Case Study of Security in Teleradiology Reporting System for Management of Data from Multiple Enterprises

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Abstract

This paper is a case study that describes the methods used by a radiology practice in Southern California to address the specific security requirements for providing teleradiology service to multiple hospitals and clinics. The context of the case study revolves around the organization's goal to achieve maximum efficiency in the usage of human capital for generating radiology reports while radiologists are geographically scattered across numerous locations. As background, this paper starts by describing how a radiology practice transitioned from the conventional transcription-based reporting method to one that allows the radiologists to create reports directly through the use of a hybrid speech recognition and structured reporting system. With HIPAA, healthcare providers are concerned about securing their patients' health data. Healthcare providers are especially concerned when their patient health data are being stored outside their premise. The security challenges for this radiology practice stem from an environment where radiologists are doing interpretation from disperse locations and each radiologist can interpret for any of the healthcare providers under contract. The "efficient use human capital" by this radiology practice, hinges on how well they can mitigate the security concerns of the healthcare providers.

Keywords: electronic medical records, HIPAA compliance, knowledge base, lexicon, macro, macro reporting, menu navigation, patient health data, radiology reporting systems, security, speech recognition, structured report, structured reporting, taxonomy, template, teleradiology

Introduction

The background for this paper is on a software company's experience in deploying a radiology reporting system at a teleradiology practice. This is a continuation of a case study that was first introduced in 2001 at the annual meeting of the Radiological Society of North America (RSNA) [i,ii,iii]. In 1995, the software company's cofounders began developing radiology reporting templates for the purpose of generating structured reports. Those initial efforts focused on CT and MRI studies of the cervical, thoracic, and lumbar spine. The original motivation for developing templates was to improve the interpretation and reporting abilities of the non-neuroradiologists. By 1996, the cofounders had developed a general template structure for all modalities; although the majority of the detailed work was focused on structured reports for chest x-rays—as they make up a significant portion of the workload at that time. Along the way, free-text editing and continuous speech recognition were added to the system.

In 2008, the software company deployed this hybrid speech recognition and structured reporting system at a radiology practice in Southern California. The radiology practice's stated goal was to operate the practice as a teleradiology organization to obtain maximum efficient usage of their premium human capital, i.e. the radiologists. In order to do so, they also transition from the conventional transcription-based reporting method to one that allows the radiologists to create reports directly. Without the delay in turnaround time of transcription intermediaries, radiology reports could be completed at the same moment as image interpretation, followed by immediate report dissemination. In today's mostly filmless environment, image viewing is done on PACS (Picture Archival and Communication System). During that transition period from conventional transcription, some reports were still being generated through transcription while the majority were produced with the hybrid speech recognition and structured reporting system.

Within six months, the transition by the radiology practice to the usage of the hybrid speech recognition and structured reporting system was completed. From that point forward, nearly all radiology reports are being produced with this hybrid speech recognition and structured reporting system.

When compared to transcription-based reporting, the hybrid speech recognition and structured reporting system has:

(1) Enhanced the efficiency of the radiologists.
(2) Improved the quality and consistency of reports.
(3) Enabled instantaneous dissemination of reports to improve patient care and decreased hospital stays.
(4) Eliminated transcription costs.

Others have discussed the problems associated with transcription-based reporting, as well as the advantages and disadvantages of structured reporting [iv,v]. Success of this implementation also depends on how well the security concerns of the healthcare providers are mitigated. Note that the healthcare providers are the customers of the radiology practice. The purpose of this paper is to describe the methods used in an environment where radiologists are doing interpretation from disperse locations and each radiologist can interpret for any of the healthcare providers under contract. It also discusses how healthcare providers' concerns for patient privacy and HIPAA (Health Insurance Portability and Accountability Act) are addressed.

