GENERATION OF DICOM STRUCTURED REPORTS IN RADIOLOGY AND THEIR TRANSFORMATION INTO DIAGNOSTIC IMAGING REPORTS BASED ON HL7 CDA

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Abstract

Dose reporting is vital in radiation protection efforts. This paper gives a brief description of dose reporting using DICOM SR and HL7 CDA. On the basis of the DICOM standard and the HL7 implementation guidelines a DICOM SR and HL7 CDA document were generated. Mapping and transformation of a DICOM SR into a HL7 CDA document facilitates the exchange of imaging based observations between imaging information systems and clinical information systems. As a result dose related information can be provided electronically for a further integration into healthcare information systems.

Keywords – DICOM SR, HL7 CDA, Electronic Health Record, Radiation Exposure, Radiology

1. Introduction

Radiation constitutes a part of our lives. People are exposed to natural sources of ionizing radiation (e.g. earth crust or cosmic radiation) and to human-made ionizing radiation sources as well. Ionised radiation has beneficial effects in medicine and is used for diagnosis and therapy. When radiation doses exceed certain levels, acute health effects such as skin burns or acute radiation syndrome can occur, but also low doses of ionizing radiation is believed to increase the risk of long term effects such as cancer [1]. For any medical use of radiation the benefits must outweigh the risks and people must be protected from unnecessary or excessive exposure [2].

Many approaches have been made in the last decade to calculate excess cancer risks in exposed groups at low or moderate doses. In contrast to low dose exposure, there is little doubt about the existence of deterministic and stochastic effects associated with high dose ionizing radiation exposure [3, 4]. Current radiation protection regulatory limits are based on the experience of the Japanese atomic bomb survivors (typically exposed to a range from high dose rates to moderate doses with an average of 0.1Sv or 100mSv) [3, 5]. The linear no-threshold (LNT) theory is the shaky foundation of these calculations and is highly debatable. LNT implies that any radiation exposure, independent of the amount, causes excess cancer risks and poses risks for genetic (hereditary) defects [5]. At the current state of scientific knowledge, developing cancer following acute or cumulative doses below 0.1Sv cannot be directly proved [4]. The reason for that is that it is

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a real challenge to perform a study with adequate statistical power to detect an excess risk of cancer in exposed groups, since radiation is in fact a weak carcinogen. In addition, human beings already run a high natural cancer risk of about 25%-40% [6, 7].

1. 1. Electronic Dose Reporting

In February 2010 the FDA[1] emphasized that every effort should be made by scientific and political authorities to increase the awareness of radiation risks among practitioners, prescribers and the general population. Therefore the "Initiative to reduce unnecessary medical radiation exposure from medical imaging" was started. In particular, research institutions were recommended to develop an educational/decision-making software tool including every patient's cumulative lifetime radiation dose [8]. In 2012, the European Union started the PALANTE[2] project and as a part of it, the development of an electronic Xray-Record (eXray-Recod) was initiated, which is the Austrian contribution to PALANTE. Currently, exposure data of patients is not available electronically and even less in a cumulative way. The aim of the electronic eXray-Recod is to summarize X-ray exposure data for every patient's life time [9]. All these projects and initiatives are converging in documenting the radiation dose, reducing unnecessary radiation exposure and increasing the awareness of dose risks. Ideally, for this purpose, exposure data is captured at the time of each new medical imaging procedure, by using electronic dose reports. Approaches to electronically extract cumulative radiation exposure histories and calculating risk estimates are vital in moving forward with radiation protection efforts [10].

