

# Reporting and Communication

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## Key words:

Reporting  
Speech recognition  
Order entry  
Computerized physician order entry (CPOE)  
Decision support  
Results communication  
Natural language processing (NLP)  
Data mining  
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## Overview

Accurate and timely communication of patient-care related information between medical professionals represents a major challenge in prevailing health-care delivery systems, which typically involve multiple providers and auxiliary sources of patient-related information, such as laboratory and imaging data. It is important for each participant in patient care to know that information sent has been successfully received and understood by the intended recipient. This is called “closed-loop communication” because the information is first sent out on one leg of a hypothetical loop to its intended recipient, and then a message returns back to the originator, confirming that the information was received.

Confirmation of receipt and understanding is easy when communication is synchronous (i.e., both participants involved in the communication physically participate in the activity at the same time via telephone, online meeting, etc.), but when communication is asynchronous (e.g., e-mail) and separates participants in space and time, confirmation of successful communication may be more difficult. Additionally, permanent documentation of successful and timely communication is often critical for medicolegal and quality assurance activities, despite the challenges of asynchronous communication.

Radiologists are particularly susceptible to failures in closing the communication loop. Using speech recognition, reports can be created and finalized in near real-time. Such reports are immediately available in the radiology information system (RIS) and, if an electronic health record is present, may become available in a patient’s electronic medical record (EMR) soon thereafter. However, there is no built-in confirmation mechanism that the ordering and consulting physicians have read (and completely understood) the report. In many instances, reports are still distributed to referring physician offices via fax or other analog means. Rarely, the imaging examination may have been requested by a third party such as an insurance company in context with employment or immigration procedures. In those instances there may not be an ordering physician of record, and the radiologist essentially may have entered a direct doctor-patient relationship with all of the associated responsibilities. This may require direct communication of results of the examination to the patient [1]. In addition, specific radiologist’s recommendations in a given report may be overlooked, and thus failure of communication is one of the most common sources of litigation against radiologists [2].

When emergent or urgent findings are discovered, radiologists may decide to use synchronous communication tools to convey the critical information (e.g., a telephone call to the ordering physician). However, even this system may succumb to closed-loop

failures when the ordering physician is unavailable and a proxy, such as a nurse or physician assistant, must be used. Furthermore, synchronous communication methods are resource intensive for both the radiologist and the ordering physician, requiring physician time, therefore such communication methods cannot be applied universally to all radiology interpretations. Direct radiologist-to-patient communication is one method of addressing this issue, but it does not solve the underlying problem that the ordering physician may not have received the needed information. Additionally, patients may not be able to fully understand nor completely relate the information given to them by their radiologist.

Ensuring that routine results and long-term follow-up recommendations are received and understood is a universal challenge in medical imaging. To ensure complete and timely relay of relevant information, the entire communication loop must be considered, starting with the decision to order a radiologic test followed by image creation, report creation, report dissemination, and concluding with confirmation of receipt. Seamless interoperability of various software systems is a necessary foundation for success, as is a data model that allows for quality control and benchmarking of successful closed-loop communication.

### Order Entry

Order entry or request for a radiology consultation by the clinician is, ideally, the start of a closed-loop communication instance that ends with the clinician receiving the finalized radiology report.

#### *RIS or EMR*

There is an increasing number and complexity of imaging procedures. Many clinicians, especially nonspecialists, may be challenged to select the most appropriate examination. In many cases, the study eventually performed is not the correct or the most appropriate one. Telephone communication between clinician and radiologist may be required to determine what procedure best answers the clinical question.

#### *Computerized Physician Order Entry Software With Decision Support*

A description of the computerized physician order entry (CPOE) process is as follows:

- Clinician chooses patient's signs and symptoms as well as reason for study from menu.
- Clinician chooses imaging study from menu.
- CPOE software analyzes the entered data as well as patient demographics and presence of prior examinations.
- ACR Appropriateness Criteria® rank is assigned to the examination order entered.
- Clinician is notified at the time of order entry if the study is deemed appropriate, questionable, or inappropriate. Often an empiric sliding scale is used to express level of appropriateness.
- The system may suggest an alternative imaging study if the initial study requested is considered inappropriate.
- Clinician can override the suggestion if so desired, but this action may be logged and can be subjected to peer and/or administrative review.

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Current ACR Appropriateness Criteria combine consensus-based or evidence-based approaches to arrive at decision rules. Advantages of CPOE with decision support include the following:

- Clinician receives assessment of choice at time of order entry, which provides guidance and an educational opportunity.
- The software process is accepted by some insurance companies in place of authorization by radiology benefit management companies.
- The database of historic physician orders is available for process management by authorized administrators. Outliers and undesirable ordering patterns can be identified, and physicians may be counseled on better choices.
- Substantial decreases in the growth rate for imaging utilization have been described after deployment of such systems, documenting a potential sustained effect on ordering behavior [3].

The CPOE software should ideally be embedded within the EMR for seamless physician ordering, however standalone technology is available from several companies engaged in this domain.

Ordering rules should be extensible and updated periodically. Centers may decide to codify interdisciplinary consensus on an institutional standard of care in a particular clinical context. Some systems are highly customizable, allowing for rapid incorporation of such local preferred practice patterns. A standing committee consisting of radiologists and referring physicians may be assigned to this task of defining ordering rules.