Spectrum of radiological reporting systems

Before discussing the details of the hybrid speech recognition and structured reporting system, we will review several types of reporting systems, in order to establish a context for comparing and contrasting the strengths and weaknesses of the system.The most widely used method for radiology reporting is transcription, where radiologists dictate their "findings" which are then transcribed by a transcription service. When the report is returned from the transcription service, the radiologist verifies the accuracy of the report and signs it. The report is then distributed to other departments in the hospital. In the cases when transcription errors occur, reports must be returned to the transcription service for correction. With transcription, the final output is a printed report or a text file that is distributed outside the radiology department.

Another commonly used method is to use speech recognition, rather than relying on stenographers [vi,vii] to input free-form text. In this case, findings are recorded narrations followed by speech-to-text automation. Unfortunately, free-form text does not lend itself to quantitative analysis in the way that a structured database would. Therefore, some groups have attempted to apply natural language processing to free-form text reports in order to produce structured reports[viii,ix].With this extra processing step at the end, text-based radiology reports are turned into structured data; which may be mined at a later time for research into individual studies, analysis for trends, or outcomes research.

Given the desirability of producing structured data, another approach is to capture findings as "structured data" just at the point where the radiologist is observing the study results. In this case, there is no separate step of transcription. The radiologist enters the findings directly, enabling the software to capture them as structured data. In contrast to some systems that allow for speech recognition input—utterances are captured as unstructured data, this software is in the category of radiology reporting systems that capture structured data at the point of observation, as are several other structured radiology reporting systems that provide for menu-based data entry, such as ProVation Medical gastrointestinal virtual colonoscopy [x], PenRad mammography [xi], ClickView obstetrics and gynecology [xii] and SPIDER (structured platform-independent data entry and reporting) [xiii].

In the versions released since 2007, the evolutionary development of the knowledge management and communication methods lead up to the conceptual design that was first described in an article published in a 2006 issue of the Journal of Digital Imaging [xiv]. The current input method of this software is a hybrid of structured and free-form input, therefore the resulting document can contain a mixture of structured and free-form blobs including Microsoft Excel objects. Continuous speech recognition was added to augment the input of free-form text via user narration as oppose to keyboard entries.

Description of the hybrid speech recognition and structured reporting system

Environment

This hybrid speech recognition and structured reporting system is used at a radiology practice in Southern California, a full-modality image interpretation service operating from both off and on premise at the healthcare providers' facilities.

When this case study began, the radiology practice was reading for 4 hospitals and an imaging center for a total of five locations. By the time this paper was written, the number of locations grew to 6 hospitals, four imaging centers, and a nighthawk operation. Modalities generally include x-ray, mammography, fluoroscopy, ultrasound, CT, CTA, MR, MRA, nuclear medicine, PET, conventional angiography, ultrasound angiography, and interventional radiology. In general, each location usually has at least two radiologists and ten technologists on premise; and each radiologist produces approximately 20,000 reports per year. Report generation is a high volume production activity; hence, every effort is made toward the enhancement of a radiologist's efficiency.Teleradiology and remote users have unique requirements for radiology reporting. Quick turnarounds, ease of reporting and flexible workflow are very important. Reporting solutions for these situations need to be specifically designed to automate teleradiology workflow, with immediate report distribution. Teleradiologists may be centrally located, in remote reading rooms or even at home. In addition, reporting solutions need to provide online data entry of client hospital requisitioning information, RIS (radiology information system) and PACS integration, and web access for referring physicians. Reporting solutions should optionally provide HL7 (Health Level Seven) or custom interfaces to capture requisition information from client sources. In other words, everything must operate securely and through the Internet.

Usage

The reporting process begins when a technologist enters demographic data into the modality, the RIS or the PACS. This creates a file for the study, which appears in the radiologist's inbox. The radiologist periodically checks the inbox, which may be sorted by the attributes of the studies. The inbox contains new studies for which no report has been generated, as well as the work in process which the radiologist has begun but has not yet completed.The reporting system contains templates for the modalities and anatomic sites for which radiology exams are performed in the hospital. Each template has a complete knowledge base of possible findings that are appropriate for the given modality and anatomic site. Therefore, the reporting task for the radiologist is to navigate through menus of possible findings and select items that correspond to observations for the given study.

