Radiology Reporting, Past, Present, and Future: The Radiologist's Perspective

Bruce I. Reiner, MD[a], Nancy Knight, PhD[b], Eliot L. Siegel, MD[a,b]

Although imaging technologies have undergone dramatic evolution over the past century, radiology reporting has remained largely static, in both content and structure. Existing free-text (prose) reports have been criticized for a number of inherent deficiencies, including inconsistencies in content, structure, organization, and nomenclature. A number of new initiatives and technologies now present the radiology community with the unique opportunity to fundamentally change the radiology report from free to structured text. These new developments include a standardized nomenclature (RadLex), automated information technologies (picture archiving and communications systems and electronic medical records), and automated data tracking and analysis software (natural-language processing). Despite the increasing availability of these tools and technologies for revolutionizing reporting, clinical, psychologic, legal, and economic challenges have collectively limited structured reporting to mammography. These challenges are most evident in the current environment of heightened expectations for improved quality, timeliness, and communication, along with increasing stress, fatigue, and malpractice concerns. In conclusion, the authors present an alternative to traditional reporting that attempts to address some of these diverse challenges while incorporating the aforementioned initiatives and technologic developments. This approach uses a graphical symbol language that is directly mapped to a standardized lexicon (RadLex) and is automatically converted into a structured hierarchical text report, which can then be much more easily searched and analyzed.

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A HISTORICAL PERSPECTIVE

The radiology report is in many respects the single most important basis on which radiologists are judged by their clinical colleagues. Most patients have little, if any, direct contact with the diagnostic radiologists interpreting their imaging examinations, and their perceptions of radiologists' work are largely an extension of their referring clinicians' perceptions. With the advent of picture archiving and communication systems (PACS), physicians are no longer held captive by the physical constraints of the medical imaging department and can now access imaging studies remotely, often without accessing the formal reports issued by radiologists. As a result, direct interactions between clinicians and radiologists have decreased substantially with the adoption of filmless imaging [1]. In this atmosphere, radiologists have begun to refine and redefine their service deliverables, with the radiology report as the most critical element.

Although imaging technologies have undergone dramatic evolution during the past century, the radiology report has remained surprisingly static. The earliest radiology report, *Eine Neue Art von Strahlen*, was published in 1896 by Wilhelm Röntgen [2], who introduced a novel technology that could "see through human flesh" and would dramatically change future medical diagnosis. The occupational requirements for "roentgen photography" were yet to be determined, with photographers, electricians, physicists, and physicians with varied backgrounds all volunteering their services. After a period of adjustment not uncommon with new technologies, this discovery led to the creation of a new medical specialist, the roentgenologist, whose unique abilities were defined by the quality of the written report.

Most early reports took 1 of 2 basic forms: the written consultation (free text) or the fill-in-the-blank report (structured reporting). Over time, the free-text (prose)

[a]Baltimore Veterans Affairs Medical Center, Baltimore, Md.

[b]University of Maryland School of Medicine, Baltimore, Md.

Corresponding author and reprints: Bruce I. Reiner, MD, 6 Greenleaf Lane, Seaford, DE 19973; e-mail: breiner1@comcast.net.

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report became the standard, although some radiologists used the "customized" report as a means to prove their roles (and added value) in patient care. Lewis Cole, MD, a Park Avenue radiologist in the early part of the 20th century, supplemented his free-text "deliverables" with annotated photographic prints (key images), literature references, and background information; all enclosed on fine stationery and tied with a powder-blue grosgrain ribbon [3]. In an inspired touch, Cole produced these little packets in duplicate: one for the referring physicians and one for the patient. He was highly successful in his professional endeavors, which were undoubtedly enhanced by his market-oriented approach to report packaging.

