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Medical Imaging Informatics: How It Improves Radiology Practice Today

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"Great case, next case."

—Private practice radiologists' mantra

"Faster, better, cheaper..."

—Business paradigm

Radiologists are under pressure to add more value to medical imaging—to provide more educated, accurate, useful, and efficient interpretations in the face of increasingly large and complex imaging studies and to communicate this information quickly and in the most useful manner. The radiology department and radiologist both need to be better, faster, and cheaper.

Medical imaging informatics (MII) includes many of the processes radiologists need to reach these goals. MII is the development, application, and assessment of information technology (IT) for clinical medical imaging. It includes the interfaces of IT and people.[1–3] In practical terms, MII already occurs at a basic level throughout radiology practice, from the moment a clinician considers ordering an imaging study, until images and interpretation are used to plan the patient's treatment.

MII is not an academic exercise. Every radiologist should appreciate its basics. Radiologists do not need to write computer code, but their lives will be better if they comprehend MII benefits, products, and processes and how to implement and integrate these systems at visionary and managerial levels.

Picture archiving and communication systems (PACS) and Radiology information systems (RIS) are the most visible parts, but MII is more than that. Radiologists were intimately involved in PACS and RIS throughout their evolution. Now, as basic PACS/RIS become commodities in radiology practices, radiologists may lose their informatics focus. They delegate it to the IT department, radiology administrator, or certified imaging informatics professional (CIIP). To deal with the current workload, and to maintain income, radiologists often feel driven solely to interpret imaging studies. They keep their eyes on images and dictate; anything that detracts from that pattern they delegate.

As in many fields, radiologists are expected to know exponentially more about new imaging techniques, findings, and clinical applications. Why, then, should they learn about MII, a potentially large and complex field that is not applicable to one's interpretation skills, and at first glimpse, does not tie directly to patient care or revenue production?

Our private practice radiology group works at disparate sites that encompass multiple PACS, dictation systems, and RISs. Qualitative observation of these various situations suggest between 25

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and 100% difference in radiologist efficiency between the best and worst of our combinations. Even between two sites with supposedly the most efficient, mainline PACS, radiologist efficiency varies perceptibly. Why?

Causes for this are hard to quantify. In one setting, radiologists with MII knowledge participated in PACS from the start, through design, RFP, implementation, and continued oversight. In the second setting, the hospital corporation and its IT department drove MII decisions and implementation. The second setting's IT department is fine, and their PACS vendor is excellent. Both systems run well, are reliable, and on the surface, provide "a state-of-the-art, filmless, radiology department." Radiologists are most efficient, however, at the hospital with an involved, designated, MII radiologist.

Eliot Siegel, MD of the VA Maryland Health Care System gives a well-received talk on the tsunami wave of increasing radiology work crashing over radiologists.[4] His talk contains a movie clip of Lucille Ball on the chocolate factory assembly line and her travails as chocolates on a conveyor belt rush by ever more rapidly. This analogy is painfully apt for radiologists, with their eyes on images, dictation mike in hand, who race to interpret thousands of images in time to get home for dinner. What follows is an unabashedly radiologist-centric examination of the radiologist on the assembly line and examples of how MII can improve a radiologist's life.

In a simplified model of the radiology assembly line, one may define the patient and information about him as the "entire patient entity" (EPE) that moves through the radiology department. Stations on the radiology assembly line, upstream from the radiologist, perform functions on the EPE, such as add demographic information and history, place an IV, scan the patient, post-process images, and attach relevant priors. The patient's images and clinical information eventually arrive at the radiologist station on the assembly line. The radiologist's responsibility is to synthesize all available information in the EPE and translate it into a clinically relevant written interpretation that, combined with relevant images, helps the treating physician decide what to do next. This interpretation is just another (albeit important) process performed on the EPE. Then, the patient and his image information, now with a report attached, move on down the line—the report distributed as needed, and the patient to the appropriate treatment.

Like Lucy in the chocolate factory, the radiology assembly line is increasingly demanding and in need of improvement. One established approach to improve an assembly line is to decrease by even a tiny amount the time it takes to perform an individual step.[5] If that step repeats often, the total time saving is significant. In a simplified example, for a radiologist who reads a two-view chest radiograph every 2 min, cutting out 12 s per case means that during a 10-h day, the radiologist either earns 10% more or gets home an hour earlier.

Done correctly, MII can cut tiny time fragments from every facet of the radiologist's tasks. The key concept, however, is "done correctly". This is critical. What a radiologist does can be described simply, but beneath that description is a rich, deep set of knowledge, habits and processes every radiologist uses to perform the practice of radiology. *Nobody except the radiologist will appreciate MII's subtleties that will cut minor time increments from each task the radiologist performs for every case*.

If radiologists delegate decisions on planning, vendor selection, and implementation of MII components and systems, the result may be good for many things, but it will not optimize radiologists' efficiency. A current example of non-radiologist-centric MII is voice recognition (VR) dictation of the radiology report. Errors in original project planning, vendor selection, or implementation of VR can make radiologists up to 25% less efficient.[6–8] On this issue, one hospital administrator facing a group of frustrated radiologists declared, "...but VR only adds a minute or two of radiologist time to each case." Only the radiologist has enough at stake to refocus MII onto radiologist efficiency.

