Customization of Medical Report Data

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Structured reporting offers a number of theoretical advantages, perhaps the most important of which is creation of standardized report databases. The standardized data created can in turn be used to customize data display, report content, historical data retrieval, interpretation analysis, and results communication in both a context and user-specific manner. In addition, these referenceable report databases can be used to facilitate the practice of evidence based medicine, through data-driven meta-analysis and determination of best practice guidelines. This concept will only be realized if the customized data delivery technology provides real and tangible value to end users, accentuates workflow, can be seamlessly integrated into existing information system technologies, and be shown to yield reproducibility of the evidence domain. The time is here for the medical imaging and clinical communities to embrace this vision in order to improve clinical outcomes and patient safety.

KEY WORDS: Structured reporting, data customization, evidence-based medicine, data mining, decision support

INTRODUCTION

Medical data and information systems technologies are similar in that they currently exist in a “one size fits all” form.¹ Both medical reports and the technologies used to create them operate on the premise that the end user must be the one to adapt, resulting in relatively static and inflexible data. The end result is that a great deal of the intrinsic value and functionality within medical information systems goes unused or wasted. If there was a way to adapt medical data delivery to the specific needs and preferences of each individual end user and the context at hand, one could theorize that improvements may result in productivity, workflow, diagnostic accuracy, and clinical outcomes. Unfortunately, this hypothesis cannot be tested because the technology currently available does not exist to carry out this seemingly

logical and simplistic concept. In order to do so, we must understand how medical data and the information systems currently operate, the technical challenges associated with data customization, and the potential clinical and economic gains which can be achieved through successful implementation. This article will discuss the concept and theoretical benefits associated with medical data customization, with an emphasis on the radiology report.

CURRENT STATE OF THE MARKETPLACE

As mentioned in the first article of this reporting series,² the current standard in radiology reporting is the free text report, which has been in existence for over a century, despite the myriad of problems associated with it.^{3,4} Structured reporting has been promoted as a preferable alternative but lacks widespread adoption largely due to technical and workflow concerns.^{5,6} If these could effectively be overcome, a number of theoretical advantages could be realized including standardization of report content, ability to create referenceable report databases, and computerized decision support.^{2,7}

While structured reporting address some of the concerns clinicians have posed regarding report content, organization, and structure; does it go far enough? How do we take into account that there

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are multiple “customer” groups which rely on report data, in addition to clinicians? Perhaps most importantly, are report expectations consistent within each of these stakeholder groups?

The American College of Radiology practice guidelines identifies a list of data elements which should be contained in each radiology report.^{8,9} These include relevant clinical information, study limitations, clinical issues, comparison, likely diagnosis (or differential diagnosis), and additional diagnostic studies or tests for confirmation. In reality, however, few reports outside of mammography consistently contain all of this requisite data. In addition to societal standards, what other catalysts are required to mandate fundamental change in radiology reporting and improve report quality?

While the answer to these questions may seem elusive, perhaps the single best starting point is economic. Simply stated, market forces and financial reimbursements remain the primary driver of change; be it clinical practice, technology innovation, or societal.¹⁰

DEFINING STAKEHOLDER EXPECTATIONS

Several publications have discussed clinicians' expectations in radiology reporting,^{11–13} with several predictable findings. Clinicians want reports that are concise and clear, and devoid of ambiguity. Clinicians also want the findings of greatest significance to be clearly stated in an impression with associated “take home” points including differential diagnosis and follow-up recommendations. Unfortunately, these survey questionnaires were often limited to a single institution and focused on clinicians as a homogeneous population of observers. Clinicians, like their radiologist counterparts are heterogeneous in nature, and as a result often have opinions, biases, and practice patterns different from one another.

These divergent perceptions can be defined according to a number of variables including geography, occupation, education and training, practice type, institutional size and demographics, available technology, and patient population served. In addition, other often-ignored variables may contribute to physician perceptual differences including workload, stress, personality, and technology proclivity. If one was to inquire the

perceived quality of a mammography report to a group of clinicians, one would certainly expect to be given different answers based upon differences in occupation (e.g., family practice versus surgeon), practice type (e.g., academic versus community practice), and institutional demographics (e.g., tertiary care versus small community hospital). At the same time, for a given occupation (e.g., family practitioner), a family practitioner who is fastidious has a relatively light workload, reviews images and report in tandem, and adapts quickly to new information system technology will, in all likelihood, have different expectations in reporting than a counterpart who has an excessive workload with high stress, reviews report impressions in isolation, and is relatively averse to new technology.