Speech has served as the principal input for reporting over the past century, with technologic advances in the form of transcription aids. The earliest dictation machine was in use by the 1910s, imprinting recordings of the spoken word onto a wax cylinder for playback and transcription [3]. These dictation devices were the mainstay for more than three quarters of a century, until the advent of digital dictation, which today is giving way to speech recognition software that provides contemporaneous computer-generated transcription. Although these advances have led to improved operational efficiency and timeliness in report turnaround, the end product has nonetheless remained static, in both content and structure. For better or worse, the free-text (prose) radiology report has been the main deliverable for radiologists over the past 110 years. It would not be inappropriate if our clinical colleagues suggested that it is high time that service keep pace with technology and that radiologists evaluate and adopt alternative reporting strategies. Before doing so, however, it is important to investigate the existing challenges and perceived limitations of radiology reporting to gain insight about the types of change and enabling technologies that would be most beneficial. Here the words of Winston Churchill seem timely: "There is nothing wrong with change, if it is in the right direction."

DEFINING THE QUALITIES OF A "GOOD" RADIOLOGY REPORT

The attributes of a good radiology report have been summarized as the "6 C's" by Armas [4]. The first C is clarity, which has been reported to be the single most valuable attribute in a radiology report [5,6]. The second is correctness, which is affirmed in the ACR's [7] standard for communication, which states, "The radiology report should contain a precise diagnosis whenever possible." The third C is confidence, which describes the level of certainty that can be attributed to the observed findings. The fourth is concision: the ability to report findings with brevity. It is been noted that the length of the radiology report tends to vary inversely with the confidence and preparation of the radiologist [8]. The fifth C is completeness, which allows a clinician to derive the maximum amount of significant clinical information associated with the findings. Not all radiologic findings are deemed clinically relevant, and the distinction of clinical significance is often left to the referring clinician, so the completeness of reporting becomes crucial [9]. The sixth and final C is consistency, which is important in ensuring that components remain the same throughout the report. If a finding is reported as "right sided" in the body of the report, this should be repeated in the impression of the report to avoid confusion.

Two additional C's not included in the list by Armas [4] are communication and consultation, which take on greater importance in the current radiology practice. As radiologists are faced with increased volume, complexity, and criticality of medical imaging examinations, additional time and medicolegal constraints are imposed. In an attempt to address these burgeoning expectations, radiologists (and technology providers) are being asked to provide added value to the equation by improving information delivery in the form of direct clinician contact and enhanced informational content.

The inherent importance of report quality in radiology was first formally recognized in 1922 by Preston M. Hickey, MD [10], who suggested that each radiologist seeking membership in the American Roentgen Ray Society (ARRS) should be required to submit 100 radiology reports with the radiologist's application. Acceptance to the society would be contingent on a favorable review of the quality of these reports. In an article on this topic, Hickey [10] wrote, "The ARRS should recommend a standardized nomenclature to be used in writing roentgenological reports." This call for standardization in radiology nomenclature went unheeded for more than 80 years and is at last being addressed from an informatics perspective through the RadLex initiative of the Radiological Society of North America [11]. This organized effort aims to continue to work with subspecialty societies in diagnostic imaging to create a standardized radiology lexicon for all imaging modalities, anatomic regions, and types of pathology. Lacking such a tool, radiologists often create free-text reports with inconsistent terminology, leading to ambiguity and uncertainty for referring clinicians, who are often tasked with important management decisions on the basis of the report findings.

In addition to content, an important attribute of a good radiology report is timeliness. A report that reaches the referring clinician after management decision making has taken place is of little value, regardless of how well organized and accurate is the content. This emphasis on report timeliness has taken on greater importance with

the adoption of the filmless and paperless health care enterprise, as new information technologies (such as PACS and electronic medical record [EMRs]) now allow clinicians to access medical data rapidly and from almost any site inside or outside the medical enterprise. As teleradiology is integrated into radiology work flow, radiology providers are now available on a 24/7 basis, placing greater emphasis and expectation on the timeliness of service. To effectively manage these heightened demands and deal with increasing competition, radiology providers are tasked with the challenge of providing "real-time" radiology, in effect rendering diagnostic interpretations at the time of image acquisition. Clinicians are simultaneously focused on the quality and timeliness of reports, because these underpin their perceived value in delivering health care to patients. The radiology report of the future must be attuned to these demands and leverage new technologies and applications in support of these efforts.