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### Report Creation

#### *Speech Recognition*

Speech recognition has been available in various forms for decades, although few radiologists initially adopted the technology. New technologies finally allowed continuous and rapid dictation enabling speech recognition use in a typical busy radiology practice. Pressure from clinicians to improve turnaround time as well as pressure from administrators to save transcription costs have been major factors in the transition to speech recognition.

Original voice-to-text speech engines relied on the dictionary model. Each spoken word was considered on its own, with little or no contextual analysis. In the late 1990s, hardware and software advances enabled a fundamental change in speech recognition. The newer (and current) speech engines consider not words but individual and unique sounds called phonemes. The sounds preceding and following each phoneme are analyzed in an iterative statistical model to create the most likely text from a spoken phrase. Rather than having to pause after each word, users could now dictate in continuous and rapid speech. For radiology reports in particular, a language model was created. This allowed the software to “expect” the phrasing typical for radiology reports, which is often different from regular English prose. In addition, most current speech engines are able to track and learn the pronunciation and syntax patterns of individual users, allowing recognition to improve with time.

## Speech Recognition Versus Conventional Dictation

The advantages of speech recognition have been debated at length [4,5]. Improved turnaround time has been realized by most users. Rapid return on investment with transcription cost savings is also a common result. The specifics differ by site and can be calculated depending on how many studies are self-edited versus the number of studies sent to transcription for backend correction.

Some sites report decreased productivity [6,8]. Some argue that radiologists' salaries are too high to have them engaged in much text editing. Others contend that it is the radiologist's primary responsibility to provide an accurate report [7]. Due to the often complex workflow involved in report creation using speech recognition, the potential for distraction during image interpretation is ever present.

The benefits of improved turnaround time are most apparent to the recipients of the reports and often invisible to the radiologist; therefore, alterations to radiologist workflow to achieve improved turnaround times are frequently met with resistance. Likewise, transcription savings most often accrue across the board to the hospital or health system. Radiologists benefit indirectly from this, but the effect is often so diluted as to be negligible [8]. Although radiologists bear the brunt of decreased productivity, these inefficiencies are often invisible to both administrators and referring physicians. Thus, the opportunity cost of using speech recognition usually falls squarely on the shoulders of the radiologists.

For these reasons, many radiologists resist the transition to speech recognition. Even after installation, a number of radiologists find it faster to send cases to a backup transcriptionist for editing rather than make corrections themselves and sign the report at the time of dictation. This workflow diminishes both the turnaround time and cost saving advantages of speech recognition but improves radiologist productivity. Each site should evaluate the motivating factors for implementing speech recognition and create workflows to achieve the desired effects.

### Components of Speech Recognition

#### Speech Engine

The speech engine software converts the spoken word into text. Basic knowledge of the technical aspects of the speech engine can be valuable in optimizing recognition accuracy. Application specialists for a particular product may be able to help radiologists learn the specifics of the system and optimize recognition.

#### Dictation Style

The speech engine searches for a string of individual sounds, or phonemes, to build words and phrases. Phoneme-model recognition requires continuous rather than halted speech. It is vital to dictate enough phonemes without pausing to give the software enough context to create the proper text. For example, consider "and" and "diastematomyelia." The first word gives little context as to the difference from other near-homophones such as "an" or "than." Consequently, this and other similar short words are common sources of error. They need to be dictated as part of a longer phrase. By contrast, very few phoneme strings could be

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confused with “diastematomyelia.” This word can be dictated alone without the need for surrounding contextual phrases. This concept applies not only to dictation but, perhaps more importantly, to spoken corrections, a process in which radiologists can become frustrated at the futility of trying to correct single, short, ambiguous words. An example of this is the phrase “one of these.” Rather than train the software to recognize each individual word, it is better to add the entire phrase to the system dictionary.

### Corrections

There are several ways to correct dictation errors. One is to highlight the error and speak the correct word or phrase. There are other ways to make corrections, which vary with speech recognition vendor and engine employed. For example, voice commands to assist in editing are commonly available as well as opportunities to train the software to recognize certain phrases or words within the dictionary. Some vendors allow users to have access to the vocabulary editor. Using this tool, words and phrases can be added to the individual user profile. The system can be trained to accept idiosyncratic pronunciation. This is particularly useful for non-native English speakers. Unwanted problem words can also be deleted from the vocabulary.

### User Profiles

The speech engine software in most speech recognition systems tracks and updates individual user profiles after each reading session. The system should improve as the statistical database of typical phoneme strings increase for each user. This learning feature of the speech engine works best when reports from a particular user are consistent across time. Using speech recognition systems is similar to training a dog in that consistency is key. This learning feature can often be deactivated if users find that it has the opposite effect, and the system does not improve.

### Microphone

Knowledge and control of microphone functionality is vital for recognition accuracy. The volume setting within the speech recognition software should be adjusted frequently and in specific situations: when a microphone is changed, a new user logs on, and if there is poor or decreasing recognition accuracy.

Correct microphone position is critical. Almost all microphones have noise-canceling technology in which the microphone “listens” to a small cylinder of sound directly in front of it. For this reason, hold the microphone less than 1 inch from the side of the mouth, pointed toward the mouth. Many users have a tendency to lose this configuration due to head movements during image viewing and dictation. In these cases, a headset microphone has proven helpful. These can be used without losing the microphone button functionality. Removing one’s hand from the microphone has other potential positive effects including decreasing noise created from microphone handling and freeing up the hand for another task such as using the keyboard. Use of an array microphone will allow the hands to be free; however, the disadvantage of faulty microphone position remains and is often worse than with a conventional handheld microphone.