1. 2. Complexity of Dose Calculation

Nowadays medicine is one of the largest sources of radiation and comprises almost 50% of per capita radiation dose compared to 15% in the early 1980s [11]. The WHO[3] pointed out that worldwide more than 3,600 million X-ray examinations are performed, 37 million nuclear medicine procedures are carried out and 7.5 million radiotherapy treatments are given per year [12]. The technology progress of medical imaging devices and high use of computed tomography (CT) has led to an extensive increase of medical radiation exposure. Due to this increased radiation exposure there have been some approaches to reduce unnecessary radiation exposure and to record patient's radiation dose histories in their electronic health record (EHR) [11]. Unfortunately there are several barriers to overcome for a successful dose report implementation. As described in [10] the following barriers exist:

- Currently most imaging systems do not record patient dose
- Output and parameters from imaging devices can be captured, but they are not routinely recorded in digital and database-friendly formats
- Currently no robust methods exist to convert exposure data of radiology treatments to patient-centric doses

1. 3. Objectives

This paper aims to show the possibility of a manual DICOM SR generation from different sources with radiology data, in contrast to an automatic, device-generated DICOM SR. The generated

[1] US Food and Drug Administration

[2] PAtient Leading and mANaging their healThcare through EHealth

[3] World Health Organisation

DICOM SR should provide sufficient data from a radiology information system (RIS) as well as a picture archiving and communication system (PACS) for an effective dose calculation. This helps to overcome the lack of information for radiation dose reporting. The effective dose is the common parameter reflecting risk from exposure to ionizing radiation [13]. Furthermore we want to integrate the radiology information and radiation dose data into the ELGA (Austrian EHR) to support health care professionals with additional information. Therefore the DICOM SR should be mapped into an HL7 CDA document to allow storing and exchanging medical data. An additional goal is to implement the HL7 CDA standard for radiation dose reporting and to represent radiology data on the basis of the Austrian implementation guidelines for CDA reports. In order to ensure the possibility of dose data integration into an EHR, the existing implementation guidelines for CDA have to be enhanced.

2. Methods

A systematic literature research was performed to survey different approaches of dose reporting with the use of DICOM SR and HL7 CDA. To be able to build up a test environment, the important components of the medical imaging environment were identified. For this purpose the radiological equipment and infrastructure of a Styrian hospital, including hardware and software, were examined. In addition, an investigation of used standards within the communication channels of the system was necessary. An analysis of the latest DICOM supplements and Austrian implementation guidelines for HL7 CDA reports was done to develop an accurate mapping process of DICOM SR into HL7 CDA reports. Furthermore, an investigation of the ELGA architecture was necessary to be compliant to ELGA specifications and requirements.

3. Results

The prototype of our mapping system concentrates on diagnostic imaging in radiology. Relevant radiological data and patient data are consolidated within a single DICOM SR. In addition the DICOM SR includes the basis for the calculation of the effective dose. Therefore the following radiology modalities and necessary examination data were identified:

- Conventional X-ray – dose area product, tube current, tube potential
- Mammography – parenchyma dose, tube current, tube potential
- Computed tomography (CT) – dose length product, total tube current
- Fluoroscopy – total dose area product
- Positron emission tomography (PET) / Single-photon emission computed tomography (SPECT) – activity of the radiopharmaceutical agent

3. 1. Architecture

Figure 1 shows the framework of the overall system architecture. Our approach simulates a patient data acquisition from different databases (EHR, RIS, PACS) of a hospital information system. If no DICOM SR is available from the radiology treatment, the DICOM SR Generator creates a structured report for each radiology treatment. A complete DICOM SR is the basis for the effective dose calculation and the generation of an HL7 CDA document. The data collected from radiology examinations in the DICOM SR are transformed into an HL7 CDA document by a CDA Generator. After the generation, the HL7 CDA document is stored in the EHR repository. The generated HL7 CDA documents provide the opportunity for an implementation into the ELGA, especially the prospective module “eXray-Record”.

