Clinical Decision Support using a Terminology Server to improve Patient Safety

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Abstract. Clinical Decision Support Systems (CDSS) are software applications that support clinicians in making healthcare decisions providing relevant information for individual patients about their specific conditions. The lack of integration between CDSS and Electronic Health Record (EHR) has been identified as a significant barrier to CDSS development and adoption. Andalusia Healthcare Public System (AHPS) provides an interoperable health information infrastructure based on a Service Oriented Architecture (SOA) that eases CDSS deployment. This paper details the deployment of a CDSS jointly with the deployment of a Terminology Server (TS) within the AHPS infrastructure. It also explains a case study about the application of decision support to thromboembolism patients and its potential impact on improving patient safety. We will apply the inSPECt tool proposal to evaluate the appropriateness of alerts in this scenario.


Introduction

One of the major benefits obtained through introducing interoperability inside healthcare environments is patient safety improvement. Additionally, interoperability make it so information linked to the patient doesn't have to be inspected manually and reduces the number of times that the same information is needed to be processed or recorded by different systems or professionals.

Incorporating Clinical Decision Support Systems (CDSSs) into clinician workflows is one of the main strategies for preventing decision errors in healthcare environments e.g. prescription errors [1]. They assist in providing health professionals
with clinical information and recommendations based on clinical practice guidelines and medical experience and evidence [2]. In order to maximize the benefits of the adoption of CDSS, it is recommended to include knowledge management strategies that support knowledge evolution on a regular basis [3].

Andalusia, a region in southern Spain, has a population of more than eight million inhabitants with the Andalusia Healthcare Public System (AHPS) being the main health services provider. AHPS has a Service Oriented Architecture (SOA) infrastructure that covers primary and specialized care providing support to around 85,000 health professionals.

The central node of this SOA infrastructure is an EHR that utilizes Health Level 7 (HL7) v2 messages to facilitate the exchange of information between different health information systems. Information included in the Electronic Health Records (EHRs) is encoded using standards and local code systems. A standardized interface for the usage and management of terminologies, which also contribute to add semantic interoperability in the exchange of EHRs, is a Terminology Server (TS).

Despite, the regional EHR infrastructure provides more than 200 interoperable web services there are only 2 that provide access to terminology resources so the integration of a TS that provide Common Terminology Services (CTS) will contribute to the implementation of semantic interoperability within and among AHPS and extend the consistent use of standard and local terminologies. Moreover, in 2015 the regional EHR infrastructure will migrate from ICD-9 to ICD-10 to identify clinical diagnoses and procedures. To support this transition it will be required a terminology framework that allows mapping between terminologies and version control will be required. With an incidence rate of 75 out of 100,000 patients per year that yield 6,000 Venous Thromboembolism (VTE) yearly in our region [4], we determine that this is a suitable scenario to test and evaluate the potential impact of a CDSS.

1. Methods

The aim of this paper is to present the deployment of a semantic-interoperable CDSS based on a repository of computer-interpretable medical knowledge. The focus is on the analysis of the impact that the integration of a TS could bring to the CDSS.

Within our developed CDSS, we included the following components (i) a Clinical Decision Support (CDS) Knowledge Management Framework for rules definition and management; (ii) a CDS engine that applied to EHRs produces outcomes based on a knowledge module (KM) and (iii) a Terminology Support Framework to maintain the content of medical vocabularies and the associations from one vocabulary to another.

1.1. Clinical Decision Support System

We needed a CDSS to be included within the AHPS where decision-making support was based on EHRs. We used a Knowledge Management Framework to create a Knowledge Repository (KR) and integrated a CDS engine into the CDSS to generate decision support based on this KR jointly EHR.

Kensaku et al. propose recommendations for establishing a national CDSS that assists clinicians in disease prevention, diagnosis and therapy [5]. Within the definition and development of the infrastructure we focused on satisfying the five requirements recommended for CDSS on a large scale:
1. **Centrally managed repositories of computer-processable knowledge**: We created a KR that integrates knowledge modules (KMs), also known as rules, created by JBoss Drools Guvnor software as the associated authoring management tool.

2. **Standardization of the CDS information**: Our regional EHR provides a web service to gather the electronic clinic history. The information is exchanged through HL7 v2 messages where the necessary standardized information related to the patient can be identified: clinical observations, problems, adverse reactions, active prescriptions, doctor visits, diagnoses and procedures.

3. **Standardization of how patient data are represented**: We have harmonized the EHR information according to the Virtual Medical Record (vMR) standard. Within EHR, information is coded with standard (ICD-9, NANDA) and local terminologies.

