Automating Clinically Relevant Prefetch Processes in Picture Archiving and Communication Systems Solutions

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As picture archiving and communication systems (PACS) hit the mainstream of projects gaining attention and priority in healthcare organizations, the promise of achieving better operational efficiencies in the radiology department is at the forefront of the financing discussions. Although some positive economic returns have been documented from the early proponents of PACS, most of the PACS installations are still working through operational changes in regards to digital image prefetching to achieve this objective. The lynchpin for achieving the desired operational efficiency is the enabling of an automated, clinically relevant prefetch process for comparison studies from the digital archives. This report explores the solutions deployed at two hospital systems in Minneapolis to utilize a "comparative region of interest" data element to augment the body region information typically available for prefetching in the PACS system. With this information, the prospective PACS implementer will know how to build in their body region requirements up-front in order to maximize their operational efficiency benefits later.

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IN A 1998 article discussing the requirements for an ideal picture archiving and communication system (PACS) workstation, Dr Bradley Erickson, an associate professor at the Mayo Clinic, is quoted as saying that he "wants the next generation of workstations to be far more intelligent than the last." He believes the systems should be smart enough to recognize that pertinent historical studies for a particular patient are in the archive. Selected images should be prefetched so they are ready for viewing.¹ Unfortunately, since that comment, most of the prefetching response to Erickson's request has been delivered via the "human" support system, not a computer system.

The basic problem is that the automated prefetch process has not been robust enough to accommodate the various requirements of the radiologist's diagnostic interpretation task. The PACS implementation brought with it an expectation for shortened turn-around times for radiology reports. It has been demonstrated that the overall responsiveness of the department does improve very quickly with the introduction of the PACS. However, the individual productivity of the radiologist has only been maintained with the continuation of the same, if not more, image "prepping" services by the tech-

nologist or file room staff. If the anticipated financial benefit of PACS is to be achieved, this manual, labor-intensive work by the staff needs to be supplanted by more automated processes which leverage the information available in the RIS-PACS environment.

This report describes a solution explored at two medical centers in Minneapolis, MN to address one of the major shortcomings in providing a clinically relevant prefetch in PACS solutions today.

PROBLEMS ENCOUNTERED WITH EXISTING PACS DATA ELEMENTS

The realization of a fully automated filmless operation within the Radiology Department as promoted by the PACS vendors and healthcare informaticians dictates a number of information system prerequisites. Some are related to the content of the relevant data elements in the radiology information system (RIS) and its information exchange with the PACS. Others have to do with the support, or rather the inconsistent support, of these data elements by the technology components of the RIS, PACS, and imaging devices involved in the digital solution.

The PACS initiative at a premier Trauma Center in Minneapolis encountered a number of challenges in its attempt to automate the prefetch process at its institution. The critical challenges, not unlike other institutions that have implemented PACS into an existing radiology operation, were as follows:

1. The Procedure description text used in the RIS was inconsistent from one image type (ie, modality) to another in regards to its use of the organ or body part to be examined, eg, PELVIS W/ CONTRAST CT, PELVIS 3V, PELVIC/VAGINAL US: PA & LAT.

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2. The use of the organ/body part data element was inconsistent from modality to modality. In addition, at the modality itself, the technologist was required to select a particular body part or region/subregion for the examination. This selection is used to drive the drive the related processing (computed tomography [CT], magnetic resonance [MR]) or postprocessing (computed radiography [CR]) algorithms utilized by the scanner/reader in the creation of the digital image itself. Unfortunately, without any guidelines in the industry for the uniform definition of these organ selections, each modality manufacturer proceeded to name these selections at their discretion and in the interest of their own internal programming. Even different modalities from the same manufacturer have used a different nomenclature for the identification of the body part for their individual procedures.

Besides the differences in the name of the body part being examined, the location where this information is ultimately stored in the image header is inconsistent. Each manufacturer has opted to "enhance" its participation in the PACS arena by using its own Digital Imaging and Communications in Medicine (DICOM) Shadow Group. For example, the CT and MR devices might value the header element DICOM BODY PART EXAMINED (0018, 0015) with the technologist selection. However, the CR systems at this medical center would not use this header element at all. It would value the header elements REGION (0019, 0027) and SUBREGION (0019, 0028) for its studies. The data element ORGAN (0011, 0010) would be valued intermittently by the various imaging devices as well. The data element PROCEDURE DESCRIPTION (0008, 1030), that originally contains the procedure text from the RIS order, ended up getting overridden at some modalities with comments entered by the technologist at the console.

3. Use of the full text description of the ordered procedure (eg, FINGER RIGHT HAND AP/OBL/LAT) was too granular for effective prefetching of comparative studies. Modality, on the other hand, was too broad of a

definition. As a result, the only prefetch formulas that could be implemented with the data elements available would be:

- (a) A two-tiered algorithm that first attempted to find an exact match to the procedure, if that failed, then a previous study of the same modality would be retrieved. Cross-modality comparisons were not possible.

Or

- (b) A complicated character-string based set of rules using the full procedure description text that would be processing intensive and could slow down the entire prefetch performance at times of high study volumes.