If dictation is begun too quickly after pushing the record button, the first syllable of the

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dictation can be dropped. This is a common cause of diminished recognition accuracy.

Many users report diminishing accuracy during the course of the day. Sometimes changing the microphone and rebooting the system can help. In some cases, the decreased accuracy may simply be due to slight changes in voice or slurring of speech due to fatigue.

### Navigation

Most radiologists view images and dictate nearly simultaneously. Therefore, navigation tools must control both the picture archiving and communication system (PACS) and speech recognition functions at the same time. The traditional keyboard and mouse combination is inadequate for this task. Alternate interface devices should be considered, including multifunction mice, one-handed keypads, foot pedals, or combination keypad-scrolling devices. The exact combination of navigation devices will depend on specific PACS and speech recognition software as well as user preference. Department-wide solutions are ideal, especially if workstations are shared by a number of users. The overall goal should be to keep the radiologist's eyes on the images and not on navigational icons or keyboard keys.

## Interoperability

### *PACS Integration*

The reporting system should be interoperable with PACS and RIS. Ideally, RIS creates an accession number at order entry and sends this to both PACS and speech recognition to be stored in the databases. When a case in PACS is opened for interpretation, PACS queries the speech recognition database for a matching accession number. The appropriate dictation shell is presented to the radiologist, ready for dictation or other data entry without any requirement other than pressing the record button on the microphone. This is not the case with all PACS/speech recognition integrations but is certainly desirable. When the study is signed off in speech recognition, a message is sent to PACS to close the case. The next case on the PACS worklist can be opened automatically depending on user preference and specific PACS software. The cycle can be continued ad libitum.

### *RIS Interface*

RIS/speech recognition interoperability is a two-way interface. RIS creates an accession number for each study and sends this data to speech recognition. When the dictated report is finalized, text is sent automatically to RIS and populates the proper patient and study record based on the accession number. The report is distributed based on RIS rules to EMR and other software. RIS or speech recognition can also fax or print reports as desired. Addenda should be treated in the same manner as a finalized report.

The text reports can be stored in speech recognition for varying periods based on system preference. This is desirable if the speech recognition software is needed for historical comparisons. It is also very helpful to keep recent reports in speech recognition to facilitate addenda.

### *Decision Support for the Radiologist*

Just as clinicians derive benefit from decision support, so can radiologists. This can take the

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form of automated Internet searches, information searches in a favorite online text, or access to free or subscription-based websites.

Decision-support tools are not specifically a part of speech recognition, but it is helpful to have radiologist decision support tightly coordinated with the reporting system. Voice-enabled decision support without the need for a third-party login can save time and decrease distractions during image interpretation.

### Training and Applications

Training and application specifics should be included in any vendor contract. Protected radiologist time for initial training should be built into the radiologist schedule. The learning curve will vary depending on user. Part-time users will have a longer learning curve. Non-native American English speakers may require more training. You should plan for initial decreased productivity and consider phased rollout by division in larger departments. In addition, consider scheduling initial applications followed by the return of an application specialist after several months of use. Do not overlook the need for ongoing applications systems training to acquaint new radiologists joining the group after initial deployment as well as residents and locum tenens. Large sites should consider a full-time on-site vendor application specialist or in-house full-time administrator/trainer. Develop radiologist “superusers” when possible. A superuser is one who has a deep understanding of system features and can use this knowledge to help others improve accuracy and efficiency.

### Problem-Solving

Dissatisfaction with speech recognition is often due to user-related issues, which can be corrected with good training and application support:

- A dictation style that uses complete phrases rather than individual words (see “Speech Engine”) will result in greater accuracy.
- Microphone position and timing issues (see “Corrections”) are among the most common causes of poor recognition. Correct these problems with user education and practice. Many users will benefit from the use of a headset microphone.
- If a user reports a sudden decrease in recognition, first check the microphone connection. Next, perform the microphone setup and adjust the volume setting within the speech recognition software. If the problem persists, try changing the microphone.
- Extraneous noise can cause decreased recognition. This is particularly true for sudden sounds such as a slamming door. Carpeting and acoustic ceiling and wall panels may be helpful. Some individuals have reported improved recognition with low-volume white noise generators [10].
- Despite multiple correction attempts, there are often specific words that speech recognition repeatedly cannot understand. These vary by user and vendor. In some cases, a slight workaround can be helpful (e.g., “gouty arthritis” instead of “gout”; “first digit” instead of “thumb” etc.).
- Frequent use of the vocabulary editor to correct errors will result in long-term improvement in accuracy.
- Non-native English speakers may have recognition difficulties. Using the vocabulary editor (see “Corrections”) to alter the pronunciation expectations of the software will be especially helpful. These users will likely have a longer learning curve.

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- Resident/attending dictations and double reads can present workflow issues. Vendor workflow should be evaluated before purchase if possible.
- Dictation using multiple accession numbers (e.g., chest CT, abdomen CT, pelvis CT) can be problematic in some cases. This requires coordination between speech recognition and RIS software. User should check whether this option is available to them and which specific workflow they need to follow with multiple accession number dictations.
- Users must be motivated for successful implementation (see “Radiologist Resistance”). Strongly consider implementing individual incentives for using speech recognition and for self-editing.

