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Strategies for Radiology Reporting and Communication

Part 2: Using Visual Imagery for Enhanced and Standardized Communication

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> "Of all of our inventions for mass communication, pictures still speak the most universally understood language." Walt Disney

> "Words are the source of misunderstandings." Antoine de Saint-Exupery, *The Little Prince*

Introduction

The current communication model in medical imaging largely centers on the free text, narrative report which consists of lists of abnormal (i.e., pathologic) and normal findings, along with a summary impression. In the event that the interpreting radiologist or societal standards deem additional communication is required (e.g., emergent, clinically unexpected report findings), direct communication with the referring clinician will be instituted, with the goal of expediting clinical management. The methodology for this "direct" communication is highly variable and can include text-based communication in analog or digital formats (e.g., facsimile or e-mail alert), or verbal communication (e.g., telephone call or voice mail). In rare circumstances, face-to-face communication can take place, but this is inefficient and requires physical travel on the part of the radiologist and/or referring physician, which has been largely obviated with the advent of picture archival and communication systems (PACS) [1].

Unfortunately, in the current medical practice environment where radiologists and clinicians are generally operating in a "workload overload" capacity, these communication responsibilities are often delegated to third parties, who can include technologists, administrators, nurses, or clerical staff [2]. While the delegation of these communication responsibilities is intended to improve timeliness and operational efficiency, it can also lead to communication failure, which has been shown to be a major contributor to medical error and adverse clinical outcomes [3, 4]. Once the initial communication has taken place and been documented in the radiology report (through narrative text), it is assumed that the communicated information will be promptly and correctly acted upon. If this is not the case, however, and an adverse event results, it is often difficult to definitively identify the source and nature of the communication error. This not only places the involved parties at increased risk for medicolegal action, but also makes it difficult to create correctional interventional strategies. A broad-based solution is required which addresses existing deficiencies in data creation, display, exchange, and verification. Ideally, this strategy would be multifunctional in nature, applicable to a wide array of communication applications, and customizable to multiple stakeholder groups, including radiologists, physicians, support staff, and patients.

Visual Literacy and Imagery as a Communication Tool

Any attempt to improve communication should begin with an analysis as to what and how information is being conveyed. Existing communication strategies in medical imaging primarily utilize textual data as the principal information source, which is somewhat ironic given the rich nature of imaging data, which also serves as the primary source of analysis. One could argue that the translation of information from visual imagery to text has the potential to introduce error, ambiguity, and uncertainty in the analysis and communication of imaging data. This leads us to the premise that communication in medical imaging may be improved by directly integrating images into the communication schema (i.e., visual communication and literacy).

Visual literacy can be defined as the ability to construct meaning from visual images [5] and utilize visual imagery to enhance communication [6]. There are many forms of visual communication including gestures, objects, signs, pictures,

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and symbols. The concept of visual literacy is certainly not new and actually predates written language in both historical and developmental perspectives. Humans have relied upon images to convey ideas for several millennia, as evidenced by the cave drawings used by prehistoric man. At the same time, children in early development (beginning at 12 months of age) can interpret graphic imagery with accuracy [7]. The refinement of visual literacy is at the core of the medical imaging profession, in which radiologists, technologists, and clinicians learn to create complex understanding and meaning from medical imagery. While it is often said a "picture is worth a thousand words," this was given greater meaning and context in medical imaging by radiologists Benjamin Felson and Edward Neuhauser, who popularized the term "Aunt Minnie" to describe a radiology concept (i.e., pathologic state) which was more easily understood and communicated in imagery than words [8].

Scientific studies can provide ample evidence as to the practicality of visual communication in everyday personal and professional applications. Research at 3M Corporation concluded that humans process visual data 60,000 times faster than text [9]. Other studies have shown that the human brain deciphers image elements simultaneously (i.e., in parallel), whereas language is decoded and processed in a linear and sequential manner (i.e., in sequence), thereby requiring more time to process language than imaging data [10]. A noted expert on visual literacy, Dr. Lynell Burmark, has said, "unless our words, concepts, and ideas are hooked onto an image, they will go in one ear, sail through our brain, and go out the other ear. Words are processed by our short-term memory which can only retain about 7 bits of data. Images, on the other hand, go directly into long-term memory where they are indelibly etched" [11].