4. The timing of when the body part designation selected as part of the image capture process is available is too late for an effective prefetch process to be initiated. Ideally, the prefetch logic should be triggered as close as possible to when the "patient arrived" status has been entered into the RIS order. This would permit the optimal balance of prefetching after the order request has been reviewed (and adjusted, if necessary) by the technologist, but in sufficient time for the results of the prefetch logic to be obtained and routed to the diagnostic workstation(s) while the current order is being fulfilled.

As a result of the above situation, it was determined that a totally independent data element that would be dedicated to optimally de-archiving the required comparison studies would be the best solution to automating the prefetch process. For our project discussions, the new data element was called the Comparative Region of Interest (CROI).

BENEFITS AND DEFINITION OF THE CROI DATA ELEMENT

The objective of this data element is to provide a method to optimally de-archive comparison studies from the PACS archive to automatically make them available to the "Reading package" for the radiologist without other human intervention. Since, however, a truly optimal prefetch process would take into account radiologist preferences and patient/pathology characteristics, solving the body organ correlation issue will, at best, provide a suboptimal improvement over the current options.

It would, however, provide an estimated 20% to 30% efficiency gain to those procedures where a cross-modality interpretation is required. For such procedures, it would also almost eliminate the ambiguity of the nonpredictive value of the radiologist's report for the referring physician and, as such, would provide efficiency improvements in their operations as well. In addition, the imaging department itself would realize a considerable reduction in the demand on its file room or technologist staff for manually "prepping" the digital reading package for the radiologist.

The foundation of the CROI definition is the master list of imaging procedures available to the ordering physician. This list is usually the result of an iterative update process in-sync with the availability of the radiological service offerings of the facility. As such, there is likely to be considerable variation between a procedure list for a Level 1 Trauma Center, a Veteran's Administration Medical Center, a University Medical Center, a Community Hospital, etc. However, since PACS is typically being implemented into an existing imaging services operation, the problem of inconsistent procedure description text is applicable to all tiers of facility. It is just a matter of degree.

The best starting point for the definition of the CROI definition is typically the CR system tables. The region/subregion designations do a relatively thorough job of covering the entire set of body parts due to the breadth of the procedures it needs to accommodate for its postprocessing algorithms. An example of the CR regions specified at this Minneapolis Trauma Center is shown in Table 1.

Once an initial list of body regions has been deduced from the CR regions/subregions, the next step is determining their applicability to the other modalities (CT, MR, ultrasound, etc). Remember

Table 1. Regions Specified by a Computed Radiology System

CHEST	SHOULDER
CERVICAL	HEAD
HAND	ARM
THORACIC	PELVIS
ABDOMEN	HUMERUS
LUMBAR	FOOT
LEG	FEMUR
KNEE	

Table 2. Sample of CROI Designations

Procedure Ordered	CROI	
	L/R	Organ
Medical Center #1 (Trauma Center)		
Abdomen Ultrasound w/duplex	^	ABDOMEN
Abdomen 2 View Flat & Upright	^	ABDOMEN
Abdomen with contrast CT	^	ABDOMEN
Ankle Left Tomogram	L	LOWER EXTR
Ankle Left w/contrast MR	L	LOWER EXTR
Ankle Left 3V AP/OBL/LAT	L	LOWER EXTR
Foot Left w/o contrast MR	L	LOWER EXTR
Foot Left 1 view	L	LOWER EXTR
Pelvis AP	^	PELVIS
Pelvis w/o contrast MR	^	PELVIS
Pelvic/vaginal US: non preg	^	PELVIS
Scapula Right AP & LAT	R	SHOULDER
Shoulder Right Tomogram	R	SHOULDER
Sinus Coronal Modified CT	^	HEAD
Sinus 1 / 2 view	^	HEAD
Skull Series	^	HEAD
Spine Cervical AP & LAT	^	SPINE
Spine Lumbar FL/EXT 3R Bend	^	SPINE
Spine Lumbar 5V w Obliques	^	SPINE
Spine Thoracic 1V	^	SPINE
Etc		
Medical Center #2 (VAMC)		
Abdomen Flat	^	ABDOMEN
Abdomen 3 or more views	^	ABDOMEN
CT abdomen w/Cont	^	ABDOMEN
Hand AP-LAT-OBL views	L	UPPER EXTR
Magnetic Image, Upper Extremity	L	UPPER EXTR
CT Head w/IV Cont	^	HEAD
Skull Less than 4 views	^	HEAD
Etc.		

that the intention is to provide a "link" to bring together studies that are the most appropriate to the radiologist's reading process. To this end, it will be necessary to incorporate a data component for the left/right indication of the study into the CROI data element to accommodate extremity studies effectively. In the interest of not excluding some potential useful comparison studies, it is better to keep the CROI categories broad as opposed to narrow (eg, use a single CROI of "Head" v two CROIs for "skull" and "mandible"). For this institution, it was determined that the CROI regions of LOWER EXTREMITY and UPPER EXTREMITY would be better than the individual body regions of LEG, FOOT, ARM, etc.

Table 2 is a sample of some CROIs and their correlation to the ordered imaging procedures for a couple of medical centers in Minneapolis.