If one was to attempt to strategize how to create the “optimal” report for different clinicians, one would have to ascertain what are the common data elements required to meet community standards, what data is essential (and unique) to their specific clinical practice, the manner in which this data is reviewed and assimilated into practice, and how technology can best serve both the individual and collective needs of stakeholders.

The reality is that report data and technology in its present form does not satisfactorily accomplish these challenges. Innovation in both clinical practice and technology development is required to ensure reporting standards are maintained to community standards, while providing a means to customize data delivery in accordance with the often diverging needs of clinician stakeholders.

Before we go on to discuss strategies for innovation, we cannot overlook other stakeholder groups; including administrators, third party payers, IT specialists, and patients.² Each of these groups has different priorities when it comes to report content, delivery, and analysis. While traditionally, the radiology report has focused on the needs and expectations of the clinician group of stakeholders, this is no longer the case. Patients in particular have become a stakeholder group of great importance and are demanding direct access to their radiology reports.^{14,15} One could reasonably surmise that the manner in which report data is communicated to patients (in content, structure, and organization) should be different than report content delivery to clinicians. At the same time, the patient stakeholder group is heterogeneous, and

the vast differences in the patient population must be considered when creating optimal data delivery strategies. Ironically, the one documented area, to date, in which medical data has been customized in accordance with the specific needs of the individual stakeholder is in patient medical education,^{16–18} which can serve as an example for customized data delivery in reporting. While these studies have shown customized medical information is more effective than generic information, a primary challenge is automating end-user customization. Computerized systems have been developed aiming at delivery of customized medical information to both patients and clinicians.^{19,20}

The respective report priorities of the administrator, IT, and payer groups are primarily focused on compliance with standards, data integration, and outcomes analysis. For these stakeholder groups, individual report customization is less important than collective data customization and analysis. For these stakeholders, creation of a standardized and referenceable database is a high priority. From this database, customized data mining and analytics can be extracted in accordance with each individual stakeholders needs. As an example, an administrator might want to identify all report outliers which did not conform to institutional standards (e.g., mammography reports without Breast Imaging Reporting and Data System (BIRADS) codes), while another administrator may want to identify reports with improper billing code data. The common denominator in all cases is the ability to record comprehensive report data in a standardized format for the purposes of customizable individual and collective data analysis.

CUSTOMIZING REPORT DATA

Before we can discuss strategies to customize data, we must first address two fundamental requirements. The first requirement is the creation of content standardization, which allows for the core data to be recorded in a standardized fashion and from which the various customization schemas can be created. Creation of standardized content is one of the principle components of structured reporting, which maps data to a standardized lexicon, thereby eliminating the problem with redundancy and synonyms. Many radiologists

complain that existing structured reporting systems constrain their language and ability to communicate complex ideas. As a result, some structured reporting systems have created an option to incorporate free text, which can serve as a deterrent to data standardization. If data customization and mining are to become a reality, data standardization is an absolute prerequisite. The immediate challenge is for structured reporting technologies to create an acceptable method for standardizing data output, without adversely affecting workflow and expression.

The second requirement is the creation of a stakeholder profile, which stores the customization requirements for each individual stakeholder. This is highly flexible and can be modified at any time to reflect changing preferences on the part of each individual stakeholder. The customization schema can be exportable so that one end user can replace his/her customization schema with that of a colleague. In addition, customized default templates could be created to serve as a starting point for new end users, based upon analysis of customization schemas of peers with similar profiles.

If our goal is to create a mechanism for customizing data, we must identify the various processes which will be involved in the customization process (Table 1), which include data display, content, retrieval, analysis, and communication.

Data display is by far the simplest process to customize for it is largely cosmetic in nature. Once standardized content has been created, it is relatively simple to customize the manner in which the data is displayed and can be easily customized to a given individual preference. Table 2 illustrates four different data display templates for a mammography report, which contains three “positive” findings, two of which are unchanged on serial exams, and one of which is new. In addition to the manner in which this data is presented, customized filters can be created which display only those data elements which meet pre-defined criteria. In this example, a clinician (e.g., surgeon) has requested

Table 1. Data Customization Processes

1. Display
2. Content
3. Retrieval
4. Analysis
5. Communication

clinically insignificant report data (equivalent to a BIRADS 2) be filtered from the display. The clinician would have the option of reviewing all unfiltered report data at any time, but the default presentation state would be determined by the individual end-user's predefined customized filters.

