iCARDEA: a Practical Approach to Facilitate Data Integration of Implantable Cardioverter Defibrillator Patients in Cardiological Treatment

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Abstract. In cardiology departments supporting implantable cardioverter defibrillator (ICD) patient follow-up, patient data reside in a number of autonomous healthcare information systems that support different standard and proprietary formats, and it is up to each organization to choose electronic health record (EHR) integration solutions, underlying technologies, and standards based on their own needs, experience, and budget. However, without efficient data integration, significant gaps in the workflow will continue to hinder immediate availability of the patient data needed by healthcare professionals and their patients, and thus optimal use of clinical information and human resources. In this paper, we present the iCARDEA healthcare integration platform from the view point of ICD patient follow-up in a cardiology department, driven by the story of fictitious Mr. Schmidt, who is using the latest remote monitoring technology, manages his own personal health record (PHR), and hopes to live a long active life, supported by the latest developments in eHealth technology.

Keywords. implantable cardioverter defibrillator, data integration, cardiological treatment

Introduction

One of the main challenges facing current healthcare industry is the enabling of timely and efficient access to information, which could greatly improve both the quality and cost-effectiveness of care [1]. Some medical treatments such as cardiological treatment would benefit from data integration of different healthcare systems such as EHRs, PHRs and ICD vendor services. In other words, more and more, various healthcare information systems need to work in a coordinated manner, increasing the demand for information exchange. The quality and safety of cardiological treatments is deeply impacted by the availability of clinical data from various healthcare systems.

In the iCARDEA project, a healthcare integration platform as shown in Figure 1 applies clinical guidelines and data analysis mechanisms on the data retrieved from various healthcare systems to integrate patient information residing in and out of hospital, e. g. laboratories, outpatient clinics, vendor portals, thus facilitating prompt decision making.

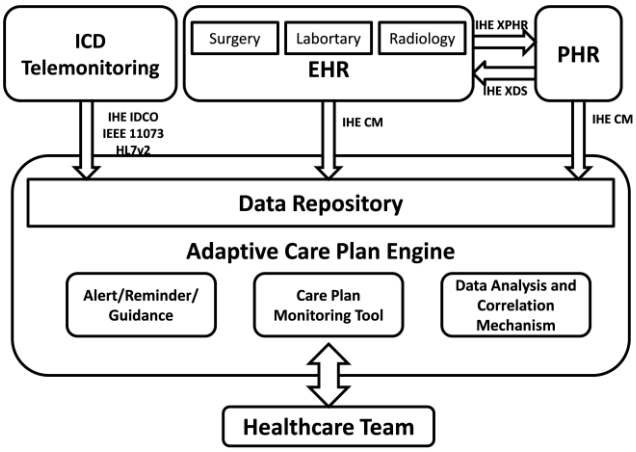

Figure 1. iCARDEA healthcare integration platform

1. Methods

1.1. Demand and Motivation for ICD Patient Data Integration

Currently, there are various types and brands of ICDs implanted in patients. Different models of ICDs are associated with dedicated software tools and sometimes proprietary data standards. ICD patients' health data are also distributed in different healthcare systems within and across hospitals. The lack of data standardization results in limited interoperability even within a single institution [1]: there exist incompatible systems, disconnected islands of information unable to communicate with each other and support integrated medical workflows in an efficient manner. Recognizing this problem IHE profiles have been defined to address the problem of systems and data integration and support the industry in developing standards based integration [2].

iCARDEA proposes a clinical guideline-based follow-up of ICD patients, including clinical indications, contraindications, reminders as well as alerts shall also be based on the evaluation of all available related clinical data, i. e. the data from the evaluation of the cardiac implantable electronic device (CIED), patient personal information from EHR/PHR based on personalized care plan templates proposed by the iCARDEA healthcare team.