### *Newer Technologies*

#### **Improved Speech Engine Accuracy**

Speech engines are continuously being updated and incorporated into newer versions of speech recognition programs. Although accuracy will continue to improve, even achievement of 100% error-free recognition would not be sufficient for efficient reporting. Navigation tools, macro features, and other workflow enhancements will still be necessary.

#### **Findings-Only Dictation**

At least one vendor offers a feature known as “findings-only dictation.” With this advancement, the user can dictate findings in random order without navigating a macro. The software uses predefined editable keywords and key word fragments to place each individual sentence in the proper place within a standardized or structured report.

#### **Natural Language Processing**

Natural language processing (NLP) can be considered as speech recognition’s smarter cousin. Although speech recognition recognizes spoken sounds, NLP can infer specific meaning from text. This technology can create backend structure to a report to facilitate data mining and search features (see “Data Mining”). NLP can also be used for automated coding and correction of reporting errors. Some vendors refer to this feature as “clinical language understanding.” Advanced NLP that incorporates such understanding is more specific to health-care concepts and context and may be able to detect “left-right” errors and other inconsistencies in the report and alert the dictating radiologist in real time.

#### **Auto Population of PACS and Modality Data**

Work is underway to enable population of the report with measurement data from imaging modalities, a 3-D workstation, or PACS. This will prove particularly helpful for studies with multiple measurements such as fetal ultrasound. The further development of the Digital Imaging and Communications in Medicine (DICOM)-speech recognition standards will assist vendors who wish to share this type of structured data.

#### **Annotated Image Markup**

Developers are making good progress in creating methods to generate a complete report using a combination of PACS measurements and computer-assisted diagnosis. This is currently in the research stage but shows promise as a timesaver for report creation.

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## Mobile Dictation

With improved speech engine accuracy, mobile dictation is increasingly available and will become even more important as mobile image viewing technology progresses. This feature will allow radiologists to create, edit, and sign reports away from workstations and even outside the hospital or imaging center. It will also facilitate clinicians' remote access to imaging data and reports.

## Macros and Templates

### Macros Defined

Macros can be defined as any text or data stored and inserted by user command. The terms *macro* and *template* are often used interchangeably. Sometimes *template* refers to a *macro* with blank spaces to be filled in by the user. A macro can consist of an entire report, a commonly used sentence or phrase, or even a problem word that is poorly recognized. It is helpful to create a macro for any report or phrase that is dictated frequently. If a group of radiologists use a macro in the same way, it may be used to standardize reporting of certain imaging examinations of choice.

### Macro Naming

Macros are most often inserted by speaking the macro name. Macro naming becomes important when choosing between the hundreds of macros available. Naming should be systematic and consistent across all modalities, logical and descriptive, and as short as possible to minimize spoken syllables, particularly for commonly used macros. For example, use *chest two* instead of *chest two view normal*; use *CT AP IV* instead of *CAT scan abdomen and pelvis with contrast normal*. Macro lists can grow to the hundreds and even thousands. As the number of macros expands, a well-organized, systematic, and consistent naming convention becomes more critical.

Newer systems can auto populate the correct macro based on procedure and diagnostic codes as well as patient demographics. In this setting it is vitally important to create an institutional naming convention, as these macros are intended to be shared and potentially edited by many individuals.

### Macro Number

In some older software, the number of macros is limited to several hundred. In these cases, macros need to be multiuse (e.g., rather than using a separate macro for right and left side, the laterality can be left as a blank within the template to be filled in by the user). Another example of a multiuse macro is as follows:

- *There is no acute fracture in [ ] ribs.* The blank space is filled in by the user as right, left, or bilateral.

### Optimizing Macro Use

When used, macros can decrease both dictation time and proofreading time. They also decrease the need for report editing and result in standardization of reporting frameworks.

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Macros should be constructed to minimize the need for modifications. Navigation and changes within the macro text should be easily voice-driven. In many systems, RIS data can automatically populate various macro fields, further minimizing the need for data input by the radiologist. This feature requires a robust RIS/speech recognition interface.

Consider the following macro example:

[CT ABDOMEN AND PELVIS with IV CONTRAST]

Comparison: [None]

IV contrast: yes; Oral contrast:

Liver is normal in size and CT density. Spleen is normal in size and CT density. Pancreas is normal in size and CT density.

Kidneys are normal in size and CT density. Adrenal glands are unremarkable.

Aorta is normal in caliber. No adenopathy is identified.

Bowel loops are unremarkable.

Visualized pelvic organs are unremarkable. Bladder is normal.

Skeletal structures are unremarkable.

IMPRESSION: No significant CT abnormality

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Additional issues to consider when implementing macros include the following:

- Create macros to automatically insert RIS data (in this case the procedure description). In the example above, the procedure description can be inserted automatically from RIS data. This feature is dependent on RIS, interface, and speech recognition functionality.
- Use *None* as the comparison default so that you need to dictate a prior date only when necessary.
- Match the order of anatomy with the general search patterns of most radiologists.
- Begin each sentence with the organ name when possible. This makes it easy to navigate and modify dictation by voice only. For example, to modify the spleen sentence dictate the following: <select spleen thru period> <spleen is slightly enlarged period>
- Modify macros without visual input. The eyes should be reserved for image viewing, minimizing “look away time” when the radiologist’s eyes are diverted from the clinical images.
- Note the phrase *Visualized pelvic organs...* If the uterus is absent or an ovary is not identified, this will not need to be modified.
- Note the phrase *No significant CT abnormality...* If there is an incidental finding such as renal cyst, this will not need to be modified.