Most of the data entry occurs by selecting items in a sequence of cascading menus. Hence, selecting one menu item will cause another submenu to be displayed with additional options. Any of these menu items may contribute standard block of text to the report. Some item selections will prompt the radiologist to enter a value. For example, the radiologist might be asked to enter the size of a mass in centimeters. Users are allowed to navigates these menus and enter values via voice.

As the radiologist makes selections and enters values, the system dynamically incorporates the new data and re-renders the report. Unlike dictation, this provides the radiologist with immediate feedback as to the exact layout of the resulting report.The radiologist may save a partially completed report. Eventually when the report is complete, the radiologist will approve the report, causing an electronic signature to be applied, and the report may be distributed at that time. A copy of the partially completed report can also be saved as a "macro" in the macro library. These macros can be reused in other reports.The process of generating a report is more efficient if a new report for similar study can be quickly assembled from components or previous created "macros", in part or in whole. Hence, the software company added the macro management mechanism to help circumvent the learning curve problem associated with structured reporting and to ease the migration from the traditional method of dictation/transcription.

Integration with other systems

This hybrid speech recognition and structured reporting system is integrated with the PACS system, so for digital images captured within the PACS, images and reports are linked together by the PACS. For images captured outside the PACS (e.g. x-ray film), the reporting system can also be used to generate a report that has no computerized link to the digital images.Previously, the radiology practice dictates their report into the dictation systems of their customer. Since each customer has their own dictation system, the point of integration is the radiologist. The radiologist reads the images from a customer's PACS system and in turn, dictates the report for that particular interpretation into the corresponding dictation system of that same customer. Note that there are multiple customers that a radiologist will read for in a single sitting. With the deployment of this hybrid speech recognition and structured reporting system, the radiologist uses a single reporting system regardless of which customer's PACS invokes the reporting system. A location code is passed as a parameter to the reporting system which is used later by the reporting system to electrically transmit the completed report back to the appropriate hospital's electronic medical records system.

Deployment

In the past, all radiology reports were produced through a conventional transcription process, in which radiologists would dictate their findings. The dictation was transcribed by an outside transcription service. When the report was returned from the transcription service, the radiologist verified the accuracy of the report, which was then distributed to other departments in the hospital. In some cases, reports were returned to the transcription service, in order to correct transcription errors.

In 2008, the menu-based computer system was introduced, in which a radiologist reports findings by selecting from menus of all possible choices. During that year, a portion of the reports was produced through transcription and a portion was produced through the hybrid speech recognition and structured reporting system. The software was developed and deployed over a period of six months during 2008. As templates for each modality and anatomic site was developed, transcription was phased out and replace by this reporting application.Since 2009, nearly 100% of the radiology reports at the radiology practice were produced through this software—a proprietary system built with Microsoft .NET technologies. After the initial deployment, reporting templates continue to be expanded and improved based on feedback from the referring physicians, and is constantly updated to meet any new reporting specifications at the radiology practice. These enhancements include:

(a) Developing additional content within existing templates.
(b) Improving the navigation within templates.
(c) Revising the underlying reporting model to improve the naturalness of voice navigation.
(d) Revising the underlying reporting model to accommodate for the blending of unstructured data.

Security Requirements

General Requirements

Several general requirements regarding information security and integrity must be satisfied when using a teleradiology reporting system. These requirements [xv] are as follows:

a. Limited access to teleradiology data
b. Protection of data against unauthorized disclosure
c. Binding between patient data and other data
d. Audit trail

The rationale for these requirements is as follows:

Limited access to teleradiology data:

Patient privacy, medical ethics, and simple good business sense are important considerations. HIPAA mandates that patient medical records and their health information be kept confidential. Fines and lawsuits for failure to preserve the confidentiality of medical information are threats. In building well regarded public relations, a teleradiology practice does not want to have a reputation for having a cavalier attitude towards, or being careless with, the personal information of its patients especially since that would run the risk of losing business to competitors. Hence, teleradiology data is restricted to only those requiring access.

