Creation and Storage of Standards-based Pre-scanning Patient Questionnaires in PACS as DICOM Objects

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Abstract Radiology departments around the country have completed the first evolution to digital imaging by becoming filmless. The next step in this evolution is to become truly paperless. Both patient and non-patient paperwork has to be eliminated in order for this transition to occur. A paper-based set of patient pre-scanning questionnaires were replaced with web-based forms for use in an outpatient imaging center. We discuss this process by which questionnaire elements are converted into SNOMED-CT terminology concepts, stored for future use, and sent to PACS in Digital Imaging and Communications in Medicine (DICOM) format to be permanently stored with the relevant study in the DICOM image database.

Keywords Paperless · Pseudo paperless · Filmless · SNOMED-CT · Data mining · Clinical workflow · Data collection

Background

A majority of radiology departments have now become filmless, with studies done via direct or indirect digital modalities and with interpretation done on picture archiving and communications system (PACS) workstations [1]. Filmless radiology has been shown to improve workflow, to increase patient throughput, and to provide more

opportunity for real-time quality control [2, 3]. Furthermore, many institutions have successfully transitioned to becoming filmless in as little as 60 days [4]. In light of the benefits and successful transitions to filmless departments, some departments have gone one step further and addressed the goal of implementing paperless radiology as well. This has included not only speech-recognition, but also protocols, requisitions, and technologist sheets being scanned into the PACS or radiology information systems and associated with the selected study [5–8].

The trend toward paperless departments has seen similar benefits of efficiency [9]. To be complete, a transition to a truly paperless department should include the elimination of patient-associated paperwork, such as safety and consent forms and patient histories. Furthermore, just as the Digital Imaging and Communications in Medicine (DICOM) standard revolutionized the filmless transition, incorporation of standards for medical information can enable effective decision support, enhance patient safety, and reduce overall costs of healthcare delivery [10]. We present a system that seamlessly integrates a paperless collection of required pre-scanning patient questionnaires into the practice of an outpatient clinic at an academic radiology department. In addition, by collecting the information in a structured and electronic format, we present how the patient information is mapped to the Systematized Nomenclature of Medicine—Clinical Terms (SNOMED-CT) terminology for maximal reuse and standardization.

Methods

Currently, when a patient arrives for imaging in our institution, they are given paper forms associated with the type of study that will be performed, based on modality and the body part being imaged. The forms are used to obtain important clinical information required for accurate study

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interpretation, to identify patient safety hazards, and to rule out procedures that are contra-indicated. The forms become part of the patient file and must be included in the permanent record. Because of the large number of studies performed and the limit of on-site storage available, patient questionnaires are kept for a period of time, and then moved to an off-site storage facility. When this happens, patients returning for follow-up imaging are often required to fill out new forms answering the same questions. This repetition is inefficient for the imaging department and inconvenient to the patient.

We designed a web-based system to replace these paper forms for which the creation of and usability testing of have previously been discussed [11]. All the questionnaire elements were manually matched to SNOMED-CT concepts with the exact or closest related concept. While the healthcare enterprise has been slow to adopt the use of standard terminologies, SNOMED-CT has been mandated and effectively used for the encoded collection of patient health information by numerous US federal government panels, committees, and studies, as well as private institutions [12–19]. SNOMED-CT has also become available free of charge for use in the USA through an agreement with the National Library of Medicine's Unified Medical Language System [10].