4. **Standardization of how leverage computer-processable knowledge repositories and patient data to guide clinical decision making**: We used OpenCDS [6] decision support service to evaluate patient data modeled as a vMR and generate patient-specific conclusions based on the KMs integrated within the central KR. To map HL7 v2 messages to vMR we designed several Mirth Channels [7].

5. **Standardization to locate and retrieve patient data from across disparate health information systems**: We integrated all the infrastructure elements with the regional EHR that permits gathering health information from other public health information systems with the utmost security and reliability [8].

### 1.2. Terminology management

We needed to use and maintain large standard (ICD-9, NANDA, etc.) and local terminologies (active ingredients, drugs, etc.) and explore how best to produce mappings between concepts identified in our regional EHR to values in the OpenCDS reference code system. These mappings were necessary because OpenCDS decision support service bases its results on a set of OpenCDS concepts that meet KMs centrally managed in a KR.

We chose the CTS open-source implementation study case, Apelon [9]. With the deployment of a local instance of Apelon inside our regional CDS infrastructure we were able to: Manage active ingredients AHPS local terminology, import standard terminologies such as ICD-9 and ICD-10 and define mappings between OpenCDS concept codes and other terminologies concept codes. OpenCDS system provided a utility that connects Apelon local instance to the OpenCDS public instance and creates mappings that, in the end, supports OpenCDS decision support.

### 1.3. Case Study: Decision Support to prevent Venous Thromboembolism

Nowadays, health professionals from AHPS use a simple desktop application that calculates VTE risk factor without any integration with the EHR system. This application is an electronic version of the National PRETEMED guideline [4] for thromboprophylaxis but there isn’t any possible traceability about the risk punctuation and prophylaxis recommendations that health professionals should adopt.
In our developed CDSS, we implemented a KM within the central KR with a set of rules written in concordance with the Clinical Guide that determine patient’s risk of VTE linked to EHRs. In addition to the risk punctuation, the CDSS shows the active patient prescription, diagnosis and procedures list, to offer context information. Moreover, it saves the risk punctuation in the database linked to the patient to provide risk monitoring throughout the patient stay. There is previous evidence showing that CDSS reduces rates of VTE [10, 11] so we have designed a pilot stage to assess the reduction in the frequency of VTE, patient safety and end-users improvements within the internal medicine department.

2. Results

Our CDSS supports integration with web services offered by the regional EHR to gather patient history information. This information exchange is based on HL7 v2 messages. Figure 1 shows the CDSS that has been deployed inside the AHPS. We mapped HL7 v2 records to vMRs that were sent to OpenCDS decision support service for its evaluation through Mirth channels. OpenCDS decision support service’ results are based on a specific KM. KMs are created through Guvnor Software and stored inside the central KR. Clinical concepts that must be included within decision rules belong to OpenCDS terminology maintained in a publicly accessible Apelon instance. Other code systems should be loaded inside the local AHPS Apelon instance to ease mappings between local set of codes and OpenCDS reference code system.

![Figure 1. CDSS infrastructure.](image)

The evaluation results will be presented to health professional along with information related to the patient such as problems, active prescriptions, diagnoses and procedures, including an analysis of the appropriateness of the alerts, according to the model proposed in the inSPECT tool (Interactive Portal for Evaluating Surveillance Clinical decision support) [12].

3. Discussion

Previously, in the AHPS, professionals were using non-interoperable CDSSs, not integrated with EHRs. They executed rules founded only on human-chained events that are liable to have human errors. They also failed to provide medical context information so patient safety was not properly assured.
Thanks to the integration of the CDSS in an EHR infrastructure, patient information doesn’t need to be rewritten. Moreover, the CDSS implemented gives more context information that assists the physician in better decision making for the patient. Also, we integrated the calculated risk factor punctuation within the database linked to the patient, so health professionals would be better assisted in monitoring the risk of VTE evolution throughout the time.

Regarding the terminology management, our TS offers benefits to existing terminology management services such as better management of mappings from one vocabulary to another, supporting the transition from one terminology version to an updated one and providing a standardized interface for the usage and management of terminologies. This is especially relevant in the transition to new terminology systems planned for next adoption of ICD-10 in the coming year.

We hope to provide a useful tool to improve clinical decision-making in a field with a high range of inappropriateness in VTE prophylaxis [13]. Moreover, following the inSPECT tool model, to determine the appropriateness of the alerts in this scenario, may even serve to propose improvements to this assessment methodology.

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