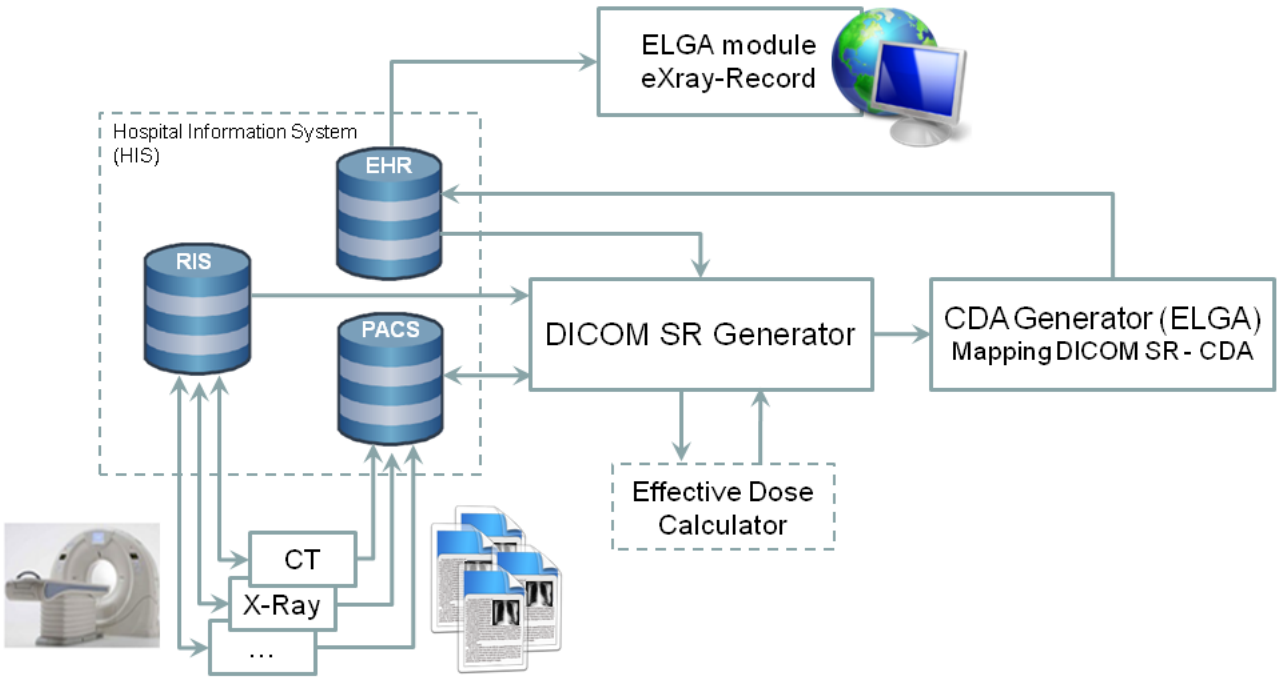

Figure 1: System Architecture for a DICOM SR generation and HL7 CDA transformation

3. 2. Generation of a DICOM SR

Diagnostic reporting in radiology relies on capturing clinical data during the medical imaging process. The widespread standard DICOM has achieved great success with images or documentation of findings, but interoperability of clinical data has struggled with proprietary solutions. To remove this obstacle, DICOM has developed DICOM structured reports (DICOM SR). A DICOM SR is able to express clinical data by using hierarchically organized coded vocabularies [14]. It only encodes the actual data and not how it is intended to be visualized.

The SR information object definitions (IODs) specify valid combinations of atomic components like relationships and value types. DICOM developed SR templates for special domains to further constrain vocabulary and its hierarchical organization. Such templates are not mandatory, but can be used to achieve consistency and greater interoperability. All information within a DICOM SR is conveyed by individual content items, where each item is a name-value pair. The name is defined by a code rather than by free text. In this way, indexing and searching are supported. A DICOM SR also can contain references to external objects such as images and waveforms. To model the meaning of the content, content items are encoded as a single tree, whereby the root content item conveys the document title [15].

