apoio ao Médico - Physician Support System, in English) and SAPE (Sistema de Apoio à Prática de Enfermagem - Nurse Practice Support System, in English) [19]. This tool supports the standardisation of clinical record procedures in order to guarantee the standardisation of information. The use and sharing of patients' clinical information among health professionals from various areas enhances the homogenization of information at a national level, resulting in a more effective and efficient provision of health care. The CardioBase® is a cardiology HIS that assists in the management of cardiology services by managing the patient's

medical record from admission to discharge and enabling the registration of tests in this specialty. This platform also contains services for scheduling, hospitalisation, medical imaging, surgery, etc. This service presents a great advantage in the area of exam registration since it allows the connection with the exam equipment (echocardiographs, ECG, etc.), enabling the sending and receiving of information from them. CardioBase interoperates with all hospital systems that allow it and is a widely chosen solution in Portugal. The treatment record interface presents a lot of information: from patient information (including clinical history) and an indication of the test in question to the diagnoses or conclusions drawn from its execution [17].

Agency for Integration, Dissemination, and Archive of Medical and Clinical Information (AIDA) is an innovative platform, implemented several Portuguese Healthcare Institutions, that allows communication between heterogeneous HISs, the archive and management of information, as well as information sharing between all systems. This platform emerged with the objective of making the HISs interoperable and provides intelligent agents that, besides having a proactive behaviour, provide several services such as the communication between several subsystems from the sending and receiving of information from medical reports, medical images, etc., as well as allowing the registration of the patient's examination process from its reception to its discharge [3]. AIDA is composed of different subsystems, one of them being the information system of all departments or services, in particular the laboratories, the radiological information system, and medical imaging [14]. Similarly to CardioBase, this also allows the scheduling of exams and the storage of images registered in them, presenting, however, the advantage of being oriented to different medical specialties existing in the hospital, therefore displaying a greater spectrum of information. Regarding the registration of treatments, this service allows recording the moment patients are received, the execution of the exam, and also the preparation of reports.

MOSAIQ Plaza for medical oncology provides digital support to oncology healthcare professionals, enabling multidisciplinary patient care [1]. It promotes precise and efficient multidisciplinary oncology workflows, connecting the healthcare professional to the whole patient journey from diagnosis through therapy. This technology assures the right and secure ordering of a patient's prescription dosage, calculates doses accurately, reduces manual calculations, and enhances the management of adult and paediatric patients. Elekta Axis saves oncology software data in the Microsoft Azure cloud storage system. This service simplifies and improves the oncology environment by providing support, control, security, dependability, and scalability. The programme gathers evidence on the efficacy and safety of oncology treatments to optimise patient care. MOSAIQ® Oncology Analytics provides treatment information, making it easy to analyse performance patterns, enhances operational efficiency, and ensures patients get aid from several providers.

3. Methodology and Tools

Figure 1 represents the workflow developed during this case study. As a first step of the research pipeline, openEHR structures will be modelled for the data structuring of clinical records. After modelling, data binding will be performed from a private CDR request dataset to the previously modelled structures. The resulting clinical records will then be used to create a DW. For this to be possible, it will be necessary to implement an ETL process so that the designed DW can be populated. Finally, from the data present in the DW, it will be possible to extract information and develop BI indicators to be incorporated in the future.

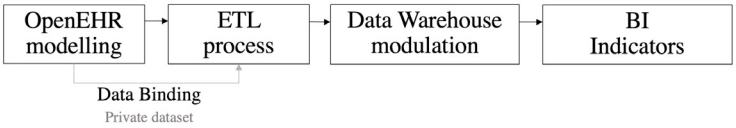

Fig. 1. Proposed pipeline and its several phases.

The demand for the reuse of openEHR modelling frameworks is possible through the support of the collaborative Clinical Knowledge Manager (CKM) platform, and its use is fundamental to developing the first phase of the presented pipeline [6]. Archetype Designer will also be used to model the required clinical structures. Priority will be given to choosing archetypes already existing in CKM and introducing the necessary changes to them. After choosing the necessary archetypes, the template will be built, and the implementation of the ETL process will start through the

planning and the elaboration of the relational model of the DW. ETL operations and DW creation will be carried out on the PostgreSQL Database Management System (DBMS). After that, all tables will be generated and populated and available for consultation.

4. Results

Complementary Diagnosis Request Template

The generated template was created by combining existing CKM archetypes, as previously mentioned. These were modified to meet the needs of the CDR request standards [18]. The ”openEHR-EHR-COMPOSITION.encounter.v2” archetype was used as the root archetype for building the final template, that is composed by two sections denominated ”Context” and ”Content,” and figures 1 and 2 show the archetypes found in CKM and suitably adapted to create the openEHR template for complementary diagnostic requests. To identify the patient for whom the CDR will be requested, the archetype ”openEHR-EHR-CLUSTER.person.v0” presented in figure 1 was used, allowing the administrative information of the patient from whom the diagnostic test is being requested.

NodeId	Attr.	RM Type	Name	Description
EVENT_CONTEXT				
Person CLUSTER: *openEHR-EHR-CLUSTER.person.v0*				
at0001	1..1	DV_TEXT	Name	The content of this data element may be derived from one or more components from CLUSTER.structured_name combined together as a text string. For example: 'John Markham', 'Professor Sir John Markham', 'John Markham Jnr MP'.
at0011	1..1	DV_TEXT	Num_Sequential	

Fig. 2. Context of the CDR template.