Protection of data against unauthorized disclosure:

Issues of privacy, medical ethics, and good business sense are considerations in this case. Certain categories of teleradiology data require a greater degree of protection than do others. For instance, patient identification data -- name, DOB, etc. require a greater degree of protection against unauthorized disclosure than do the images themselves—which generally do not have sufficient identifying information.

Binding between patient data and other data:

Radiological images (coming from the PACS) and clinical information are often the basis for making the interpretation and the recommendation for further diagnostic procedures. There must be a mechanism to ensure a positive, detectable binding between patient identification information (e.g., of whom the image is about) and the other pertinent information (e.g., images, annotations, previous reports) stored on the electronic medical record system. Otherwise, the possibility of administering medical care based on someone else's radiological images could happen and would potentially lead to serious if not fatal consequences.

Audit trail:

An audit trail of system resource usage, log of patient information access, etc. , is an essential element in providing the other requirements detailed above. An audit trail provides the critical details (who, what, when and how) an event or action occurred that could trigger a security incident.

Functional Areas of Security

In addition to having the information security requirements discussed above, teleradiology systems have certain functional areas of security. Six functional security areas are particularly important for teleradiology systems and will be discussed below. These functional security areas [xv] are:

a. Communications Security
b. Access Control
c. Report Archive
d. Information Binding
e. Information Separation
f. Security Administration and Management

Communications security

Communications security entails the protection of information during its transfer between geographically separated systems. For the purposes of teleradiology reporting, communications security concerns focus on how to protect information that travels over the Internet. A key consideration for communications security is whether any portion of the communications network is accessible to persons unconnected with the organization and using that network. The security of information transferred on physical media is assumed, i.e. positive control over the physical media is assumed. Although a completely private network can theoretically control physical access to its components; it is generally not economically feasible. In addition, any networks having components that are physically accessible to outside persons, are susceptible to being monitored by an outsider. Confidentiality, integrity, and authentication are communications security concerns.

Access Control:

Access control is defined as the granting of access to teleradiology information and reporting application functionalities. Varying degrees of access may be permitted; for instance, a hospital staff may be allowed to read a completed radiology report, but not to change or delete it. Access control generally involves a combination of some form of entity identification with a rule-based permission system. An entity requesting access to a system is generally first authenticated (e.g., identity is verified). After authentication, a rules-based process determines whether or not this entity is allowed to access and manipulate the requested information. This is the authorization stage of the access control. Authorization is especially important in the context of medical information systems, for the significant consequence of the impact on, for example, a report due to different types of accesses - any alteration of such information may have direct consequence in the diagnosis and treatment recommendation, which can be critical to the health of the patient.

Report Archive:

Teleradiology reporting systems typically include the use of a report archive—a repository of digital radiological reports for long-term storage. Access control is essential for teleradiology databases and report archives. HIPAA and ethical considerations dictate that access to this data must be strictly controlled. The ability to authenticate the source of data is required; this is necessary to ensures that only data from authorized sources is placed into the repository. The accuracy and availability of data stored in databases and report archives is also of paramount concern. Any changes to stored data must be detectable and traceable. In addition, there must be a way to determine with certainty that reports correspond to the accompanying patient data.

Information Binding:

Information binding between teleradiology reporting system, PACS, RIS and the hospital's electronic medical records is essential. Patients may be imaged multiple times on different dates; multiple times on the same date; a single time on a given date; imaged in different modalities on either the same or different dates; or some combination of the above. The system need to deal with many imaging events for many different patients. The condition in which an image is mis-identified and is used for diagnosis must be avoided. Therefore, the binding of patient information to radiological images is of critical concern.

Information Separation:

The need for information separation between hospitals is mandatory. For reporting efficiency, the radiologist may wish to see all the patients from all the hospital in a combined worklist. However, safeguarding is required to ensure that one hospital does not inadvertently gain access to patient information from another hospital. Since all radiology reports generated by the teleradiology practice are stored within the same teleradiology reporting system, separation between items of different hospital must be vigorously reinforced.