The same concept can be applied to report data and corresponding images. While many clinicians prefer to review report data in the absence of the corresponding imaging data, some clinicians prefer to review both datasets in tandem. In the current practice environment, most Picture Archiving and Communications Systems (PACS) vendors support the storage of "key" images, consisting of images containing important findings contained within the text report. These images are often annotated to graphically correlate imaging and report findings. This annotation and image mark-up is currently becoming a standardized process, through the AIM initiative of the National Cancer Institute.²¹

The ability to customize data presentation in accordance with an individual end-user's profile is a flexible process, and can be altered in accordance with the clinical context of report data. As an example, the same surgeon whose customization profile calls for selective filtering of mammography reporting to only display clinically significant findings, may place a restriction on those mammograms with prior breast surgery and/or radiation therapy. In those circumstances, the surgeon may request that all findings be displayed in the report, including those reported as low clinical significance and unchanged on sequential exams. This illustrates an important concept, in that an individual end-user's customization schema can be dynamic in nature and change in accordance to the clinical context, modality, anatomy, and pathology.

The next opportunity for data customization is content, which is particularly relevant given the shift in medical opinion towards supplying patients with medical reports.^{14,15} To date, mammography is the only mandated area within radiology which requires mammography providers to provide patients with report data through MQSA,²² and this will in all probability extend into other areas of radiology in the near future.²³

In their existing form, radiology reports are often perceived as somewhat confusing and ambiguous by the clinical community. Given the marked disparity in education and training between the clinical and lay communities, one would expect customized report

content for clinicians and patients to be quite different. Patient educational programs have already been used to customize content in accordance with the individual patient profile; resulting in enhanced patient understanding and satisfaction. In their existing forms, radiology reports are often seen as confusing and ambiguous to clinicians,^{24,25} who have advanced medical education and training. One would certainly not expect the same report given to a physician would be optimal for the patient population. In order to address this disparity in medical knowledge, the only viable solution would be to modify report content commensurate with patient medical understanding, and this should again take into account educational differences within the heterogeneous population of the lay community. Patient educational programs have been already used which customize content in accordance with individual patient profile, and the same approach would, in all likelihood, enhance patient understanding and satisfaction.

If we were to take the previous mammography report example cited in Table 2, we could explore potential ways in which report content could be customized to the patient. Perhaps the easiest way to accomplish this goal would be the addition of supplemental content to explain the various findings and recommendations described in the report. For the most significant finding of new microcalcifications prompting the recommendation for biopsy, a brief descriptor can be added to the report, describing the relationship between microcalcifications and breast cancer. In creating such a descriptor, a number of options can be inserted in accordance with the patient profile. This profile can be determined through a number of data sources including a patient questionnaire, data supplied by the referring clinician, and technologist feedback. Table 3 provides three representative examples of "suspicious microcalcifications" descriptors, which could be automatically incorporated into the patient report version by inputting the patient profile classification and finding. A computerized repository could then retrieve the appropriate content descriptor and insert that into the patient report.

Customizing content for clinicians might take a slightly different approach. If one had a firsthand knowledge of each clinician, supplemented by a computerized profile, content specific to each individual clinician could be incorporated into the report. While not an impossible task, this approach