The ”openEHR-EHR-INSTRUCTION.request.v0” archetype was chosen since the aim of this study is to provide a template to record the requests of diagnostic tests. Figure 3 illustrates the attributes derived from this archetype that are relevant to the subject under discussion.

NodeId	Attr.	RM Type	Name	Description
Service request INSTRUCTION: *openEHR-EHR-INSTRUCTION.request.v0* For example equipment request.				
at0121	1..1	DV_TEXT	Service name	Coding of the 'Service name' with a coding system is desirable, if available.
at0148	1..1	DV_TEXT	Service type	For example: Treatment or Diagnosis.
at0135	1..1	DV_CODED_TEXT	Specialty	• Cardiologia (local_terms: CARD) • Pneumologia (local_terms: PNEUMO)
at0062	0..1	DV_TEXT	Reason for request	Coding of the 'Reason for request' with a coding system is desirable, if available.
at0064	1..1	DV_CODED_TEXT	Module	• Consulta (local_terms: CON) • Internamento (local_terms: INT) • Urgências (local_terms: URG)
at0065	0..*	DV_TEXT	Sub-specialty	The sub-specialty is a subcategory of specialty. Examples: Cardiologia de intervenção (Especialidade: Cardiologia)
at0068	0..1	DV_TEXT	Exam code	Refers to the code of the exam.
at0145	0..1	DV_DATE_TIME	Scheduling Date	This date/time is the equivalent to the scheduling date
at0144	0..1	DV_DATE_TIME	Exam Date	This date/time is the equivalent to the exam date
at0011	0..1	DV_TEXT	Executant Ident	
at0127	0..1	DV_CODED_TEXT	Request status	• In progress (local_terms: 0) • Done (local_terms: 1)

Fig. 3. Content of the CDR emplate.

In order to make the template more complete, an external coded has been incorporated in some of its fields. The ”Specialty” field contains the values ”CARD - Cardiology” and ”PNEUMO - Pulmonology” that specify the two of the specialties addressed in the dataset used. The ”Module” field also contains the values ”CON - Consultation”, ”URG - Emergency Room” and ”INT - Inpatient” that specify the hospital unit through which the diagnostic test is requested. Finally, the ”Request status” has a value set of ”0 - In progress” and ”1 - Done”.

CDR Data Warehouse

A logical data map was developed with the source data of the private dataset used and its proper SQL transformation performed to match the target data of the DW. Initially, the relational modelling of the database was performed. When structuring the relational model of the DW, six dimension tables were created: ”dim_patient” which has ”id” (primary key), ”sequential_num” and ”name” as attributes to identify the patient. The reason of the request was identified through the table ”dim_reason” with the attributes ”id” (primary key) and ”description”. The table ”dim_executor” is also constituted by an ”id” (primary key) and the respective ”name”; The identification of the requested exam is done through the dimension table ”dim_exam” which includes a ”num_exam” (primary key), the number that identifies the ”exam_name” and ”exam_type”. The specialty requesting the CDR, on the other hand, is defined by the table ”dim_specialty” which contemplates an ”id” (primary key) followed by ”specialty” and ”subspecialty”. The context in which the CDR is requested is described in the ”dim_module” dimension, which contemplates its ”id” (primary key) and its ”description”. Finally, the fact table ”fact_cdr” which includes the ”id” identifier (primary key), the ”state” which identifies the state of the request as in progress or ongoing, the ”request_date” and the ”exam_date”, both contemplating the date and time of the request for the diagnostic test and the date of the scheduled exam, respectively. But in the same table, there are six foreign keys that are used to identify each of the six dimension tables that have already been talked about.

Business Intelligence Indicators

The report bookmarks allow the user to have an overview of statistics for the management of requests for complementary diagnostics and support for clinical decision-making process. Some of the BI bookmarks considered useful in hospital environments in this context are:

- **CDRs waiting time average:** The waiting time between the date of the request and the date of its actual execution is a very useful indicator for a better prediction of the period that the patient will have to wait to do a certain complementary diagnostic test. On the other hand, this indicator can be the basis for improving the waiting time.
- **The most and least requested Complementary Diagnostic Tests:** The most and least requested test is a valuable reporting marker in the management and control of over- and under-requested CDRs. This indicator also allows hospital facilities to forecast all the equipment and materials needed according to the average amount of each test done in certain time periods.
- **CDRs executation rate per period of time:** This indicator is critical for analysing the number of requisitions issued in relation to the number of CDRs completed and cancelled. This information is useful for making health professionals more aware of their needs and reducing costs and processes that aren’t necessary.

5. Conclusion and Future Work

The implementation of an international standard such as openEHR allows institutions to achieve several levels of interoperability: semantic, syntactic, and structural. For the case study of CDRs, a high level of interoperability in HIS improves the patient experience, from the reduction of their waiting times to the simplification of clinical records, the reduction of costs associated with under- and over-use of the requisitions made, and also ensuring patient privacy.

This research allowed the design of a pipeline aiming at improving CDRs in health institutions and promoting interoperability between HIS in order to minimise gaps and communication losses through the improvement of universal

semantic understanding. The modelling of CDRs in openEHR followed by the mapping of data to the new clinical record structure led to the creation of a DW and its populating through an ETL process.

As future work, a web application will be developed to enable the registration of CDRs through forms based on the model openEHR template, as well as the creation of dashboards with the BI indicators developed, updated in real time, so that each health institution can improve its performance in the daily CDRs performed as well as in the prediction of monthly average requests.

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