Four issues illustrate how an II radiologist can improve every radiologist's experience on the assembly line. First, how should the EPE be processed before it arrives at the radiologist station, or phrased differently, what should already be attached and what steps performed before the imaging study arrives for the radiologist's interpretation? Second, what tools does the radiologist need to maximize the time spent to get all possible information from the images or "quality eyes-on-images time?" Third, what tools and process allow the radiologist to synthesize efficiently and robustly the images, clinical data, and his medical knowledge database into a cohesive, accurate, helpful interpretation? Finally, what should be the report format as the EPE leaves the radiologist station, to enhance fast, correct, and efficient patient treatment?

IN WHAT STATE SHOULD THE EPE ARRIVE AT THE RADIOLOGIST STATION?

What should occur before "the study" is presented to the radiologist? The radiologist needs (a) history, including chief complaint, pertinent past medical history, and relevant laboratory and pathology results;[9,10] (b) the current study in a state ready for interpretation. This assumes radiology technologists obtained the correct images, preprocessed and labeled them, and put them in the proper presentation state in PACS; and (c) relevant prior studies with reports.

First, the II radiologist should ensure that all of these data are available to the radiologist. Second, the II radiologist wants to cut tiny (or often large) amounts of time from each step the radiologist performs to get this information. Questions the II radiologist might ask include: How does the radiologist currently get clinical information? Can radiologist workflow change to best use existing software? If useful data are on separate enterprise IT databases, can they integrate with the radiologist workstation so the data are immediately available in a manner that helps the radiologist? Are the data in an electronic medical record (EMR), and if so, how does the EMR integrate into the physician workstation in the best way possible for the radiologist? For all current hospital informatics software, the II radiologist should check a list of that entire program's capacities. A familiar system may have helpful features that are not turned on or implemented because nobody else saw their value. One example is that the hospital information system (HIS) may have a physician index module, with fields for physician contact numbers, fax, and even pager and cell phone information, which might be accessible in a way that makes it easier to communicate with clinicians. Every piece of information delivered correctly and automatically to the radiologist is radiologist time saved.

If an enterprise plans to buy a new EMR, HIS, or RIS, the II radiologist should evaluate it with the thought, "How does this make the radiologist better, faster, and more efficient?" Questions the radiologist may ask, from easier to more difficult, include: Does the process involve excess clicking through screens? Are relevant data easily accessed? Is everything on a single console, with single login and single screen? How easily are clinical data corrected or updated? Which integrating the healthcare enterprise (IHE) criteria does the software meet? Does it have smart capabilities, such as alerts about allergies, renal disease, prior malignancies, or other radiologist-defined information? Can the software interact easily and robustly with other systems? Can it transfer clinical information to the report electronically, either manually or automatically? Does the system have an application programming interface (API) or software development toolkit that allow the radiologist to direct someone to write a program to collect all relevant clinical data into a radiologist-centric data page that pops up simultaneously with the images, and dump relevant data into the final report?

WHAT TOOLS DOES THE RADIOLOGIST NEED TO OPTIMIZE QUALITY EYES-ON-IMAGES TIME?

Radiologists appreciate this part of MII because it deals most directly with the images. If the radiology group already uses PACS, are workstations configured to maximize radiologist's productivity? Are useful hanging protocols available? Are search criteria for relevant priors configured correctly? Are toolbars well organized? Workstation use is astonishingly idiosyncratic, however. Over time, each radiologist evolves his or her own distinctive PACS/RIS workflow. Despite these diverging workflow patterns, it is worthwhile for the II radiologist to review the PACS workstation manual and tools every 6–12 months. As radiology exam characteristics change or as frustrations of a particular PACS workflow crystallize, the manual may describe helpful tools or processes one did not think to learn the first time around. For example, the MR on which we initially did dynamic temporomandibular joint (TMJ) Magnetic resonance imaging (MRI) automatically re-sorted images by table location, so a movie of the jaw opening and closing played correctly on the PACS workstation. The MR was replaced with a new model lacking that capability. After months bemoaning the inefficient PACS that now forced us to walk out to the MR monitor to review dynamic images, a partner perusing the PACS manual found the tool to do this.

The rules that allow digital imaging studies to move between disparate systems are known as Digital imaging and communication in medicine (DICOM). Even rudimentary DICOM knowledge allows an II radiologist to identify DICOM issues and solutions that affect radiologist productivity dramatically. When an imaging exam is transmitted electronically, DICOM defines information describing that study to be sent first, in the "DICOM header". Most PACS vendors allow radiologists to use header information to build hanging protocols, which cause similar types of exams, such as lumbar spine MRs, always to open on the workstation in the same manner. Several PACS include in their hanging protocol algorithm the MR series descriptor, such as, "Sag T1". When a different MR vendor uses a different series descriptor such as "T1 Sag", the hanging protocol may not work. A workaround is to develop an internal institutional list of approved MR series descriptors for all MR machines. Thus, any "Sag T1" type sequence on any vendors' MR is labeled as such. MR vendors do not appreciate a competitor's labels on their machine, but it works for the radiologist.