In everyday medical imaging practice, we know that visual imagery frequently trumps text in conveyance of quick, concise, and clear communication. Many nonmedical occupations such as photojournalism, advertisements, and finance routinely use visual imagery in the forms of pictures, photos, graphs, and charts to communicate ideas, concepts, and emotions in meaningful ways. The combination of imagery and text has a synergistic communication power that neither singularly possesses, with the combined data producing levels of comprehension and memory that can exceed what is produced by text alone [12]. So given these practical and scientific considerations, why does medical imaging communication continue to rely almost exclusively on text-based communication in the absence of readily available and illustrative imaging data?

Technology-Enabled Visual Communication

If we want to discuss the role of technology in communication, we need to go back to 1450 with the invention of the movable type printing press by Gutenberg. At that time, text became the predominant form of communication, with graphics limited by cost constraints. As printing technology evolved and printing costs declined, use of graphics increased. The transition from textual to visual literacy and de-emphasis of text as the principal communication mode have been further accelerated by the analog-to-digital conversion, which has led to the decline of print media [13].

Computers have required different pathways for learning and communication. As information in our everyday and professional lives becomes more complex, voluminous, and diverse, communication has become more dominated by images [14, 15]. Computer-based imagery has taken a variety of forms including photos, graphics, graffiti, animation, video, schematics, pictures, icons, and symbols. This visual literacy is promoted by a wide array of portable computerized technologies including smartphones, electronic notebooks, and pocket computers, which facilitate rapid and ubiquitous digital communication. Software applications provide easy-to-use tools for rapid image modification and interactive communication. These interactive media can extend beyond images alone and can include tactile and auditory methods of communication, along with visual syntax. Examples of visual syntax include scale, dimension, motion, boldness, depth, and color, which create a diverse structure and organization for image manipulation for the purpose of improved communication and understanding. This has in turn led to the creation of abstract information visualization techniques, which display hierarchical data in nontraditional, interactive graphical formats [16].

In everyday medical imaging practice, the technologies to support visual communication are currently available in the forms of image acquisition technologies, image processing and advanced visualization software, PACS, radiology information system, and the electronic medical record. When combined with portable computer technologies (e.g., smartphones and portable tablets), the technologic infrastructure is readily in place to support interactive visual communications in a safe, secure, reliable, and consistent manner. The challenge is to create a methodology which is inherently intuitive, uses standardized data, and is customizable to the unique needs and preferences of each individual end user.

Defining the Innovation Strategy

In order to optimize communication, the proposed innovation will combine visual and textual data, in an attempt to improve comprehension, memory, and clarity. This approach is particularly well suited for communication of medical imaging data, given the fact that the data is inherently image-based and relatively independent of language. One can argue that in the creation of medical imaging reports (which is the existing primary mode of communication), the concepts and information contained within the imaging dataset are converted into textual data, which often introduce uncertainty, confusion, and ambiguity [17, 18]. While textual data retains an important role in the proposed communication strategy, it becomes secondary to the primary visual data source, the imaging dataset. In Fig. 1, an example is provided illustrating how a single "key image" from a chest CT angiography dataset can be captured in both native (i.e., nonannotated) and annotated states to visually identify and communicate the finding of interest.

In order to create a referenceable database, which is an essential component to data mining and outcomes analysis, a primary goal of the innovation is to create standardized data. Since the imaging data is acquired and recorded using existing Digital Imaging and Communications in Medicine standards, no additional standardization requirements exist for the imaging data component. Since traditional text-based narrative reports contain nonstandardized data, an alternative input or data conversion strategy is required in order to create a standardized text data communication methodology. Since conversion of nonstandardized data to standardized data is somewhat problematic and requires inferencing, which can introduce error, a preferable approach is to create a method for standardizing data input. One approach to accomplish this task is to create a comprehensive radiology lexicon, which is a formidable task. Alternatively, one can narrow the scope of accompanying textual data to incorporate the essential data elements which are of greatest importance in defining the pathology and recommended clinical actions (Fig. 2). These essential data elements include anatomic location, differential diagnosis, temporal change, clinical significance, and follow-up recommendations. In the absence of a comprehensive ontology to support complete standardization, descriptive textual data (e.g., size, morphology, number, enhancement characteristics) can be incorporated in a nonstandardized fashion. This provides a mechanism for the radiologist to add descriptive text data to the communication strategy in a free text format to support the pictorial imaging data, which arguably provides the most effective means of conveying visual descriptive information. An example of how essential data such as temporal change, clinical significance, and follow-up recommendations can be standardized is presented in Table 1.