Table 2. Different Versions of Report Presentation for Mammography

Report A: Conventional Free Text (Prose) Report	Report B: Anatomical Structured Text (data classified according to anatomic location)	Report C: Hierarchical Structured Text (data classified in order of clinical importance)	Report D: Sequential Structured Text (data classified according to interval change)
<p>Comparison is made with multiple prior studies, the most recently dated 06/17/08. The breasts remain heterogeneously dense, with prominent fibroglandular elements. Again noted are multiple bilateral vascular macro-calcifications, which have not significantly changed from the prior examination. These are benign in nature and do not require additional evaluation, other than routine yearly mammographic follow-up.</p> <p>There has been subtle interval increase in number of indeterminate micro-calcifications at the 6 o'clock position of the left breast. Based upon this interval change in number, biopsy would be recommended for definitive tissue diagnosis. Numerous bilateral breast cysts are also identified, which have demonstrated interval change over several sequential mammographic and ultrasound exams. Based upon the chronicity of these findings and benign appearance, no further evaluation is deemed necessary at this time.</p> <p>No dominant mass, architectural distortion, or focal asymmetry is identified within either breast at this time.</p> <p>Impression:</p> <ol style="list-style-type: none"> 1. Benign appearing macro-calcifications and bilateral breast cysts. 2. Interval increase in number of indeterminate micro-calcifications, at the 6 o'clock position of the left breast. Biopsy is recommended for definitive evaluation. <p>BIRADS: Category 4</p>	<p>Comparison studies: 06/17/08 Mammogram</p> <p>Overall Breast Density: Heterogeneously dense</p> <p>Left Breast:</p> <ul style="list-style-type: none"> -Macro-calcifications (BIRADS 2) Benign, bilateral, vascular -Micro-calcifications (BIRADS 4) Indeterminate, focal, 6 o'clock, increase in number, Biopsy recommended -Cysts (BIRADS 2) Benign, bilateral, variable interval change, no follow-up required <p>Right Breast:</p> <ul style="list-style-type: none"> -Macro-calcifications (BIRADS 2) Benign, bilateral, vascular etiology -Cysts (BIRADS 2) Benign, bilateral, variable interval change, no follow-up required <p>Negative Findings:</p> <ul style="list-style-type: none"> -Architectural distortion -Mass -Focal asymmetry <p>Global BIRADS: 4</p> <p>Left Breast BIRADS: 4</p> <p>Right Breast BIRADS: 2</p>	<p>Comparison studies: 06/17/08</p> <p>Mammogram</p> <p>Overall Breast Density:</p> <ul style="list-style-type: none"> Heterogeneously dense Positive Findings: -Micro-calcifications (BIRADS 4) Left breast, 6 o'clock (focal) Interval increase in number Indeterminate Biopsy recommended -Macro-calcifications (BIRADS 2) Bilateral, diffuse Stable, no interval change Vascular, benign No follow-up required -Cysts (BIRADS 2) Bilateral Multiple Interval change variable Benign No follow-up required <p>Negative Findings:</p> <ul style="list-style-type: none"> -Macro-calcifications (BIRADS 2) Bilateral, diffuse Stable, no interval change Vascular, benign No follow-up required <p>Negative Findings:</p> <ul style="list-style-type: none"> -Architectural distortion -Mass -Focal asymmetry <p>Global BIRADS: 4</p>	<p>Comparison studies: 06/17/08</p> <p>Mammogram</p> <p>Overall Breast Density:</p> <ul style="list-style-type: none"> Heterogeneously dense Significant Interval Change: -Micro-calcifications (BIRADS 4) Left breast, 6 o'clock (focal) Interval increase in number Indeterminate Biopsy recommended Insufficient Interval Change: -Cysts (BIRADS 2) Bilateral Multiple Interval change variable Benign No follow-up required <p>Negative Findings:</p> <ul style="list-style-type: none"> -Macro-calcifications (BIRADS 2) Bilateral, diffuse Stable, no interval change Vascular, benign No follow-up required <p>Negative Findings:</p> <ul style="list-style-type: none"> -Architectural distortion -Mass -Focal asymmetry <p>Global BIRADS: 4</p>

Table 3. Content Variations for Patient Mammography Report (Micro-calcifications)

Version A

Microcalcifications are tiny bits of calcium which can appear within breast tissue and visible on your mammogram. They may or may not be associated with breast cancer; and may result in further evaluation with an additional mammogram, ultrasound, or biopsy

Version B

Microcalcifications are tiny bits of calcium, which can uncommonly be associated with breast cancer. The determination of breast cancer risk often depends upon the size, shape, and distribution of calcifications. Scattered microcalcifications are usually a sign of benign breast tissue, while tightly clustered microcalcifications may be a sign of early breast cancer. Depending upon the physician's degree of concern, additional testing may be recommended; which can include additional mammogram images, ultrasound, or biopsy. In lower risk cases, a follow-up mammogram in 4-6 months may be recommended to assure interval stability