IMPLEMENTING THE CROI DATA ELEMENT IN THE RIS-PACS ENVIRONMENT

Now that it is understood the origin of the CROI data element, implementing it offers its own set of challenges. Once the radiologists have arrived at a consensus of the number of and names for the CROIs to be deployed (not as easy as it sounds), implementing this new data element effects every component of the RIS-PACS interface. For starters, there are typically at least three vendor's products involved: the RIS, the RIS-PACS Broker, the PACS plus the vendors of the imaging devices themselves.

For the RIS vendor, the challenge is getting this new data element incorporated into the RIS data and file structure. The requirements here are:

- It must be in a master file or table that can be linked to an ordered imaging procedure.
- It must be maintainable as part of the procedure code update process (usually via an interactive online application), including the combination with the left/right indication if this is reflected in the procedure text.
- It must be included in the Health Level 7 (HL7) or other proprietary order transaction passed to the RIS-PACS Broker (if the left/right indication is only specified at time of order, then the final CROI value must be "built" as part of the creation of the order transaction).
- Depending on the number of procedure codes to be updated in the RIS database, it might be necessary to develop a custom batch update program for the initial CROI data element load.

The RIS-PACS Broker is usually the least problematic component to update for the CROI data. By design, this product routinely maps incoming data elements from the ADT or Order transactions to data fields in its own internal database. In our project, Mitra Imaging (the PACS Broker deployed in most institutions PACS solutions; Waterloo, Ontario, Canada) was very accommodating and helpful at identifying an appropriate data base field and revising their mapping logic to value it with the new CROI data element. For our project, the new data element would be transferred via a special observation request (OBR) record following the common order (ORC) record as part of the HL7 Order Status Update message set.

Difficulties can occur when the interaction with the PACS is not via the standard DICOM Query/Retrieve service object pair (SOP). If a proprietary query transaction is used, then it might be necessary to transfer the CROI data element to the PACS via another data field already included in the transfer message but not used at this particular facility. It would then be necessary for the PACS system to either map this "transfer field" to the CROI element in its database or utilize this transfer field directly in its prefetch algorithms in lieu of using a CROI data element.

Accommodating the CROI data element in the PACS is the most difficult due to its required interaction with the various imaging devices and the "flexibility" of the DICOM standard. The PACS must correlate the Image header demographics from the modality to the Order demographics received from the RIS. As noted earlier, typically each imaging modality is already generating a body part designation of its own as part of the image capture process at the scanner/reader. It is critical that this modality-based body part be stored and processed independently of the CROI data element and does not corrupt the RIS-supplied information.

INTERIM RESULTS

Full implementation of the CROI data element at the two medical centers in Minneapolis is still a work-in-progress.

For one, the RIS and RIS-PACS Broker components have been updated to accommodate this new field and testing has been successfully completed for storing the element in the Broker's database. Unfortunately, the PACS component encountered a problem with getting this field uniformly updated (without getting corrupted) for all study types. The legacy CR systems, identified as the primary source of the problem, are currently in the process of being upgraded, at which time the CROI implementation will be revisited.

The second medical center is in the process of reassessing its list of ordered procedure codes. Once this prerequisite is completed, the new procedure table can be updated with an appropriate CROI data element.

CONCLUSION

The transition to a PACS-based imaging services department from a historically film-based

operation has uncovered a number of "hidden processes" that are considerably more difficult to automate than moving the digital images around on a network. The "humanoids" of the radiology support system have been very creative and adaptive at providing an effective reading environment for the radiologists. As we attempt to automate more and more of this departmental support process, it is an opportunity to review each of these adaptations and only incorporate those that are in the best interest of the digital reading environment going forward.

With the growth of cellular imaging (as reflected by the recent increased interest in nuclear positron emission tomography studies) into the Radiology mainstream, the need to correlate conventional anatomical imaging results with their cellular counterparts will increase the importance of a CROI data element in the RIS-PACS solution. Although the current PACS archiving trend is to provide a higher volume of imaging studies available in the "fast-response" redundant array of inexpensive disks (RAID) storage, it will always be an objective to optimize the use of computing resources while maximizing the degree of automated "prepping" that can be done at the diagnostic workstation itself.

Some other features that should be considered in enhancing this study preparation for the radiologist that would further help reduce the manual intervention by the departmental staff are:

- Incorporate radiologist- and patient-/pathology-specific characteristics into the prefetch logic (eg, provide a different search/retrieval logic for a neuroradiologist or for an intensive care unit [ICU] patient)
- Enhance the comparison study search to utilize more robust date/time relationships to the current study (eg, for ICU patients, provide the first study for this patient's encounter at the hospital)
- Accommodate a procedure that may belong to more than one CROI and retrieve comparison studies for all of them

With the PACS decision moving to be one of "when" and not "if," it is important that the increasing number of vendors and care-providing institutions participating in this arena converse openly and often on what is required to optimize the use of everyone's most precious resource—time.

REFERENCE

1. Brice J: In search of smart and simple PACS workstations. *Diagn Imaging* 20:35-37, 1998