CURRENT GOALS AND CHALLENGES IN REPORTING

The most formidable goals and challenges facing radiologist reporting in 2007 can be distilled into several simple lines of advice:

1. do better (ie, improve quality and reduce errors),
2. improve safety (ie, reduce medicolegal risk and improve clinical outcomes),
3. work faster and more efficiently (ie, increase productivity and work flow), and
4. increase profitability (ie, improve the economic equation).

Some of these may at first glance seem to be mutually exclusive goals, but all can be realized by optimizing existing technology and education.

In an attempt to improve quality (as defined by diagnostic accuracy), we must first understand the existing limitations and frequency of reporting errors. It has been suggested that as many as 30% of radiology reports contain errors, regardless of the imaging modality, radiologist's experience, or time spent in interpretation [12-14]. These can be classified as errors in observation (perception) or interpretation (cognition) [15]. Perceptual errors have been shown to be common in radiology and can be reduced through the practice of double reading [16]. Interpretation errors do not exclusively result from a lack of knowledge and often can be attributed to other factors, including an inadequacy of clinical information [17], technical deficiencies [18], and a failure to consult historical imaging studies or reports [14]. Many new technologies and applications provide the means by which radiologists can decrease both observation and interpretation errors. These include computer-assisted decision support tools such as computer-aided detection, computer-aided differential diagnosis, and integrated clinical and imaging data.

Reducing medicolegal risk is of great importance to radiologists in the current practice environment, in which litigation risk has altered the practice of radiology in several ways. In the United States, medical malpractice awards and insurance premiums have steadily increased during the past decade, with "failure to diagnose" as the most frequent and expensive allegation in radiology malpractice, accounting for 28% of all lawsuits filed and 38% of dollars paid to plaintiffs [14,19]. The rising risk for malpractice in mammography has resulted in changes in mammography reporting, along with an overall reduction in mammography services [20,21]. This has had the unfortunate effect of reducing access to cancer screening services, a result that affects lower income patients most. Reducing medicolegal risk by changing practice patterns and technology could have a tremendously positive impact on medical care delivery and the economics of medical imaging.

Communication errors are another common cause for medical malpractice within the radiology community. The most common error cited has been the failure by a radiologist to directly contact the referring clinician about urgent, clinically significant, and unexpected findings [22]. The 4 specific situations in which "direct contact" is required, according to the ACR's [7,23] standard for communication, are

1. findings requiring immediate medical intervention,
2. conclusions of the radiologist that differ from prior interpretations,
3. findings that suggest a likely worsening condition if not treated, and
4. unclear findings that require direct follow-up.

Direct contact as specified by the guideline can take the form of electronic or verbal communication. Automated results reporting for emergent or unexpected findings can provide this required direct contact and offers the means for verifiable and documented two-way communication (as opposed to the unilateral communication that currently occurs). The computer software driving this electronic communication can take a number of forms, including structured reporting, "sticky notes," and "sound files." The term "sticky notes" has often been used to refer to annotations associated with images that are not part of a formal image request or report. These could include such diverse comments as a note by a technologist that a patient declined to remove his or her earring, by a radiologist that this case should be followed for pathologic correlation, or by a radiology resident or an emergency room physician with a preliminary report.

The use of such notes has been somewhat controversial because of concerns about how or whether these additions should be included in the patient's permanent medical record. Few PACS vendors have implemented this feature or have done so using a standards-based approach, such as the Digital Imaging and Communications in Medicine structured report.

A small subset of PACS vendors allow users to save sound files using either the wav or mp3 file format, but most clinical computers in hospitals today do not have speakers, so that communication of information in this manner is relatively inefficient and is not supported for archiving using most hospital EMR systems.

Other technology can be used to facilitate communication between radiologists and clinicians, including text paging, e-mail alerts, and direct contact by telephone. Multiple status updates (date and time, content, and receipt acknowledgment) can be electronically stored and archived to audit this communication [24].