Version C

Microcalcifications are tiny bits of calcium within breast tissue, which can in the minority of cases be an early sign of breast cancer. Characteristics of concern include those microcalcifications which are new, tightly clustered, and irregular in size or shape. Of all microcalcifications, 80% are benign, and when malignant often represent an early and treatable form of breast cancer called ductal carcinoma in situ (DCIS). Suspicious microcalcifications will often undergo biopsy for pathologic diagnosis

has a number of drawbacks, the most important of which would be workflow related. In the current practice environment, radiologists operate under extreme time constraints and stress,^{26,27} and creation of additional time-intensive workflow steps may not be well received. An alternative approach may be to have the clinician prospectively provide input as to how he/she would want report content customized. This clinician-specific data request could either be incorporated into the individual exam order or a part of each clinician's profile, which is stored in the Radiology Information System (RIS)/PACS databases. The information would be presented to the radiologist at the time of interpretation, and he/she would have the option of incorporating the requested data into the report. As an example, a family practitioner may request that all mammography findings include a descriptor of clinical significance for all findings (i.e., finding-specific BIRADS). A breast surgeon may request that all "micro-calcifications" have associated descriptors for morphology and

distribution. The incorporation of these data should not have a significant detrimental impact on radiologist workflow and one could argue should be a requisite part of reporting. The end result is to improve report quality (in both objective and subjective terms), which can also be used as a marketing tool to enhance referrals.

The next step in customization is the process of data retrieval, which is an integral and necessary step in medical image interpretation. If we return to our mammography example, radiologists must review prior imaging and report data in assessing the chronicity and clinical significance of current exam findings. A finding which has remained stable over a 5-year period would in all likelihood be considered to be benign and of low clinical significance, whereas a finding which has progressed in size or number over a 2-year period be considered suspicious for malignancy. In the current workflow paradigm, data retrieval and review can be cumbersome, timely, and fatiguing. A radiologist is often tasked with manually selecting individual reports from the historical imaging folder of the patient and reading each individual report to search for relevant data. Radiologists often take short cuts by limiting their search to the report impression and/or BIRADS codes, but this is often insufficient when having to compare a specific finding on the current exam with prior studies. Since reporting systems do not customarily link report and imaging findings, an additional step is required for the radiologist to review the images associated with the text report data. All in all, this is can be extremely time consuming, which adds to considerable frustration on the part of the radiologist. Some radiologists respond by taking short cuts and limiting the time and effort spent in reviewing historical data, which has the potential to adversely affect interpretation accuracy and clinical outcomes. These same challenges in data retrieval are not exclusive to radiologists and are experienced by all physicians who review imaging and report data in detail.

Customizing both context and user-specific data retrieval has the potential to improve existing workflow and interpretation challenges. Suppose, for example, we were to construct a graphical timeline in which all breast imaging studies were incorporated (Table 4). This timeline would be chronological in nature and have the ability to integrate alternative non-textual data;

Table 4. Imaging Timeline with Data Extraction Through Filtering

Date	Modality	Anatomy	Findings	Clinical significance	Interval change	Follow-up recommendations
10/11/05	CT	Brain	Small vessel disease	Low		None
12/15/05	Mammography	Breasts (bilateral)	1. Microcalcs. (left)	1. Low		1. None
			2. Mass (Left)	2. Uncertain		2. US
1/07/06	Ultrasound	Breast (left)	2. Cyst	2. Low		Mammo in 6 months
1/07/06	Ultrasound	Pelvis	Fibroids	Low		None
6/16/06	Mammography	Breast (left)	1. Microcalcs	1. Low	1. None	1. None
			2. Cyst	2. Cyst	2. ↓	2. None
10/15/06	CT	Chest	1. Cardiomegaly	1. Low		1. None
			2. Interstitial disease (bilateral)	2. Uncertain		2. CT in 3 months
12/10/06	Mammography	Breasts (bilateral)	1. Microcalcs. (left)	1. Low	1. None	1. None
			2. Cyst (left)	2. Low	2. Resolved	2. None
			3. Microcalcs (right)	3. High	3. New	3. Biopsy
1/14/07	Interventional	Breast (right)	Biopsy microcalcs	High	New	Pathology
1/22/07	Ultrasound	Pelvis	Fibroids	Low	None	None
03/21/07	MRI	Brain	Small vessel disease	Low	None	None
08/14/07	Mammography	Breast (right)	Microcalcs (DCIS)	High	Resolved	Mammo in 6 months
02/10/08	Mammography	Breast (bilateral)	1. Microcalcs (left)	1. Low	1. None	1. None
			2. Mass (left)	2. Uncertain	2. New	2. US
			3. Microcalcs (right)	3. High	3. Resolved	3. Mammo 12 months
02/17/08	Ultrasound	Breast (left)	2. Cyst	Low	New	US 12 months
02/14/09	Mammography	Breast (bilateral)	1. Microcalcs (left)	1. Low	1. None	1. None
02/14/09	Ultrasound	Breast (left)	2. Cyst	Low	Resolved	None
02/15/10	Mammography	Breast (bilateral)	1. Microcalcs (left)	Low	None	None