In some cases, it is easier to build a report using individual smaller macros rather than modify an existing complete report. If you read hundreds of portable chest radiographs, consider this: Commonly used sentences can be created as individual macros, and verbal commands become text as follows:

<macro large> <macro sternal> <macro con mild> <new paragraph> <macro ET>

*The heart is enlarged. There has been prior cardiac surgery with sternal wires sutures. Pulmonary vasculature is mildly congested.*

*ET tube tip overlies trachea at the level of aortic knob.*

Multiple sentences for any common finding can be created as macros and used to build a report or to modify an existing one.

Examples:

- <Macro IJ right> *Right IJ catheter is present with tip overlying SVC.*
- <Macro CVP left> *Left CVP catheter is present with tip overlying SVC.*
- <Macro NG> *Enteric tube is present with tip below the diaphragm.*
- <Macro cast> *Fine bony detail is obscured by a cast.*
- <Macro wet reading> *Findings were reviewed at the time of dictation with the ordering provider who expressed understanding.*
- <Macro tics> *There are scattered colon diverticula with no evidence of diverticulitis.*
- <Macro no tail> *Pancreatic head and body are normal sonographically. Pancreatic tail is obscured by bowel gas.*

The more macros used, the less time required to physically dictate and edit. This allows for improved productivity and may increase image eye-dwell time with the potential for increased accuracy.

### Sound Cues

Most systems have sound cues that trigger when a command is recognized. These can be configured in the user preferences. They are extremely helpful in providing user feedback without the need for visual inspection of the text. They are particularly helpful when using a complex macro that requires insertion of multiple words and phrases.

### Structured Reporting

The term structured reporting is often used interchangeably for a number of reporting formats:

- **Standardized format:** The standardized format is most commonly a prose format where each organ system or descriptive process resides in the same physical location across all reports. Use of this style often includes some type of structure, including organ headings and consistent formatting. This type of report can be created using conventional dictation or speech recognition. Most radiologists use some type of such standardization in their reports. Example of standardized format:

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*PROCEDURE: Chest 2 view*

*COMPARISON: None*

*FINDINGS: Heart is normal in size. Lungs are free of active disease. No pleural fluid is seen. Bony structures are intact*

*IMPRESSION: No active disease*

- **Itemized:** The itemized format consists of a list of organs or body parts, each followed by a short description of findings. Studies have shown this style to be preferred by clinicians. However, other studies have shown that there is no significant time saved in creating or reading these reports [9]. The itemized report is referred to in some published studies as a structured report. One example of an itemized format includes:

*PROCEDURE: Chest 2 view*

*COMPARISON: None*

*HEART: Negative*

*LUNGS: Negative*

*PLEURA: Negative*

*BONY STRUCTURES: Negative*

*IMPRESSION: No active disease*

- **Structured:** For the purposes of this discussion, a true structured report is one where each data element is coded for later automated data retrieval. This requires specialized software for report creation. Traditional structured reporting software has, in the past, required user input such as selections from a pull-down menu or other on-screen choices. Later iterations allow speech-driven choices. More modern versions create some structure with backend NLP.

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## Advantages and Disadvantages

In general, the advantages of structured reporting versus conventional dictation or speech recognition are enjoyed mainly by consumers of the report (clinicians, researchers, and administrators.) The disadvantages fall more squarely on the shoulders of the report creator (radiologists).

### Advantages

- Vocabulary can easily be standardized using RadLex or other ontologies.
- Coding can be built into the process, facilitating billing at time of dictation and avoiding down-coding secondary to insufficient clinical documentation.
- Compliance is easier with payer initiatives such as pay-for-performance.
- Data mining is facilitated, enabling research and other tracking capabilities such as compliance analytics.
- Real-time parallel decision-support is more easily achieved.
- Recommendations for follow-up or additional studies are easily tracked.

## Disadvantages

The actual process of structured report creation can be more time consuming and distracting compared with conventional dictation or speech recognition. This is because most current structured report systems require visual input for report creation. In fact, many current software versions require visual input using multiple mouse clicks, increasing look-away time from the radiographic display.

## Radiologist Use and Resistance

True structured reporting (see “Structured Reporting”) is not widely used in most radiology practices, with the exception of mammography. By contrast, cardiologists and other clinical specialists are more accepting of this type of reporting. One of the reasons may be that, in general, clinicians typically do not create a report while simultaneously performing a procedure or viewing images. This minimizes the potential disadvantage of distraction and look-away time. In addition, most clinicians are also consumers of their own reporting product and therefore benefit from many of the advantages of the structured report.

## Future of Structured Reporting

The disadvantages of structured reporting can be minimized by speech-enabling report creation. This creates a hybrid of speech recognition and structured reporting, allowing fewer distractions to the radiologist during image viewing. NLP is used by some vendors and allows a deeper understanding of context rather than simply spoken sounds and their conversion to text. This enables automated backend creation of a structured report with radiologist input very similar to speech recognition.