In addition to these clinician alerts for "critical findings," the software used to automate the communication pathway could also track cases for which follow-up recommendations were issued [24]. This would serve the dual purposes of ensuring that recommended follow-up occurs (and provide return receipt confirmation of finding review) and notifying the reporting radiologist of the results. Most systems currently lack the capabilities to notify a radiologist that a clinician has reviewed the findings. Natural-language processing software could facilitate this data-tracking function by identifying and searching for key words and concepts in a free-text report, with the resulting data preserved in a database for future outcomes analysis. Although a number of groups have devised and continue to report on novel approaches to natural-language processing in radiology [25-29], most remain in developmental stages, hampered by the difficulties in devising a workable system that can respond to all of the complexities, variations, and nuances in a typical report.

Working faster and more efficiently is the goal of every radiology department. Although new information technologies (PACS, radiology information systems, EMRs) have improved access to and the integration of imaging and clinical data, the reporting process and associated technologies have not produced concomitant gains in radiologists' productivity. In fact, speech recognition software has been reported to decrease radiologists' productivity and work flow through its requirements for self-editing, a process that gives radiologists new clerical responsibilities not required with conventional transcription [30,31]. The degree of decreased productivity and the potential to ameliorate this have not been adequately explored in the imaging literature.

One of the most important yet overlooked factors affecting radiologists' productivity in the current practice environment is stress, which in some cases leads to "burnout." Although new imaging and information technologies have expanded the repertoire of radiologists, they have not been implemented without a price. Adapting to new technologies produces significant stress on radiologists, and this is exacerbated by the aforementioned increased risk for medical malpractice, an increased volume and complexity of imaging studies, and heightened demands for improved timeliness and quality of service. In this environment, technology is a double-edged sword. On one hand, it can provide the means to improve performance by automating manual processes. On the other, it can increase stress and ultimately reduce productivity by requiring that the end user constantly learn and adapt to new (and often difficult) technologies. An effective approach would be to develop new reporting applications that do not call for major overhauls to radiologists' existing work flow and skill sets. These could simply allow radiologists to do what they know best and make the technology adapt to radiologists, rather than the other way around.

DEVELOPING NEW REPORTING STRATEGIES

Many challenges face radiology reporting in the current environment and make it clear that the existing paradigm is far from ideal. New reporting strategies must be developed to improve quality, communication, and productivity, while reducing malpractice risk, stress, and cumulative fatigue. The end result (in theory) would improve clinical outcomes, overall job satisfaction, and profitability.

Specific requirements for next-generation reporting systems should include the following:

1. Directly link clinically significant radiologic text and imaging findings.
2. Automate the communication pathway and track critical findings and recommendations electronically to ensure compliance and to objectively measure quality.
3. Provide direct feedback to radiologists on the basis of prospective clinical and imaging data.
4. Create the ability to provide electronic consultations among radiologists, technologists, and clinicians.
5. Develop a uniform and standardized nomenclature to be used by the entire radiology community that will be designed to avoid communication and interpretation errors.
6. Use this standardized lexicon to create structured (instead of prose) reports that can help eliminate

much of the existing uncertainty and ambiguity contained within free-text reports.
7. Ensure that these structured data reports include itemized radiologic findings (directly linked to key images), along with important ancillary information, such as clinical significance, temporal change, and follow-up recommendations.
8. Organize these structured reports to create a database that, along with clinical data from EMRs, can be used for clinical outcomes analysis and clinical decision support.
9. Share these "linked" imaging and structured text data (in a standardized and anonymous format) with other institutions for the purposes of education and research.
10. Directly integrate the display, interpretation, and reporting technologies used by radiologists so that the focus and attention of radiologists are on the imaging data.
11. Be compliant with Digital Imaging and Communications in Medicine, Health Level 7, and other current standards to ensure (among other advantages) interoperability with data from other institutions, a crucial element in supporting multi-institutional clinical trials, cooperative studies, and shared databases.

Almost all of these requirements have been previously described in suggested guidelines and in discussions of needed innovations. In fact, many of the technical and clinical requirements of such a system currently exist or are in development. The ability to electronically annotate imaging data, for example, is available on most PACS, although many practitioners do not use these features. The ability to automate communication pathways is not readily available on imaging information systems today, although such functionalities are being actively pursued by the vendor community.