Imaging timeline with data extraction through filtering of follow-up recommendations^a

Date	Modality	Anatomy	Findings	Clinical significance	Interval change	Follow-up recommendations
12/15/05	Mammography	Breasts (bilateral)	2. Mass (left)	2. Uncertain		2. US
1/07/06	Ultrasound	Breast (left)	2. Cyst	2. Low		Mammo in 6 months
10/15/06	CT	Chest	2. Interstitial disease (bilateral)	2. Uncertain		2. CT in 3 months
12/10/06	Mammography	Breasts (bilateral)	3. Microcalcs (right)	3. High	3. New	3. Biopsy
08/14/07	Mammography	Breast (right)	Microcalcs (DCIS)	High	Resolved	Mammo in 6 months
02/10/08	Mammography	Breast (bilateral)	2. Mass (left)	2. Uncertain	2. New	2. US
			3. Microcalcs (right)	3. High	3. Resolved	3. Mammo 12 months
02/17/08	Ultrasound	Breast (left)	2. Cyst	Low	New	US 12 months

Imaging timeline with data extraction through filtering of finding (e.g., microcalcifications)^a

Date	Modality	Anatomy	Findings	Clinical significance	Interval change	Follow-up recommendations
12/15/05	Mammography	Breasts (bilateral)	1. Microcalcs. (left)	1. Low		1. None
6/16/06	Mammography	Breast (left)	1. Microcalcs	1. Low	1. None	1. None
12/10/06	Mammography	Breasts (bilateral)	1. Microcalcs. (left)	1. Low	1. None	1. None
			3. Microcalcs (right)	3. High	3. New	3. Biopsy
1/14/07	Interventional	Breast (right)	Biopsy Microcalcs	High	New	Pathology
08/14/07	Mammography	Breast (right)	Microcalcs (DCIS)	High	Resolved	Mammo in 6 months
02/10/08	Mammography	Breast (bilateral)	1. Microcalcs (left)	1. Low	1. None	1. None
			3. Microcalcs (right)	3. High	3. Resolved	3. Mammo 12 months
02/14/09	Mammography	Breast (bilateral)	1. Microcalcs (left)	1. Low	1. None	1. None
02/15/10	Mammography	Breast (bilateral)	1. Microcalcs (left)	Low	None	None

Table 4. (continued)

Imaging timeline with data extraction through filtering of clinical significance (e.g., high) ^a						
Date	Modality	Anatomy	Findings	Clinical significance	Interval change	Follow-up recommendations
12/10/06	Mammography	Breasts (bilateral)	3. Microcalcs (right)	3. High	3. New	3. Biopsy
1/14/07	Interventional	Breast (right)	Biopsy microcalcs	High	New	Pathology
08/14/07	Mammography	Breast (right)	Microcalcs (DCIS)	High	Resolved	Mammo in 6 months
02/10/08	Mammography	Breast (bilateral)	3. Microcalcs (right)	3. High	3. Resolved	3. Mammo 12 months

Structured data input can be used to create a database from which report data can be prospectively mined, in accordance with the individual end-user's preferences

^aEnd user selects the filtering variable and the subsequent data is automatically extracted from the master folder for review. The filters can be created based on any of the subject headings, with the ability to customize data presentation states

such as color coding, graphics, and symbols tied to pre-defined data elements. As an example, symbols can be applied to radiologic findings and have superimposed graphics (e.g. color) to indicate clinical significance, temporal change, or follow-up recommendations.

If one was to link these report and imaging data, then a radiologist could quickly and intuitively identify prior findings of interest and retrieve the corresponding image by activating the symbol (finding) of interest.