## Data Mining

Data mining (knowledge discovery in databases [KDD]) is a process that attempts to discover patterns in large data sets by extracting information and transforming it into knowledge. Alternatively, text data mining applies the concept of data mining to unstructured textual data. This process typically involves structuring input text and deriving patterns within the structured data.

NLP is a field of computer science, artificial intelligence, and linguistics concerned with the interactions between computers and human (natural) languages. Specifically it is the process of a computer extracting meaningful information from natural language input and/or producing natural language output.

Hospital information systems (HIS) and RIS are rich sources of clinical and operational information. Health-care data are often stored as free text. Radiology reports are largely unstructured text. However, most EMR systems and RIS maintain data in proprietary or complex databases, making data mining difficult and expensive.

Radiology report text can be indexed to allow end users to perform string searches. By applying advanced NLP techniques, radiology report text can be mined for research, clinical decision support, education, operational analyses, and quality improvement. More specifically, radiology reports can be mined for the following data:

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- Clinically important findings
- Positivity rates
- Degree of uncertainty
- Recommendations for subsequent action
- Coding checks
- Physician Quality Reporting System (PQRS) measures (e.g., fluoroscopic times, diameter of distal internal carotid arteries on neck vascular imaging)
- Laterality errors
- Critical test results

Challenges and issues to consider when creating an application to perform text data mining of report text include:

- Data access and storage
- Free text versus structured reports
- Indexing and search speed
- Application development
- Intelligence and NLP expertise along with domain expertise in radiology
- User management
- Security and audits

Software that uses NLP to automatically perform KDD is commercially available and can be interfaced with one or several information sources in a given health-care enterprise. As a result, more meaningful analytics may then be performed. Examples include contextual display of (prior) relevant clinical information at the point of service (while dictating a current radiology report) or facilitating compliance analysis of radiology reporting.

## Interoperability

### Shared Data

It is almost always necessary for medical enterprises to rely on numerous software packages created and sold by different vendors. The needs of each health-care system are unique, and the optimum data storage for a retrieval system will be different for different hospital systems and may even require different software applications within an individual department. Because no one product can optimally address all needs/aspects of a unique health-care enterprise, data storage systems' ability to transfer data is critical. Unfortunately, data are often stored in proprietary formats that cannot be transferred between systems. It is necessary for each system to normalize its data into standard formats so that it can be transferred and received by other data systems. Several standards are in place in medical imaging to achieve this goal.

### DICOM

The DICOM standard defines the format of messages sent and received by PACS. Information systems that comply with the standard are "DICOM conformant," and the vendor will provide a DICOM Conformance Statement to attest to conformance and provide details of

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implementation. Not all PACS store image data internally in DICOM format, but all should be able to export data (e.g., on a CD) in a DICOM-compliant format.

### Health Level 7

Health Level 7 (HL7) defines the format of messages exchanged by software systems within the health-care enterprise. Familiar examples of HL7 messages include admission, transfer, and discharge (ADT) messages. HL7 is employed far beyond the boundaries of radiology but is necessary to transfer data (such as clinical history) into the RIS and to schedule examinations from the EMR.

#### *Specific Relationships Between Information Systems in Radiology*

### RIS/PACS

The most familiar data-sharing relationship in radiology is the RIS/PACS exchange. The RIS stores scheduling and workflow information for the department, whereas the PACS primarily stores images. However, these systems need to be tightly coordinated, so a highly detailed interface is an absolute necessity. In fact, the relationship is so important that some RIS/PACS are offered as a single entity from one vendor.

### Speech Recognition/PACS

Speech recognition is another software system that needs to be tightly integrated with both the RIS and the PACS. Older speech recognition systems were standalone entities that ran separately on the PACS computer or even a distinct computer nearby. Historically, although RIS integration was seen as essential from the beginnings of speech recognition, PACS integration lagged. This led to potentially catastrophic errors such as dictations appearing under the wrong patient or being lost entirely. Lack of speech recognition integration also undermined efficient workflow. Tight integration between PACS and speech recognition is now standard, and speech recognition vendors are generally expected to support this integration. Integration and connectivity can be facilitated with an application programming interface (API). The API specifies how different software components should interact with each other. An open API is a desirable feature found on many speech recognition systems.

### Modality Worklists

Integration between imaging modalities (i.e., individual scanners) and the RIS permits the forwarding of patient information to the modality in preparation for patient scanning. This reduces data entry errors at the scanner and can substantially improve technologist workflow.

### Federated PACS Vaults

Radiology groups often use different PACS in different locations, either within a single enterprise or across different enterprises in a single practice group. Even if all the PACS vaults are from a single vendor, it is often undesirable to create a single repository for all data because transfer times may be unacceptable. However, radiologists may need a single worklist that incorporates all studies into a single user interface regardless of physical location of storage.

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If all the PACS are from a single vendor, a “federated” relationship may be available such that the PACS vaults are aware of each other. In addition to a single worklist, these systems should allow automatic identification of comparison examination across different PACS vaults.

If the PACS are from different vendors, some features of a federated PACS may not be available, but third-party software can create single worklists. These products can function either as a temporary repository for images or as a portal to the main PACS vaults.

### EMR/PACS

It is desirable for radiologists to have complete access to patients’ EMRs when reviewing images. Although missing or insufficient patient histories were previously commonplace in radiology, they are inexcusable in a modern environment. Access to the EMR from the same computer as the PACS is an acceptable means of information retrieval, but more complete integration between EMR and PACS, with retrieval of contextual data, will improve workflow for the radiologist.