Standard Terminologies

Multiple MySQL tables were created to house different aspects of the questionnaire elements and SNOMED-CT concepts. The questions table held SNOMED-CT terminology concepts for all the elements in our forms which were matched with element name and value combinations from each form (Fig. 1) [10]. For example, a question about having a pacemaker was given element name “chk_pacemaker” and had values of “Yes” and “No” which had independent rows in the questions table mapped to SNOMED-CT concept “Patient with cardiac pacemaker”. The table “forms_data” was used to hold the mapped elements and concepts from each patient completed questionnaire answer which were identified by a auto generated exam number, patient medical record number (MRN) and the study accession number. In order to account for the lack of positive and negative concepts in SNOMED-CT, i.e., there is not a concept “Patient without cardiac pacemaker”, we used a MySQL trigger that when the value of “Yes” was used with a element the table automatically mapped it to the SNOMED-CT concept and code for “Present” in the PRESENT column and with the appropriate “Present” SNOMED-CT concept code. This

Fig. 1 View of MySQL master database table with matching SNOMED-CT codes and name/value pairs

QUESTION_ID	ITEM_NUMBER	SNOMED_CODE	SNOMED_CODE_TEXT	QUESTION_VALUE	Comments
chk_brain_surgery_text	3004	22232009	Hospital	(Null)	
chk_brain_tumor	1117	126952004	Neoplasm of brain	No	NULL
chk_brain_tumor	1117	126952004	Neoplasm of brain	Yes	NULL
chk_breast	1058	2282003	Breast prosthesis, device	No	NULL
chk_breast	1058	2282003	Breast prosthesis, device	Yes	NULL
chk_breast_pain	1064	53430007	Pain of breast	Yes	NULL
chk_breast_pain	1064	53430007	Pain of breast	No	(Null)
chk_breast_pain_date	0	296059007	Date of onset	(Null)	(Null)
chk_bulges	1233	9404003	Orbital swelling	No	NULL
chk_bulges	1233	9404003	Orbital swelling	Yes	NULL
chk_bulges_date	0	296059007	Date of onset	(Null)	(Null)
chk_bulges_location	2148	362503005	Entire left eye	left	location
chk_bulges_location	2149	362502000	Entire right eye	right	location
chk_bulges_location	2150	362508001	Both eyes, entire	both	location
chk_buttocks_numbness	1396	309537005	Numbness of lower limb	Yes	(Null)
chk_buttocks_numbness	1396	309537005	Numbness of lower limb	No	(Null)
chk_buttocks_numbness_locat	2047	32153003	Left lower extremity structure	left_buttock	(Null)
chk_buttocks_numbness_locat	2046	62175007	Right lower extremity structure	right_buttock	(Null)
chk_buttocks_numbness_locat	2157	4180000	Both lower extremities	both_buttocks	(Null)
chk_buttocks_pain	1407	279043006	Pain in buttock	Yes	(Null)
chk_buttocks_pain	1407	279043006	Pain in buttock	No	(Null)
chk_buttocks_pain_location	2047	32153003	Left lower extremity structure	left_buttock	(Null)
chk_buttocks_pain_location	2046	62175007	Right lower extremity structure	right_buttock	(Null)
chk_buttocks_pain_location	2157	4180000	Both lower extremities	both_buttocks	(Null)
chk_buttocks_sx	2183	362677002	Entire buttock	NULL	location
chk_buttocks_sx	1407	279043006	Pain in buttock	NULL	NULL
chk_calf_numbness	1396	309537005	Numbness of lower limb	No	(Null)
chk_calf_numbness	1396	309537005	Numbness of lower limb	Yes	(Null)
chk_calf_numbness_location	2095	30021000	Entire calf of leg	left_calf	(Null)
chk_calf_numbness_location	2095	30021000	Entire calf of leg	right_calf	(Null)
chk_calf_numbness_location	2095	30021000	Entire calf of leg	both_calves	(Null)
chk_calf_pain	1196	300954003	Pain in calf	No	NULL
chk_calf_pain	1196	300954003	Pain in calf	Yes	NULL
chk_calf_pain_location	2095	30021000	Entire calf of leg	right_calf	(Null)
chk_calf_pain_location	2095	30021000	Entire calf of leg	both_calves	(Null)
chk_calf_pain_location	2095	30021000	Entire calf of leg	left_calf	(Null)
chk_cancer	1373	395100000	No evidence of cancer found	No	NULL
chk_cancer	1277	266987004	History of - malignant neoplasm	Yes	NULL
chk_cancer_date	0	432213005	Date of diagnosis	(Null)	(Null)
chk_cancer_location	0	314524002	Region of bone	Bone	location
chk_cancer_location	0	384763002	Brain region	Brain	location
chk_cancer_location	0	44029006	Left lung structure	Left Lung	(Null)
chk_cancer_location	0	3341006	Right lung structure	Right Lung	location
chk_cancer_location	0	80891009	Heart structure	Heart	location
chk_cancer_location	0	69695003	Stomach structure	Stomach	location
chk_cancer_location	0	32849002	Esophageal structure	Esophagus	location
chk_cancer_location	0	119218006	Pancreas part	Pancreas	location
chk_cancer_location	0	10200004	Liver structure	Liver	location