If a finding from one study was "linked" with a finding from another study (i.e., serial representations of a single finding), the activation function would provide for an automated presentation of sequential imaging and report data. This would provide a fast and intuitive method for retrieving historical context-specific imaging data.

If we were to add a user-specific customization feature, this could potentially improve individual workflow and performance further. This data retrieval customization feature could be automatically integrated based upon each individual user's profile or be manually selected. In the manual version, the radiologist could input the desired method of data retrieval organization and filtering (e.g., pick list menu or activating the data element of interest in the graphical timeline). If the radiologist was to select the "finding" function, all historical imaging data would be presented according to "findings". If the radiologist was to select "anatomy" function, all historical imaging data would be organized according to anatomy. If the radiologist selected the "modality" function, historical imaging data would be sorted according to modality.

The radiologist could go one step further and combine the search by combining "finding" with "anatomy". In this example, the radiologist is

interested in the anatomic region "breast", and the finding "micro-calcifications". Based upon these data inputs, the database would retrieve only those reports/images which matched the search request and present the radiologist with those corresponding reports. An important distinction needs to be made to illustrate the functionality of such a system. Firstly, the search must be able to accurately distinguish between reports which contain "positive" and "negative" findings. One does not want a report which states "no micro-calcifications present" to be retrieved alongside a report which states "micro-calcifications present".

In the automated version of customized data retrieval, the radiologist may elect to have a preferred list of retrieval functions incorporated into his/her profile. In this automated version, the radiologist may request that all mammography interpretations be accompanied by an historical exam retrieval limited to a single modality (mammography) and be initially presented based upon BIRADS codes. In this manner, all prior mammogram reports would be recorded on the timeline in accordance with report BIRADS code alone. Another customized option may call for responsive data mining, where each time a radiologist inputs a finding in the current report, the database would retrieve historical reports and images with the same reported finding. This finding-specific automated data retrieval could be performed in accordance with general concepts (e.g. micro-calcifications), or detailed concepts (e.g. pleomorphic micro-calcifications). A radiologist could even "edit out" certain reports from the query, examples including reports from a specific radiologist or all BIRADS 2 reports. The advantages of such a customized data retrieval process expand as one increase the number of modalities, anatomic

regions, and exams of record (e.g., oncology patients). The same customized data retrieval process can be applied to report data outside of medical imaging and include pathology, laboratory, and other clinical reports.

In order to discuss data customization in the analytical process, we must discuss the review the tenets of evidence-based medicine (EBM), which has been defined as “the conscientious, explicit, and judicious use of current best evidence in making decisions about patient care. The practice of EBM integrates individual clinical expertise with the best available clinical evidence from systematic research”.²⁸

While the doctrine of EBM has been widely accepted as the standard of medical practice, its use in everyday practice remains somewhat elusive; largely due to incomplete and limited access to standardized medical data. This is especially the case for radiology, where the practice of free text reporting has precluded the development of referenceable databases, a necessary prerequisite for the development and refinement of EBM guidelines.²⁹

If and when standardized radiology report databases are created, the next step is determining how these databases can be effectively integrated into clinical practice. The integration of structured data and decision support technologies into information system technologies (e.g., RIS, PACS, EMR) has the potential to improve clinical performance, narrow gaps between knowledge and practice, and improve patient safety.^{30,31} In order to successfully implement computerized decision support within the radiology domain a number of challenges exist including end-user acceptance, workflow optimization, technology integration and interoperability, and reproducibility of the evidence domain.^{32–34}

One example where computerized, data-driven decision support has been implemented within the radiology practice to date is in computerized physician order entry (CPOE), which utilizes standardized data to create best practice guidelines and assist in physician ordering of radiology exams. The goal of CPOE is to improve clinical outcomes through enhanced diagnosis, patient safety, and cost-efficacy. One of the problems which currently exist with CPOE and other computerized decision support systems (e.g., drug decision support), is the generic nature in which these systems operate³⁵ and the relative inflexibility of the technology.¹ Customization of the

data analysis in accordance with the unique needs and expectations of the individual end user has the potential to improve end-user acceptance and clinical care improvement.