The concept of a standardized lexicon was realized with the release of the initial complete version of RadLex at the 2006 annual meeting of the Radiological Society of North America. Although not without its critics and limitations (specifically in the adequate reflection of terms from all imaging subspecialties and abilities to adapt and incorporate new terms with reliability and efficiency), the RadLex terminology remains the most promising available tool for standardizing radiology reports and providing a shared basis for innovations to the reporting process [32].

The challenge will be to identify ways to ensure compliance within the radiology community in using this standardized lexicon. Perhaps the best way to accomplish this is to develop reporting systems that can "translate" or map currently used language in radiology reports to defined RadLex nomenclature.

Convincing radiologists to "give up" their prose, free-text reports in favor of structured reporting is, in all likelihood, the most challenging task and one that may be more psychologic than technical or clinical. Most radiologists (like all humans) tend to be resistant to change, and asking them to adopt an entirely new reporting format has not been and will not be met with a great deal of enthusiasm. Perhaps the most effective way to accomplish such a transition would be to move toward structured reporting in a "transparent" format. This would entail having radiologists identify findings in a manner similar to that in their current work flow but with these input data "converted" into structured text by the computer. The most straightforward approach would be to create a computer program to translate "free-text" reports into a structured format, although this is a very difficult task.

Another approach would be to create a hybrid system that imposes structure on a dictated report or one that is generated using a speech recognition system. This could be accomplished with a simple template that organizes findings on the basis of the type of report, or it could entail the use of a more sophisticated or "intelligent" template that could generate a report interactively. One example of this would be the generation of reports by dictating only the abnormalities and then having the computer program fill in the remainder of a "normal report" template for that particular examination.

Attempts at novel reporting systems that make use of direct computer-radiologist interaction are not new. In the 1990s, radiologists at Johns Hopkins University developed a touch screen reporting system based on HyperCard technology for use with MacIntosh computers [33]. In an attempt to explore the potential for an entirely new direct interactional reporting system, one of us (BIR) has developed a prototype graphical symbol language that directly maps to RadLex terminology. This approach is analogous to the use of a wax pencil in a film-based system, in which marks are made on a film that represent the findings or impressions associated with a study. This is familiar to radiologists trained in a film-based environment, who used these marks as residents to remember observations and impressions from an attending radiologist or alternatively made such marks to communicate findings on a film "alternator" to referring clinicians.

In this prototype system, each graphical symbol correlates with a specific radiologic finding. For example, the pictorial representation for cardiomegaly is a modified heart shape. Graphical recognition software translates these graphical symbols into predefined structured text, which in turn is incorporated into a hierarchical structured-text report. Modifying information (eg, clinical significance, follow-up recommendations) is associated

with these radiologic findings. When a predetermined value has been assigned to a specific finding (eg, high clinical significance), an automated results-reporting pathway is elicited to deliver this information to the referring clinician. At the same time, a recommendation for follow-up (eg, "CT in 3 months") is automatically tracked by this software to ensure compliance and provide feedback to the initial radiologist. The resulting structured-text report is created using RadLex terminology and entered into a report database for future analysis. This new system is scheduled for demonstration later in 2007 and will be described in detail in subsequent publications.

Such a system is one of many potential contributions to revising the paradigm of radiology reporting that has prevailed for more than 100 years. With the speed of technologic change and innovation, it is impossible to say which approaches will prove most efficient, acceptable, and, most important, beneficial to patient care. Some critics of the gesture-based approach believe that the full-text report will remain the valuable mainstay and reflection of radiologists' expertise [34]; others, along with us, envision a future of a "virtual reality" reporting approach that allows radiologists to access a range of interactive technologies to create a new type of report that would respond to clinicians' changing needs [35].

CONCLUSION

Multiple new reporting approaches are under development. They all attempt to address some of the inherent deficiencies of traditional free-text reporting. With the convergence of new pay-for-performance initiatives, increased computational power and standards, tablet PCs, improved speech recognition systems, RadLex, and increased provider competition through teleradiology, the time seems ripe for a new reporting solution.

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