was likewise done for “No” answers which were mapped to the “Not Present” SNOMED-CT concept.

The table `patient_info` was used to hold patient demographic information which could then be used to auto populate these sections in the questionnaire if the patient returned for additional studies. Finally, a relational table named `exams` was created that tracked each questionnaire completed by auto populated exam number, exam date, exam accession number, patient MRN, and exam type. This was related to the `patient_info` and `forms_data` tables by exam number, patient MRN, and accession number and then was queried by the PHP pages in order to prepopulate questionnaire answers in cases where a patient returned to complete another test.

Questionnaire Completion

When the patient arrives to the imaging center they are directed to a table with tablet computers. After undergoing a short training session on how to use the questionnaires they are directed to enter the accession number for their study which is given to them by the receptionist. The PHP page then takes this accession number and performs two things. Firstly, it posts this number to a JSP page which uses a Java Bean created from the Pixelmed java tool kit - sends a DICOM query to the PACS database that returns information regarding that accession number assigned study including patient demographics, study description, study status, and study universal identifier (UID) and then posts it back to the PHP page. Secondly, the PHP page chooses which questionnaire the patient should complete based on study description and takes the patient MRN and queries the `exams` MySQL table to determine whether the patient has filled out this questionnaire in the past, and if so will acquire the answers from the `forms_data` table using the most recently completed questionnaire and autocompletes the new questionnaire for the patient to review. Upon completion of a questionnaire, a parser written in PHP matches each element and its value, i.e., the patient’s answer, with the SNOMED-CT concept or concepts within the questions MySQL table and stores them in the `forms_data` MySQL table which are identified by study accession number and patient (MRN). The additional needed information is also added to the `exams` table.

A three-part process is then started that allows for conversion of each questionnaire into a DICOM file. Firstly, the parser creates a HTML display version of the questionnaire by using preconfigured PHP display templates and saves it into the `HTML_Forms` folder on our server. The HTML version is then converted to a PDF document by the parser using the open source HTML to PDF PHP script and then saves it in the `PDF_Forms` folder on our server [20]. Lastly, the parser then posts the questionnaire information needed to create a DICOM header to a JSP page. The JSP page uses a Java Bean created using the Pixelmed java tool kit [21] which uses

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Brain MRI Pre-scanning Patient History

Date: 01/28/2009 Patient MRN: 9876544

First Name: Tracy M.I.: J Last Name: Robinson

Date of Birth: 08/09/1974 Gender: Male Patient Weight: 151 LBS

What was your last PSA level?

Referring Physician: Strong

Do you have an appointment with your doctor today? YES Time: 4:30

Do you have any medication allergies? Yes
What are you allergic to?:

1. What is the Main Reason your physician ordered this scan?
test 1

2. How long have you had these symptoms?

Fig. 2 Example of display questionnaire seen as a separate study series in the PACS

the PDF to DCM class and converts the PDF to a DICOM object building the DICOM header with the required patient information. The DCM file is then saved to the `DCM_Forms` folder on our server. Using this same Java Bean, the JSP then uses the `DICOMSender` class, a subclass created from Pixelmed, to send the DICOM images to the PACS server which becomes a separate series within the study (Fig. 2).