### *Integrating the Healthcare Enterprise*

Integrating the Healthcare Enterprise (IHE) is an organization founded by the RSNA that creates technical frameworks to guide robust integration between information systems in medicine. Although these frameworks are not strictly “standards,” they serve a similar role to ensure successful communication between or among information systems. The frameworks are organized into “integration profiles” that each deal with a specific problem in software integration. The RSNA continues to support “Connect-a-thon” events in which vendors can test their ability to integrate with other information systems.

### *Vendor Interactions*

Radiologists can support robust integration when negotiating with vendors. In particular, hardware or software used for patient care in the radiology department should have a DICOM Conformance Statement and an IHE Integration Statement. These documents should be carefully reviewed prior to any purchase. Furthermore, new purchase contracts should include explicit language to ensure interoperability with existing systems and clear assignment of responsibility for troubleshooting interoperability failures.

### *Conclusion*

It is critical for health-care information systems to share data in an automated and efficient manner. It is unusual for a single vendor, with complete control of system integration, to meet all of the needs of a radiology department or health-care delivery system. Thus, communication standards and integration frameworks are essential for smooth operations [11]. Even with tight adherence to these standards, interoperability failures are frequent. Radiologists and radiology administrators are urged to make interoperability a key component of contract negotiations with equipment vendors. Ideally, information exchange should be demonstrated with real-world data before final payment to the vendor.

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## Results Communication: Closing the Loop

Communication of results, whether routine or emergent, closes the loop that began with order entry.

### Report Contents

#### Prose

The prose format consists of regular sentences describing the findings. This is still the most common type of report. Use of this style does not preclude some type of structure, including organ headings and consistent formatting.

#### Itemized

The itemized format consists of a list of organs or body parts, each followed by a short description of findings. Studies have shown this style to be preferred by clinicians. However, other studies have shown that there is no timesaving in creating or reading these reports. An itemized report is sometimes referred to as a structured report.

#### Structured

Structured reporting can be considered one of three categories:

- A prose format in which each organ system or descriptive process resides in the same physical location across all reports
- An itemized report with a header for each organ system
- A report in which each data element is coded for later automated data retrieval

See “Structured Reporting” for more information.

#### Multimedia

This type of reporting can take many forms. For example, an annotated image can be linked with a short textual description. This is uncommon in current practice and requires interoperability between the reporting system and PACS as well as an EMR that accepts this annotated format. This type of annotated image markup shows promise in streamlining future report creation and consumption.

#### Impression or Summary

All reports should have a short summary of findings organized in a systematic manner, usually by order of importance

### Routine results

#### Timely Delivery

Routine finalized reports should be delivered as quickly as possible. Exact timing will depend on type of reporting circumstances. For example, a mammogram result will not be as critical as a routine emergency department study.

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## *Delivery Format*

### **Reporting System**

Depending on software capabilities the reporting system itself can be used for report delivery (e.g., fax to provider, text to voice). The reporting system can store text reports for variable periods. This is a desirable feature as a backup to the RIS and to facilitate addenda creation.

### **RIS**

The RIS is currently the most common storage of record for all radiology reports. This may change with the ascendance of the EMR.

### **EMR**

The EMR may serve as the portal for clinicians to access both images and reports, if available.

### **Other**

Alternatives are needed if the EMR is not accessible by some clinicians (fax, email, postal service, direct remote RIS or PACS access for report and image viewing). In these cases, the lack of a formal audit trail is a distinct disadvantage

### **Audit Trail**

All activities in the EMR are tracked and recorded. All reports should appear in the clinician inbox and not simply populate the patient chart. In this manner, active delivery of all reports is ensured. Flagging positive reports is helpful to clinicians. A return receipt option for radiologists can be used, if necessary, to close the communication loop. Sensitive information, such as health information of health-care system employees, may be protected through additional monitored layers of access control.

## *Critical Results*

### **Critical Test Result Communication Policy Development**

Both the American College of Radiology [1] and The Joint Commission [12] (formerly JCAHO) strongly advise radiologists to expedite notification of critical findings to referring providers in a timely manner. However, neither standard timeframes of notification nor delivery methods have been suggested by these entities. Therefore, it is crucial to establish a solid underlying policy for all related activities as the first step of this process. In addition, it is important to define “critical results” up front. The use of disease-based definitions has been proposed, but this approach is often not comprehensive, and broader definitions, to include clinical interpretation, have been preferred by many.

### **Levels of Criticality**

Critical findings should not be treated equally. Developing predefined levels (typically 3–5) of criticality is an important second step to assign appropriate communication methods and notification timeframes.

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## Delivery Format

Results with higher criticality require synchronous communication (telephone or physician-to-physician communication). Nonurgent communications can potentially happen asynchronously, but it is important to ensure receipt of the findings in these situations by using a verifiable method of communication. This allows both parties to determine the important finding was received and appropriately understood.

## Escalation

The policy should also establish some predefined procedures in the event that the intended recipient cannot be reached. The escalation parameters should be predetermined and only end when an appropriate provider acknowledges receipt of the critical findings or of the entire report.