By utilizing a standardized image annotation and markup schema akin to the Annotation and Image Markup Project [19], the graphical data used to highlight specific features within the imaging dataset can also be standardized and recorded in the referenceable database. The resulting database would consist of finding-specific images with standardized graphics (i.e., annotations) and supporting data. This provides a powerful tool for education, research, decision support, and clinical analysis. Once the technologic infrastructure has been established (which is by no means a menial task), the next step is to create a method for longitudinal data tracking, which in theory provides a mechanism for documentation of the communication process. Included in this "tracking data" would be identification of the parties involved in the communication process, date and time stamps, recording of data transfers and receipts, and acknowledgment of data comprehension. This latter feature of data comprehension is an essential component of the innovation strategy and creates a mechanism to document "clinical understanding," by defining clinical significance and follow-up recommendations of the finding or concept being communicated in a clear, unambiguous, and standardized fashion.

While current critical results communication strategies attempt to ensure timely and reliable communication of critical imaging data, it is not uncommon for the data being communicated to be lost, delayed, misunderstood, or even ignored. The proposed strategy attempts to mitigate these concerns through the creation of accountability methods which track the identities of the communicating parties, date/time of communication, and criticality of data (Table 2). Since current strategies largely rely on self-reporting of communication data (which is primarily performed through the creation of text-based report addenda), there is the possibility that erroneous data can be recorded and/or the parties involved can deny the

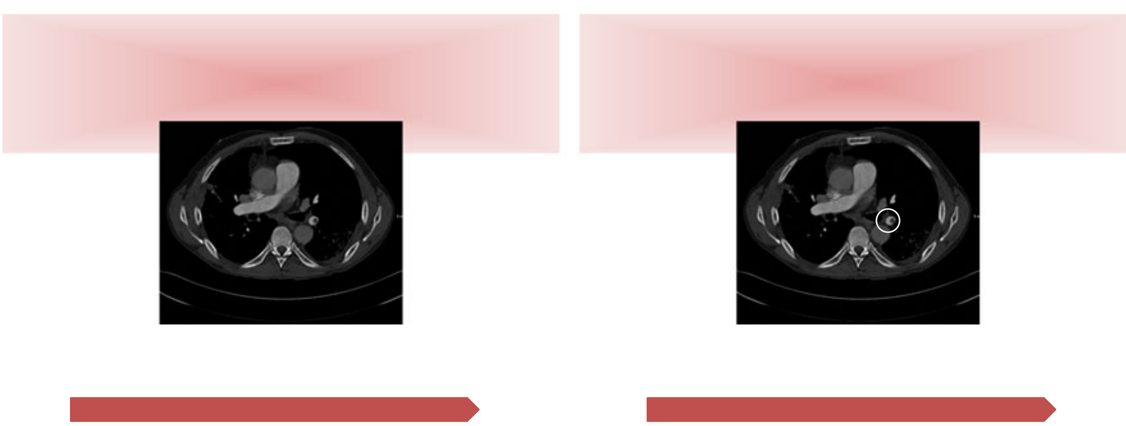

Fig. 1 Selected key images with and without annotation demonstrating a non-occlusive embolus in the left lower lobe pulmonary artery