The input of structured report data linked to an ontology and a structured report database provides a mechanism for automated, real-time decision support at the time of image interpretation. As an example, a radiologist interpreting a mammogram with new micro-calcifications wants to query the database as to the likelihood of malignancy. In addition to the structured input data “micro-calcifications”, the radiologist has also recorded additional descriptors “new” and “pleomorphic”. Based upon this input data, the database will identify all cases with similar structured input data and correlate the clinical outcome of these cases (based upon clinical follow-up and biopsy results) in order to determine a malignant probability statistic. While such a query may be of minimal value within a single institutional database due to the relatively small size statistical sample, combining structured databases from multiple institutions could create a much larger sample size for meta-analysis. If we were to further “customize” the analysis by correlating the patient’s genetic data with those of a comparable peer reference group, we could obtain a malignant probability statistic of greater accuracy. The analysis would be customized to the individual radiologist, based upon the input data and requested query. The output would be data-driven, in accordance with the breadth and depth of the structured database.

Another example would be a family practice physician who has received a report on a patient’s brain magnetic resonance imaging (MRI), which described a 2.5 cm cerebellar mass, suspicious for malignancy. In the radiology report, a differential diagnosis was not given and the physician would like to obtain this information prior to determining the next course of action. The physician retrieves the radiology report and generates a query for differential diagnosis, based upon the input data provided in the radiology report. The computerized decision support program may prompt the physician for additional data to improve analysis, which was not contained in the radiology report:

1. What is the extent of edema associated with the mass?
2. What is the specific anatomic location of the mass?

3. Is contrast enhancement present?
4. What is the age and gender of the patient?
5. Is the mass uniformly solid?
6. Is calcification or cystic component present?

Since the family practice physician is not well versed in interpreting brain MRI images, he/she cannot answer the imaging associated questions, but can respond to the age and gender of the patient. In doing so, the computer-derived differential diagnosis is more accurate, and this is reflected by probability statistics associated with the data provided. The family practice physician may request a report addendum by the interpreting radiologist to address these additional imaging questions posed by the computerized decision support system. This information is recorded into the report database and an updated differential diagnosis is automatically sent to the family practice physician notifying him/her of the refined differential diagnosis upon receipt of additional input data.

While the described customized data analysis is driven by manual input, a preferred method would be that of an automated clinical decision support system. Ideally, computerized decision support systems should be able to anticipate both latent and obvious needs of the end users. This could be the result of prior end-users workflow (through an electronic auditing tool) and the individual end-user's profile. In the case of the described brain MRI—the presence of a specific finding (mass), size (2.5 cm), anatomic location (brain, cerebellum) and modality (MRI)—should automatically trigger a computer-derived differential diagnosis as an obvious need. A latent need for this case may be the recommendation of contrast to evaluate enhancement, which is accompanied by the patient's renal status and prior contrast administration history. As each individual end-user's interactions with the decision support feature are recorded over time, a customized profile would be created to assist in the automation process. In addition, the decision support database could identify data analytics provided to peer reference groups, to provide automated prompts at the point of care.

The last area where data customization can be incorporated into the report database is in report communication. In the current practice environment, standards exist for critical results communication³⁶; which is entirely based upon specific

findings. An alternative to this approach would be the creation of customized data delivery based upon content, context, and user specificity.

In the previously described section on content customization, an example was given where a physician could request that each "positive" report finding be accompanied by a descriptor of clinical significance and/or follow-up recommendation. The physician's profile indicated that whenever a pre-defined clinical significance threshold has been achieved (e.g., high clinical significance, biopsy recommended), direct communication is requested. Upon recognition of such an instance, the computer automatically initiates a critical communication pathway. This would consist of physician notification, receipt verification, and tracking of clinical action. These data could be recorded into the communication databases of the patient, radiologist, and referring clinician to ensure compliance and appropriate actions.

CONCLUSION

Structured reporting offers a number of theoretical advantages, perhaps the most important of which is creation of standardized report databases. The standardized data created in report databases can in turn be used to customize data display, report content, historical data retrieval, interpretation analysis, and results communication in both a context and user-specific manner. In addition, these referenceable report databases can be used to facilitate the practice of EBM, through data-driven meta-analysis and determination of best practice guidelines. This concept will only be realized if the customized data delivery technology provides real and tangible value to end users, accentuates workflow, can be seamlessly integrated into existing information system technologies, and be shown to yield reproducibility of the evidence domain. The time is here for the medical imaging and clinical communities to embrace this vision in order to improve clinical outcomes and patient safety.

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