The central component in the system architecture is the DICOM SR Generator. It is implemented as a web service and serves as data logger and SR generator. Currently there are just a few radiology devices (mainly CTs) which support automatically generated DICOM SR. The DICOM SR Generator collects image data from the PACS, technical data of the examination from the RIS and patient data from the EHR of the hospital information system and manually generates such SRs. However, the web service can also handle automatically generated DICOM SRs and extend them with necessary patient data. As a result, a combined use of automatically and manually generated

DICOM SRs is possible. The SR Generator can additionally use external web services like the Effective Dose Calculator to integrate new data. After the generation process the completed SR is stored back into the PACS together with the image of the corresponding examination. In addition the DICOM SR Generator provides the completed structured reports for the CDA Generator.

3. 3. Transformation of DICOM SR to CDA document

Clinical Document Architecture (CDA) is an HL7 standard which aims to standardise the usage and exchange of clinical documents between healthcare providers and patients. The HL7 Version 3 CDA is an XML based markup standard that specifies the structure and semantics of clinical documents. The standard is used in different countries for electronic health records and provides different formats for clinical documents (e.g. discharge letters, laboratory report or diagnostic imaging report) [16]. In recent years the HL7 and DICOM standard committee have formed a collaboration and carried out harmonisation work for DICOM and HL7 based standards. For this purpose they established DICOM supplements and HL7 Implementation Guides. One part of harmonisation deals with the translation of DICOM structured reports into HL7 CDA documents [17]. Due to the fact that HL7 CDA is the document standard for electronic health records and also required for the Austrian EHR, we decided to transform DICOM structured reports into CDA documents.

The CDA Generator represents the second important part of the architecture which transforms the provided DICOM SR into an HL7 CDA document. The transformation of DICOM data into HL7 standard is base on several specifications and guidelines (e.g. DICOM PS 3.20, DICOM Supplement 135 and HL7 Implementation Guideline for CDA). At first, a mapping table was established to link attributes of the provided DICOM SR with the HL7 CDA diagnostic imaging report. The mapping constraints between the two reports were identified and considered in the transformation step. The transformation and mapping from DICOM SR to HL7 CDA was implemented through a Web Service. The CDA Generator provides the generated HL7 CDA document and facilitates the exchange of imaging based observations between imaging information systems and clinical information systems. The HL7 CDA standard used is based on the latest implementation guidelines for CDA reports of imaging diagnostic in Austrian healthcare to allow a harmonized, structured and standardized way of transferring medical documents [18]. Additionally, the generated CDA diagnostic imaging report contains information about the radiation dose and can serve as a source for the future ELGA module “eXray-Record”.

4. Discussion and Conclusion

Experts generally agree that the future of dose monitoring will rely on the two main standards in this domain: Digital Imaging and Communications in Medicine Structured Reports (DICOM SR) and the Integrating the Healthcare Enterprise Radiation Exposure Monitoring (IHE REM) profile. For this reason we have chosen the approach to first create a DICOM SR and only in the second step to generate a CDA report. In addition, we are thus able to integrate automatically generated DICOM SRs from new radiology devices without changing or extending the process. Due to the fact that this technology is currently only being established on the latest generation of scanners [10], we did not test the extending scenario.
For DICOM SR generation the data acquisition was limited to radiology procedures with ionised radiation, which will be recorded in the future eXray-Record. It includes the conventional X-ray, Mammography, CT, Fluoroscopy and nuclear medicine, but not radiation therapy. To acquire data,

different methods were analysed to obtain dose information from the radiology devices. The DICOM MPPS (Modality Performed Procedure Step) and DICOM header acquisition methods were insufficient for dose reporting [9]. Therefore DICOM SR was identified to provide all dose-related parameters. In a similar approach, a successful HL7 and DICOM based integration of radiology departments with healthcare information systems was shown in Croatia [19]. Our approach additionally deals with radiation dose reporting, the complexity of dose calculation and transformation of DICOM dose related data to HL7 CDA. As a result, we are able to provide dose related information electronically for a further integration into healthcare information systems.

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