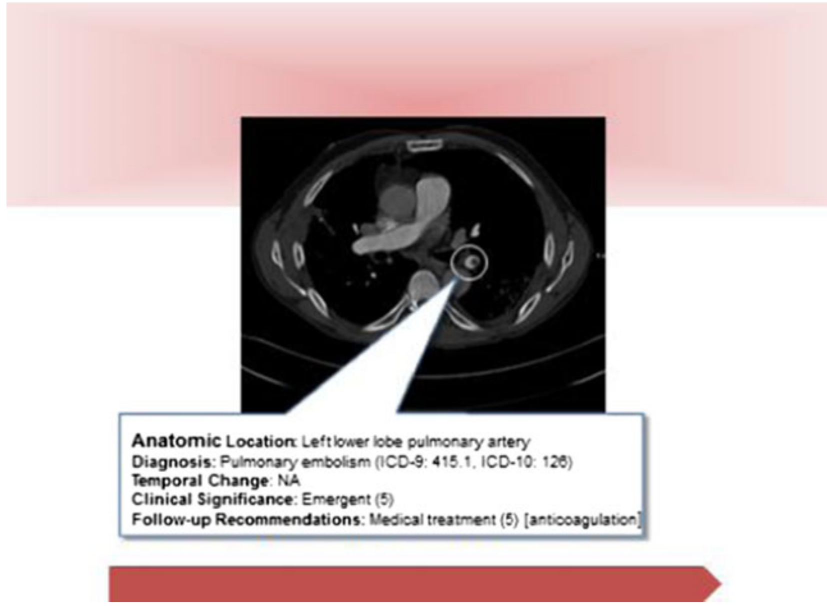

Fig. 2 When annotation is highlighted, the accompanying structured "high level" text data is presented to the reviewer which conveys standardized data related to the anatomic location, diagnosis/differential diagnosis, clinical significance, temporal change (if applicable), and follow-up recommendations

Table 1 Standardization schema of associated "high level" text data

A. Clinical Significance (scale of 1-5)
- 1- Finding of no clinical significance
- 2- Finding of uncertain clinical significance
- 3- Finding of moderate clinical significance
- 4- Finding of high clinical significance (non-emergent)*
- 5- Finding of high clinical significance (emergent)*

*Scores of 4 and 5 generate automated results reporting.

B. Temporal Change (scale of 0-3)
- 0- Interval resolution
- 1- No interval change
- 2- Interval increase
  - a. Small increase
  - b. Moderate increase
  - c. Large increase
- 3- Interval decrease
  - a. Small increase
  - b. Moderate increase
  - c. Large increase

C. Follow-up Recommendations (scale of 0-5)
- 0- No follow-up required
- 1- Comparison with prior imaging exams
- 2- Additional and/or follow-up imaging exams
- 3- Clinical consultation/testing (specify)
- 4- Tissue sampling/biopsy*
- 5- Definitive therapy (medical or surgical)*

* Scores of 4 and 5 generate automated results reporting

communication took place as recorded. This "he said, she said" scenario often becomes difficult to accurately define, since it relies on the retrospective memory of individuals without formal and standardized data confirmation. One strategy to circumvent this deficiency is the integration of biometrics data directly into the communication platform, so that the combined image/textual data used in the communication protocol would have embedded biometrics signatures of all parties involved in the communication, with accompanying time stamps to document the exact date and time the data was transferred, received, and acknowledged. An added benefit of these user-specific biometrics signatures is the ability to correlate with each individual user's communication profile, which includes his/her individual preferences as to how the data is presented. In addition to customizable visual display options (e.g., boldness, color), these user-specific display options can also incorporate alternative data presentation options (e.g., auditory, tactile). The net result is that by standardizing the

Table 2 Data elements contained within communication tracking application

1. Finding or Disease Prompting Communication
2. Person Initiating Communication (e.g. interpreting radiologist)
3. Intended Recipient of Communication (e.g. referring clinician)
4. Identity of Person Receiving and Acknowledging Communication
5. Date and Time Communication Schema Initiated
6. Date and Time of Communication Receipt and Acknowledgement
7. Date and Time Stamps of All Intervening Communication Steps
8. Method/s of Communication
9. Follow-up Recommendations
10. Resulting Clinical Actions (e.g. physician orders)

communication data, user-specific customization presentation profiles can automatically convert the data to the preferences of each end user, which is automatically performed at the time of end-user biometrics identification/authentication.