1.2. Architecture and Methodology for Project iCARDEA

As shown in Figure 1, the iCARDEA healthcare platform is comprised of the following main modules, details and functionalities of which are presented in [3] and [4]:

- *ICD Telemonitoring:* interoperability interface exposing the ICD data in ISO/IEEE 11073 nomenclature and HL7v2 standard with IHE IDCO profile.
- *Interoperability Infrastructure for EHRs/PHRs:* integrating EHR and PHR using the appropriate standards such as IHE Care Management (CM), Cross-enterprise Document Sharing (XDS) and Exchange of Personal Health Records (XPHR).
- *Adaptive Care Plan Execution Engine:* intelligent personalized adaptive care planner for ICD recipients based on semantically enriched, computer-interpretable guidelines.
- *Data Analysis and Correlation Mechanism:* providing suggestions based on information obtained from medical knowledge bases to help healthcare team.

2. Preliminary Results

2.1. iCARDEA in Action: an Illustrative Demonstration Scenario

Below we refer to the story of Mr. Schmidt, a fictitious ICD patient, to illustrate the iCARDEA healthcare integration platform focusing on the perspective of the cardiology department, at different stages of the story, first admission to the hospital, surgery, rehabilitation, daily living with the implant, and assessment of events reported through telemonitoring to the healthcare team at the cardiology department:

A. Schmidt: *cardiac patient with ICD after successfully performed surgery*
Allan: *the nurse who is responsible for the treatment of A. Schmidt*
Dr. Jones: *the cardiologist who is responsible for the treatment of A. Schmidt*

On November 24, 2010, when Mr. Schmidt opted in for ICD telemonitoring, clinical data including medical history, lab results diagnostic reports, etc, were processed in the iCARDEA EHR interoperability framework. Based on his clinical profile, a *care plan* for the management of *atrial fibrillation* was selected by his healthcare team and *personalized for him*. Based on this personalized care plan the adaptive care plan engine subscribed to clinical data updates of his PHR and EHR using the IHE Care Management (CM) profile [2]. The adaptive care plan engine is also configured to receive data from the ICD using the IHE Implantable Device Cardiac Observation (IDCO) profile. From that point on, the adaptive care plan engine receives updates from the IT systems of the hospital and Mr. Schmidt's PHR.

On March 22, 2011, nurse Allan logs in the portal of the ICD vendor and exports data related to *an alert received on her mobile phone* about an event of Mr. Schmidt. Then, Dr. Jones starts execution of the Adaptive Care Planner, opens Mr. Schmidt's personalized atrial fibrillation care plan. The electrogram (EGM) is presented to Dr. Jones, who confirms the presence of a supraventricular tachycardia (SVT) problem. The current CHADS score is automatically evaluated at 3 based on recent *data received from EHR and PHR* and presented to Dr. Jones. The *recommendation* to consider anticoagulation therapy appears. Contraindications with Mr. Schmidt's current medical condition, his recent lab results, and active medications are checked. From Mr. Schmidt's medication list as retrieved from the EHR, along with the medication compliance information from the PHR, any possible contraindications are highlighted.

Dr. Jones notices contraindications for anticoagulation drugs according to the presented summary that highlights Mr. Schmidt is using simvastatin and he has a drug

eluting stent. Therefore, the care plan recommends the medical professional to continue with rate control strategy without prescribing anticoagulation therapy. As a part of rate control, the EGM is presented to Dr. Jones and he concludes on AF tachycardia. Therefore, the care plan engine recommends Dr. Jones considering an immediate referral to clinic with a subsequent evaluation of rate control drug prescription. In this step, based on the previously PHR *information feed*, the care plan engine first checks whether Mr. Schmidt has an active life style.

Then the care plan engine checks the EHR and discovers that the patient has a history of hypertension. Therefore, the care plan engine recommends prescribing β-blocker, or diltiazem or verapamil or digitalis. For this purpose, the EGM of the patient is displayed to Dr. Jones and an "urgent in person follow-up" is recommended. It is also reported that he is in fact currently using nebivolol (a ß-blocker), hence dose adjustment or change of the ß-blocker used is recommended. After that, with the help of the care plan engine Dr Jones decides that there is a need to perform in-hospital rhythm control and directs nurse Allen to arrange for the appointment for Mr. Schmidt. Table 1 shows a general view of relevant data managed by iCARDEA.