Security Administration and Management:

Administrative and management policies must ensure teleradiology security.In general, security policies for teleradiology systems should be based on the principles of least privilege and authorized actions [xvi], i.e., only actions and accesses that are absolutely necessary for conducting a task (minimally sufficient, nothing exceeding the absolute necessity) and that are specifically authorized should be permitted. This is necessary in order to limit the potential for damage in the event of both unauthorized access to teleradiology reporting system as well as that posed by a rogue user of the system.

Security Methods Applied

When comparing teleradiology reporting system to conventional transcription, the security mechanisms and technologies employed are vastly different. However, the governing management approach and security policy and procedure are quite similar. For instance, a transcription company's policies and procedures for HIPAA compliance is applicable to a teleradiology practice that employs the direct reporting method.The security methods use in this implementation in each of the following functional areas of security is described below:

Communications Security:

Communications security requires that the teleradiology information be secure when in transit. Prior to transferring teleradiology data, users and systems needs to be confident that the other entity participating in the transfer of data is in fact who it claims to be. This authentication is mutual; both entities in communications are required to authenticate themselves to the other. In the implementation, a combination of SSL (Secure Sockets Layer) and IPsec (Internet Protocol Security) is used to provide an end-to-end connection across the Internet. SSL is used by the web applications for authentication and encryption while IPsec is used by the servers to provide for encrypted data transfer between systems. VPN (virtual private network) is used to establish a security network between different facilities and/or from remote reading locations.

Access Control:

Access control is performed at the application level. In order to provide seamless and efficient workflow for the radiologist, the teleradiology reporting software is invoked through the PACS worklist. That way, the radiologist does not have to go through the login process on both systems. Hence, the radiology reporting software trusts the authentication process of the PACS. When invoked, user identity and other pertinent information are passed from the PACS to the teleradiology reporting software. Once the identity of the user has been verified against the access control mechanism of the teleradiology reporting software, it applies role-based authorization that is appropriate for that user's credential.

Report Archive and Information Separation:

Access (remote or local) to databases and report archives within a teleradiology system require the use of SQL DBMS authentication and access control mechanisms. Report archives and databases uses the location code (which denotes the data's origin) that was passed to teleradiology reporting software upon invocation to ensure that only information from allowable sources is placed into the teleradiology reporting archive. Otherwise, it could be possible for a malicious outsider to insert apparently valid information into the system. The report archive logs user action and can provide proof/receipt of its report access. Information separation is accomplished primarily through the use of the location code field in the DBMS.

Information Binding:

Information binding between the teleradiology reporting systems and other systems, such as PACS or the hospital electronic medical records system, is accomplished through a cross reference table. This is a configurable cross reference table which was set up prior to deployment. The radiology practice has the options to cross reference via a variety of ways such as: medical record number, patient name, patient identification number, study number, etc. Once the teleradiology software has been invoked to create a new report, it generates its own unique identifier for that report and inserts a new entry into the cross reference table. Reports can be "associated" and be displayed as a group as opposed to a series of reports. Associated reports happen when multiple imaging procedures occurred at the same time or an amendment was made to the original report. A series of reports usually refers to imaging that happened on different occasions.

Security Administration and Management:

Security administration and management address both personnel and technology issues. Baseline security templates are defined by the software company prior to deployment. Security templates are essentially role-base authorization profiles.

The administrator at the teleradiology practice is given permission to assign these predefined profiles to their users. Workflow, including report dissemination, is also defined by the software company prior to deployment.The administrator at the teleradiology practice is given permission to either insert items or remove items from the workflow states. Beyond the normal service level agreements as dedicated by industry best practices, other data reliability, backup, and continuity of operations considerations are the responsibility of the administrator at the teleradiology practice.