The customization features of the communication schema can also extend into the manner of preferred data transfer, as well as institutional-defined communication protocols. While individual end users can define their individual communication preferences (e.g., telephone, e-mail alerts), the institution can define explicit communication protocols based upon individual findings, clinical significance, and follow-up recommendations. In the event that communication with a referring clinician cannot be satisfactorily documented on an emergent finding, the institution can direct a specific communication chain, which can be electronically tracked and analyzed in the database. Longitudinal analysis can also include follow-up recommendations to ensure that clinical oversights or time delays in clinical management do not occur. While the aforementioned descriptions and attributes of the proposed communication strategy have largely focused on communication between healthcare providers, the same innovation strategy can be readily applied to communication between healthcare providers and patients. In this scenario, data communication extends into an educational role, which can also be customized to the individual needs and attributes of the individual patient. The ultimate goal is to create an objective and reproducible method for improving communication in medical imaging through greater emphasis on “visual” imaging data, with the theoretical benefits of improved accountability and clinical outcomes.

References

1. Reiner B, Siegel E, Protopapas Z, et al: Impact of filmless radiology on the frequency of clinician consultations with radiologists. AJR 173:1169–1172, 1999
2. Anthony SG, Prevedello LM, Damiano MM, et al: Impact of a 4-year quality improvement initiative to improve communication of critical imaging test results. Radiology 259:802–807, 2011
3. Dayton E, Henrikson K: Teamwork and communication: communication failure: basic components, contributing factors, and the call for structure. Jt Comm J Qual Patient Saf 33:34–47, 2007
4. Manning ML: Improving clinical communication through structured conversation. Nurs Econ 24:268–271, 2006
5. Giorgis C, Johnson NJ, Bonomo A, et al: Visual literacy. Read Teach 2:146–153, 1999
6. Lapp D, Flood J, Fisher D: Intermediality: how the use of multiple media enhances learning. Read teach 7:776–780, 1999
7. Rowe ML, Silverman RD, Mullan BE: The role of pictures and gestures as nonverbal aids in preschoolers' word learning in a novel language. Contemp Educ Psychol 38:109–117, 2013
8. Teele RL, Griscom NT: Aunt Minnie (letter). Radiology 208:829–830, 1998
9. Harley T: The Psychology of Language: From Data to Theory. Psychology Press, Hove, 2001
10. Cohen L, Lehericy S, Chochon F, et al: Language-specific tuning of the visual cortex? Functional property of the visual word form area. Brain 125:1054–1069, 2002
11. Burmark L: Visual literacy: what you get is what you see. In: Frey N, Fisher D Eds. Teaching Visual Literacy: Using Comic Books, Graphic Novels, Anime, Cartoons, and More to Develop Comprehension and Thinking Skills. Corwin Press, Thousand Oaks, 2008, p 7
12. Levin JR: A transfer of appropriate processing perspective of pictures in prose. In: Mandl H, Levin JR Eds. Knowledge Acquisition from Text and Prose. Elsevier Science Publishers, Amsterdam, 1989
13. Fitzgerald M: NAA leaders disagree over value cyberspace. International Federation of Newspapers Publishers Research Association 128:48–49, 1995
14. Duderstadt JJ: The future of the university in an age of knowledge. J Asynchronous Learn Netw 1:78–88, 1997
15. Blackler F: Knowledge, knowledge work and organizations: an overview and interpretation. Organ Stud 16:1021–1046, 1995
16. Shneiderman B: Inventing discovery tools: combining information visualization with data mining. Inf Vis 1:5–12, 2002
17. Reiner B: Uncovering and improving upon the inherent deficiencies of radiology reporting through data mining. J Digit Imaging 23:109–118, 2010
18. Reiner BI: Using analysis of speech and linguistics to characterize uncertainty in radiology reporting. J Digit Imaging 25:703–707, 2012
19. Zimmerman SL, Kim W, Boonn WW: Informatics in radiology: automated structured reporting of imaging findings using the AIM standard and XML. RadioGraphics 31:881–887, 2011