PARAMETER	EXPLANATION	TYPE	SOURCE
PATIENT INFORMATION			
Name	Name of the patient	Text	CIED/EHR/PHR
ID	Hospitals ID number	Numeric	EHR
Age	Age of the patient at the time of interrogation	Numeric	EHR
Diagnosis	Main diagnosis of the patient	Text	CIED/EHR
Type of device	PM / ICD / CRT-P / CRT-D	Categorical	CIED/EHR
CIED model	Medtronic / SJM	Categorical	CIED/EHR
PATIENTS CLINICAL STATUS			
Hospital admissions	Any hospital admissions since prior visit	Numeric	EHR/PHR
Patient medical history	Medical history of recent and prior conditions	Categorical	EHR/PHR
Lab results	Recent lab results	Numeric	EHR/PHR
Medications	Current medical treatment of the patient	List	EHR/PHR
ARRHYTHMIA EPISODES			
SVT	Number of episodes classified as SVT	Numeric	CIED
VT	Number of episodes classified as VT / VF	Numeric	CIED
AF/AT	Number of episodes classified as AF / AT	Numeric	CIED
SVT treated	Number of episodes classified as SVT treated	Numeric	CIED
VT treated	Number of episodes classified as VT / VF treated	Numeric	CIED
ALERTS			
Safety alerts	Safety alerts detected by the device	Text	CIED

Table 1. Patient specified information required by iCARDEA guideline

2.2. Benefits of Data Integration for ICD Patient Management

The demonstration scenario described above, illustrates several important advantages of the iCARDEA approach: (a) the healthcare team is immediately notified of any cardiac events that Mr. Schmidt experiences and is able to respond promptly to Mr. Schmidt's condition. (b) iCARDEA assembles and processes all pertinent clinical information, so that the healthcare team saves time and effort. Thus, this demonstration scenario provides preliminary evidence supporting the effectiveness of medical treatment as well as the positive economical impact for the cardiology department achieved by iCARDEA, which enables responsiveness and quality in ICD treatment.

At the same time, obviously automating multi-data monitoring and role-specific display of the relevant data for the next decision reduce the workload of healthcare team. Healthcare teams are released from the complexity and the diversity of the healthcare system. The personalized care plan of the ICD patient and device follow-up are facilitated by the adaptive care plan engine. This approach is likely to assist decision making based on guidelines and to promote safety in treatment. Furthermore, through PHR/EHR integration and self-management, ICD patients are involved in the whole process in a more active manner. Through the exchange and sharing of information in decision-making, the interaction between ICD patients and healthcare teams empowers both parties involved.

3. Conclusion

As health needs increase, and healthcare workforce dwindles, finding ways to efficiently integrate patient data from different healthcare systems and using them to provide efficient and effective healthcare is a hot topic for research in healthcare information technology. iCARDEA facilitates data integration between various healthcare systems through the provision of an integration platform to ensure secure and reliable health data communication. Great benefit will be gained from integration of medical information that makes data much more accurate and medical information more conveniently accessible to both healthcare providers and their patients. Another major benefit is that it requires minimal changes to current legacy healthcare systems. At the same time, it can facilitate and assist healthcare providers to promote collaboration with ICD patients and empower the efficiency and quality of cardiology departments when dealing with chronic, complex and life threatening cardiological diseases such as life threatening arrhythmias. Furthermore, iCARDEA is well placed to pass and benefit from several important trends. One is the rapid growth in the amount and complexity of data from various healthcare systems and device infrastructures, which provide the raw data expressing most clinical situations in a form that one platform could interpret for personalized care plans. Moreover, because all information is revealed to the healthcare provider, inappropriate utilization will be reduced and convenience by ICD patient and healthcare provider will be raised. With respect to all these benefits, a pending iCARDEA trial in Austria is expected to confirm the positive impact on the quality of care for ICD-Patients.

Acknowledgements
The research leading to these results received funding from the European Community's 7th Framework Programme (FP7/2007-2013) under grant agreement no. ICT-248240.

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