## Audit Trail

An important element of software that deals with communication of critical test results is the ability to track any access to patient health information, communication attempts, and acknowledgement of receipt. The application needs to capture the critical finding itself, the individuals involved in the communication, the method of notification, acknowledgment of receipt of the findings, and time and date of each activity. Obtaining these variables is important to determine adherence to local policy and will be necessary to understand the sequence of actions if a case requires further investigation.

## Radiologist Tasks

The radiologist workflow to communicate a critical test result begins by recognizing the importance of the finding and the urgency level in relation to the underlying policy. Once this is established, the communication of critical results (CCR) application typically walks the radiologist through the process to ensure that all pertinent variables are captured. Tight integration between the CCR application and other radiology systems (PACS, speech recognition, or RIS) allows higher efficiency of the entire process. Manual data entry should be reduced to a minimum, and patient context sensitivity is very important to decrease human error.

## Maintenance of Database

One important aspect of the CCR software is the accuracy of its provider database. This is important from a variety of perspectives. Ensuring the message reaches the intended person is a key element to HIPAA compliance and timely CCR. If electronic escalation is built into the system, the database will also need to include the role of each individual and their relationships to each other in a particular environment. Depending on the sophistication of the enterprise master physician index and the availability of an enterprise patient list, it may be possible to identify the individual caring for a patient at a specific point in time. This dynamic database can be integrated into the CCR application to increase the efficiency of the communication process by recognizing any shift change or different assignment of responsibilities in the care of a patient. Irrespective of the type of implementation and

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level of integration, all provider contact information must be current and accurate. The maintenance of such database requires ongoing resources and may be time consuming to set up.

### Nonautomated Alternatives

Institutions without automated software can and should create a manual process to address CCR. As previously mentioned, developing a policy is crucial for both manual and automated efforts.

### Measurement of Performance

Performance metrics should be part of the policy creation and is a Joint Commission requirement. Without implementation of a CCR application, measurement of performance is typically manual, except when a department can mine the radiology report using NLP technology. With these tools, it is possible to capture standard communication statements within the report and extract appropriate information to determine policy adherence. However, NLP applications are not typically 100% accurate and some level of data compromise is typically seen. Using a dedicated application for CCR is advantageous when the data are typically appropriately captured and structured in such a way that standard report generation is generally straightforward. Business intelligence can be used in this process and may facilitate the creation of ad-hoc queries for data analysis.

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Accurate and timely communication of patient-care related information between medical professionals represents a major challenge in prevailing health-care delivery systems. Order entry, such as use of CPOE with decision support, begins the closed-loop communication that ends with the clinician receiving the finalized radiology report. Pressures from clinicians to improve turnaround time as well as pressure from administrators to save transcription costs have been major factors in the transition to speech recognition, the technology of which is continuously improving. Good training and application support can alleviate much of the dissatisfaction experienced by end-users of speech recognition. Once created, radiology report text can be indexed to allow data mining for research, clinical decision support, education, operational analyses, and quality improvement. As it is unusual for a single vendor to meet all of the needs of a radiology department or health-care delivery system, radiologists and radiology administrators are urged to make interoperability a key component of contract negotiations with vendors. Finally, accurate and timely result communication closes the communication loop that began with order entry.

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### References

1. American College of Radiology. ACR Practice Guideline for Communication of Diagnostic Imaging Findings. ACR Website. [http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Comm\\_Diag\\_Imaging.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Comm_Diag_Imaging.pdf). Revised 2010.
2. Kushner DC, Lucey LL. Diagnostic radiology reporting and communication: the ACR guideline. *JACR*. 2005;2(1):15–21.

3. Siström CL, Dang PA, Weilburg JB, Dreyer KJ, Rosenthal DI, Thrall JH. Effect of computerized order entry with integrated decision support on the growth of outpatient procedure volumes: seven-year time series analysis. *Radiology*. 2009;251(1):147–155.
4. Rosenthal DI. Re: "Voice recognition: ready for prime time?" *JACR*. 2007;4:670–671.
5. Quint DJ. Voice recognition: ready for prime time? *JACR*. 2007;4:667–669.
6. Gale B, Safriel Y, Lukban A, Kalowitz J, Fleischer J, Gordon D. Radiology report production times: voice recognition vs. transcription. *Radiology Management*. 2001;23(2):18–22.
7. Brant-Zawadzki MN. Radiology dictation and self-edited voice recognition. *JACR*. 2010;7(6):461–462.
8. Hayt DB, Alexander S. The pros and cons of implementing PACS and speech recognition systems. *J Digit Imaging*. 2001;14:149–157.
9. Siström CL, Honeyman-Buck J. Free text versus structured format: information transfer efficiency of radiology reports. *AJR Am J Roentgenol*. 2005;185(3):804–812.
10. Weiss DL. Speech recognition: evaluation, implementation and use. *Appl Radiol*. 2008;37(12):Suppl:24-7.
11. Channin DS. Standards and Interoperability. In: Branstetter B IV, ed. *Practical Imaging Informatics: Foundations and Applications for PACS Professionals*. New York, NY: Springer; 2009:81–97.
12. The Joint Commission. National Patient Safety Goals Effective Jan. 1, 2013. The Joint Commission Website. [http://www.jointcommission.org/assets/1/18/NPSG\\_Chapter\\_Jan2013\\_HAP.pdf](http://www.jointcommission.org/assets/1/18/NPSG_Chapter_Jan2013_HAP.pdf). Published 2012. Accessed October 9, 2013.

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