Conclusions

This case study described how a teleradiology practice generates radiology reports almost exclusively through a hybrid speech recognition and structured reporting system. Transcription now only serves as a backup means of radiology reporting. In this case study, the actual reporting time for direct reporting is approximately the same or slightly less in some situations than conventional transcription. This may appear as a surprising result since most people assume that dictation is a faster form of data entry than use of a computer-based system, because people without typing skills can speak faster than they can type. However, the usages of macros mean that a single selection may cause an entire block of text to be inserted [xvii]. Hence, efficient navigation of macros has resulted in the reduction of the amount of time needed to submit a completed report. It also saves vital time by removing the transcription step from the reporting process. In this environment, we found that structured reporting leads to:

a. Achieved higher efficiency in the usage of human capital for generating radiology reports crossing geographical and organizational boundaries.
b. Improved quality and consistency of reports by using report templates.
c. Improved response time by eliminating process steps, so that the final report is released directly from the radiologist.
d. Reduced costs by eliminating transcription without increasing the time required by a radiologist to record findings.
e. Security considerations have been adequately addressed; especially in an environment where the radiologists are geographically scattered and servicing multiple healthcare providers across numerous locations. Effective use of human capital requires a balanced approach to security and flexibility

i. Berman, G., Gray, R., Liu, D. and Tyhurst, J. (2001). Structured radiology reporting: a 4-year case study of 160,000 reports. Proceedings of (?) RSNA Annual Meeting.

ii. Liu, D. and Zhang, J. (2009). A Case Study on Workflow Optimization in Radiology Reporting. The Journal of Global Commerce Research, Vol. 1, No. 1: 35-47.

iii. Liu, D. (2009). Knowledge Management Mechanism as the Foundation for Structured Reporting. Journal of Information Science and Technology, Vol. 6, No. 3: 25-37.

iv. Harvey, D. (2008). Structured Reporting: Speeding Clear Results to Referrers. Radiology Today. Vol. 9, No. 3: 14-18.

v. Bell, Douglas S. and R.A. Greenes (1994). Evaluation of UltraSTAR: Performance of a collaborative structured data entry system. Journal of the American Medical Informatics Association 1994; Symposium Supplement:216-222.

vi. Borowitz, Stephen M. (2001). Computer-based speech recognition as an alternative to medical transcription. Journal of the American Medical Informatics Association 8:101-102.

vii. Rosenthal, David F., JoAnne M. Box, Rachael A. Sokolowski, Jennifer B. Mayo, Kerry A. Quigley, Roger A. Powell, Mary-Marshall Teel (1997). A voice-enabled, structured medical reporting system. Journal of the American Medical Informatics Association 4:436-441.

viii. Soderland, S.G., R.K. Taira, R. Jakobovits, E.L. Effmann, A. Warner (2000). Automated analysis of serial CT reports from pediatric metastatic lung cancer patients. RSNA Annual Meeting: infoRAD Exhibits.

ix. Taira, Ricky K., Stephen G. Soderland, Rex M. Jakobovits (2001). Automatic structuring of radiology free-text reports. Radiographics 21:237-245.

x. http://www.provationmedical.com

xi. http://www.penrad.com

xii. http://www.clickview.com

xiii. Kahn, C.E. (1998). Self-documenting structured reports using open information standards. Medinfo 9 Part 1 (2 Supplement 1):403-407. (http://www.mcw.edu/midas/papers/Medinfo-1998.pdf)

xiv. Liu, D., Zucherman, M., Tulloss, W. (2006). Six Characteristics of Effective Structured Reporting and the Inevitable Integration with Speech Recognition. Journal of Digital Imaging, Vol. 19, No. 1:98-104.

xv. Medenis, Michael M. (1997). Security in Teleradiology Systems: Requirements and Proposed Mechanisms.

xvi. Summers, Rita C. (1997). Secure Computing: Threats and Safeguards. McGraw-Hill: San Francisco,. Least privilege and authorized action are discussed in pp. 106-109; hashing functions and their required characteristics are discussed in pp. 202-205. (Note to Dave: We didn't seem to talk about hashing function in the article?)

xvii. Weiss, David (2001). A user's guide to speech recognition technology. Decisions in Imaging Economics.