Radiologists often notice monitor quality variation despite the monitor meeting QA specifications. If an II radiologist understands monitor issues such as luminance, contrast, resolution, gray scale, video quality, just noticeable difference (JND), gamma curve, and look-up-tables (LUT), it is much easier to convince the appropriate person to fix or replace a monitor.[11–13] It is also invaluable when choosing new monitors, which now come in a bewildering array of size, resolution, luminance, and cost. Their true specifications often are not the same as advertised. Rudimentary knowledge of monitor physics, perception basics, and calibration issues allows the radiologist to begin to separate vendor hype from fact. Keeping current on MII also allows the radiologist to know, for example, of current research showing that certain consumer grade (e.g., Dell) monitors are acceptable to read everything, even conventional radiographs—knowledge that may save thousands of dollars per monitor.[14] Advising on monitors for the OR, ED, and specialty clinics offers an opportunity to improve clinician relations and demonstrate II skills. Surgeons may like a vendor's fancy new offering, when something better may actually be cheaper for them. In these situations, physician-to-physician discussion has the best chance of success. An important sidepiece to image viewing quality is the workstation computer's video card, and often an II radiologist is the only physician to know this.

Sophisticated evaluation of the radiologist workstation is paramount when assessing a new PACS. The radiologist's goal is simple to state: "Does this workstation help the radiologist to interpret a case, and does it help more than other vendor's workstations?" This analysis is not trivial. How a radiologist uses the workstation is much more complex than what appears at first glance.[15–17]

Examples of trials a radiologist should personally perform on a prospective new PACS workstation include: How long does it take the radiologist to label a spine in a manner that makes it easy to read the study and label in a manner helpful to the spine surgeon? How long does it take the radiologist to build customized MR hanging protocols, and how well do they work on studies from different MR vendors? Do series automatically link and cross-reference in an intuitive, robust, fashion? Finally, despite radiologists' continued request for fewer mouse clicks, vendors often have surprisingly inefficient processes for radiologists to complete common tasks. The radiologist is the best person to assess these subtleties that may plague workflow.

A current hot topic is how to integrate effectively advanced image post-processing programs such as 3D, CAD, fusion, and functional imaging, particularly as many new programs are on the horizon.[18–24] Effective integration requires critical II radiologist skills. The II radiologist can be a visionary to identify useful programs and separate hype from reality.

SYNTHESIS OF IMAGES, CLINICAL DATA, AND KNOWLEDGE DATABASE INTO AN INTERPRETATION

The radiologist synthesizes what he sees on the images, clinical data, and his medical knowledge to produce the interpretation. This should be a cohesive, accurate, helpful discussion that adds value to the images.

Presume the EPE arrives at the station in the approved manner (proper test performed correctly, relevant clinical information easily available), and the workstation is optimized to see the images. The final piece, the medical knowledge database, is expanding in the same fashion as study complexity—seemingly too fast to keep up. MII opportunities to increase the radiologist's knowledge base are myriad,[25–27] and many new options are in development. The II radiologist can help evaluate which to use and how best to implement them. For example, since we installed a STATdx (http://www.amirsys.com) link on all diagnostic workstations in hospitals, clinics, and radiologists' homes, radiologists who use it routinely believe they save significant time everyday, by not having to search for textbooks or articles they need to buttress their own internal knowledge. They also suggest that their reports have improved through more focused and complete differential diagnoses and improved recommendations for patient diagnosis and treatment. Recently, more than one clinician commented on our radiologists' improved clinical relevance because recent reports included clinical pearls shamelessly plagiarized from online information. "Faster, better, cheaper...".

IMAGE REPORT FORMAT

Once the radiologist finishes the interpretation and generates the report, that should be defined as the moment the EPE is ready to move to the next station down the assembly line, and the radiologist is ready to receive the next case.

The report should be in a form such that (a) the station down the line charged with imaging information distribution can perform that task quickly and correctly, and (b) it adds significant value to the imaging study and facilitates fast, correct, and efficient patient treatment. The II radiologist should lead the team charged to develop the radiology report. The report content may be a combination of the radiologist's written interpretation, key images, and references to other images or clinical recommendations.[28–30] Here again, the II radiologist plays a pivotal role because of his depth and breadth of knowledge. The II radiologist is the key person on the team who understands clinical necessities as well as subtleties of key images, potential IHE initiatives, or tools within the PACS, RIS, or EMR that allow information-rich report generation.

A station further down the assembly line should distribute the report, rather than the radiologist. How that station distributes the report is a separate topic. Once the radiologist's report is "attached" to the EPE, the radiologist is ready to focus on the next EPE coming down the line.

SUMMARY

In summary, this paper offers radiologists examples of medical imaging informatics that may benefit them directly, and suggests the value of an imaging informatics radiologist to every radiology group.

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