Results and Discussion

A PubMed search resulted in multiple instances of coding radiology reports into terminologies, but only one example of coding radiology reports using SNOMED-CT [22–27]. As far as we know, there have been no previously published attempts to map these types of patient imaging information to a standard terminology. While our approach to storing the study-related data in PACS involves multiple steps and interactions with different systems, it accomplishes an important task that has been previously hindered because of just this complexity. The data transformations and update steps have been automated to provide a convenient way of collecting patient history and safety information and storing it along with study images.

Good coverage of the needed elements was obtained using the SNOMED-CT terminology, with 93% of questionnaire elements able to be manually mapped to appropriate concepts in the SNOMED-CT terminology. The small percentage of elements that did not have corresponding SNOMED-CT concepts were almost exclusively anatomically based and had to be extrapolated to a more generic concept (i.e., the

SNOMED-CT concept of “thigh” was used to represent the concept of “anterior thigh” from the questionnaire). This was very similar to other studies matching clinical information [13–19, 28, 29]. In cases where concepts also required location delineation, secondary concepts were created and submitted into the forms_data table as separate rows. For example, left leg numbness along with begin mapped to “Numbness of lower limb” was also mapped to “Entire left lower extremity”, “Entire right lower extremity”, or “Both lower extremities” depending on the patient answer.

The advantages of coding this information are multifaceted. If the patient comes to the imaging department in the future to have additional or repeat examinations, the information for the new questionnaire can be pre-populated and the patient will only have to review the information and add any interval changes. Answers are propagated over multiple questionnaires, which is especially important for text entry as the patient can look at entered information and add to them if additional details were remembered. This should increase the efficiency of the imaging department, although at this current time it has not been tested. In addition, this coded information can be manipulated by computer applications for decision support, research, and patient care both within our application, and potentially in an electronic medical record or other application that understand SNOMED-CT codes.

With this patient information now available to the radiologist digitally, there are two distinct advantages. Firstly, the radiologist responsible to protocol the study can review this information and further tailor each study to get the best possible images to evaluate the patient’s pathology. Secondly, the interpreting radiologist can use this clinical information to provide a more appropriate interpretation of the findings and correlate them to a more definitive diagnosis. These are areas of interest that we can explore after full implementation.

Data Mining

One of the more important yet less heralded outcomes of this project is the creation of a large store of patient history and safety information that can be used for data mining. Data mining is the searching of coded patient information to try and find patterns of cause and effect [30]. There are approximately 56 elements per questionnaire available for data mining. With approximately 60,000 CTs and MRIs performed at our facilities per year that amounts to 3.4 million searchable data points per year that can be used with for data mining and outcomes research [31–34].

This project provides an example of the utility for collecting patient information using a coded terminology. The widespread use of computers in patient care, both by healthcare providers and patients, allows for multiple opportunities for acquiring coded patient information. Gathering this data supports outcome related evidence based healthcare. The recent

push and monetary influx by the federal government to computerize the patient health record makes creating and using technologies such as these feasible.

Conclusion

We created a web-based patient pre-scanning safety and history questionnaire set that codes elements into a standard terminology and sends finished versions to the PACS. Mapping patient questionnaire responses from our pre-scanning questionnaires to the SNOMED-CT terminology and presenting the information in stylized HTML provides a consistent view of this information to patients and clinicians and provides opportunities for the data to be reused for research and quality assurance. By transforming the form data into DICOM image objects and sending them for inclusion in the PACS imaging database, radiologists have ready access to the information directly through the PACS interface to support more accurate study protocoling and interpretation. Patients no longer need to rely on memory alone in filling out forms they have filled out previously, and our department is one step closer to realizing the full benefit of becoming paperless.

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