

The Clinical Imperative of Medical Imaging Informatics

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Evidence-based medicine (EBM) has been defined as the process of systematically finding, appraising, and incorporating contemporary research findings into clinical decision making. The concept and name were first formally introduced by Gordon Guyatt¹ and colleagues from the McMaster University in Ontario, Canada, in 1991. The principle goal of EBM is to provide a conscientious scientific basis for clinical decision making. In doing so, EBM serves as a methodological strategy to streamline and objectify the decision-making process. EBM serves to integrate clinical experience with the best available scientific data, available through the peer-reviewed scientific literature, databases, and clinical trials.

The pooled data and knowledge offered through medical informatics and its supporting technologies provide the infrastructure to facilitate evidence-based radiology (EBR), which, in theory, leads to improved clinical outcomes. In its present form, however, EBR focuses almost exclusively on the radiology report and imaging diagnosis. By doing so, however, many of the essential steps in the imaging chain are largely ignored—steps that ultimately affect the quality of imaging services and clinical outcomes. Examples of some of these quality indicators, and the corresponding steps and technologies are listed in Table 1.

These individual, stepwise, quality-oriented metrics form the collective basis of outcomes analysis within radiology by acknowledging that the collective radiology product is a sum total of multiple steps, performed by multiple individuals, using multiple technologies. The various data elements attributed to each individual step in the collective imaging chain create the ability to use medical informatics to objectively analyze performance deliverables and differentiate medical im-

aging service providers in data-driven qualitative and quantitative terms.

This data-driven, quality-oriented analysis is crucial to the long-term survival of medical imaging, where the trend toward commoditization is accelerating because of globalization, increased information exchange, and technological developments.² The same evolutionary technology forces that have improved radiology productivity and workflow have also accentuated this commoditization trend through the widespread adoption of teleradiology and universal information technology (IT) standards (such as HL-7, IHE, and DICOM).

When products or services are perceived to be supplied equally well by multiple providers, then those products or services become a commodity, and price becomes the driving factor in determining supplier selection. This is slowly becoming a reality within the population of medical imaging consumers. Qualitative differentiation is the best solution to avoid commoditization, so that the service offering is distinguished from that of competitors through enhanced performance measures (i.e., added value service).³

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Table 1. Quality Indicators throughout the Imaging Chain

Quality metric	Imaging chain step	Supporting technologies	Outcomes measures
Image quality	Image acquisition and processing	Imaging modality, QA workstation	Interpretation accuracy diagnostic level of confidence
Patient safety	Exam and protocol selection	RIS, EMR	Radiation dose exposures contrast reactions
Operational efficiency	Exam scheduling and performance	CPOE, Modality, RIS	Scheduling backlog time to initiate clinical management
Communication efficacy	Reporting	RIS, PACS	Communication of critical results follow-up recommendations clinical significance of findings

Technology has improved operational efficiency within radiology practice and has also facilitated access to imaging studies by radiologists who are located outside the local healthcare environment. The widespread use of teleradiology for primary or secondary interpretation has become a contributing factor toward the perception of a lack of difference in quality of care among different radiology providers. This has resulted in acceptance of commoditization in diagnostic imaging, which has, in turn, made it more difficult for groups that provide higher quality service to successfully compete for contracts. Medical informatics provides the mechanism to track, store, analyze, and report quality performance indicators intrinsic to radiology practice, thereby providing an objective mechanism for providers to differentiate themselves based on quality metrics.

OBJECTIVES OF RADIOLOGY DATA MINING

The primary objectives of data mining are to objectify, quantify, stratify, clarify, and rectify.

Objectification and quantification refer to replacement of subjective assessments with objective and quantifiable measures that can be tracked and analyzed for performance measurement. Image quality, for example, is most often assessed by subjective analysis, taking the form of a “beauty contest” in which medical images are judged by their aesthetic appearance. In reality, this assessment may have little to do with an image’s intrinsic diagnostic value. A higher resolution chest computed tomography (CT) image may appear to be “grainier” and less attractive, yet, in actuality, may facilitate higher diagnostic accuracy in detection of certain types of pathology (e.g., lung nodules).

Stratification refers to the ability to dissect the comprehensive dataset into multiple components, creating the ability to identify confounding variables and perform comparative analysis based on common variables. For example, it would be inaccurate to compare the interpretation strategies of radiologists from different institutions without allowing for differences in technologies used, training and experience levels, and institutional/patient demographics. If, in this example, we were to analyze the interpretation accuracies for radiologists for chest CT angiography in the detection of pulmonary emboli, we must take into account differences in acquisition and image processing technologies (e.g., CT scanners, advanced visualization workstations), radiologist training and experience (e.g., subspecialty trained thoracic versus general radiologists), and institutional demographics (e.g., tertiary care, academic facility versus small community hospital).

Once the data have been objectified and quantified (in a standardized fashion) and then stratified according to various dependent and independent variables, the next step is clarification. This refers to the actual analysis of the data. If the data have been recorded in a standardized fashion, then co-mingling or pooling of data from multiple datasets could result in a combined dataset (meta-analysis), which in turn could result in improved accurate statistical analysis. If, in our previous example, we wanted to compare interpretation accuracy for general radiologists using a specific type of CT scanner and multiplanar reformation workstation, we could not accurately do so without the ability to pool multiple datasets from a large number of imaging providers to ensure that the analysis has a sufficient sample size to generate statistical significance.

The last (and perhaps most important) objective of data mining is to take the information gained and utilize it to create effective solutions to address documented deficiencies. A relevant example would be mammography computer-aided detection, which was created to address inter-radiologist variability in breast cancer detection. By creating large image databases of biopsy-proven breast cancer cases and associated metadata, computer algorithms were developed to assist radiologists in the detection of breast masses, architectural distortion, and calcifications, all of which are common mammographic features associated with breast cancer. Another example of a way in which the medical imaging database can be used to create computerized decision support technologies is in radiation dose optimization and image quality. If a database contains the acquisition parameters used for large numbers of digital radiographic exams (e.g., portable chest radiographs), then it can be prospectively mined to determine the acquisition parameters (for a given patient size and clinical condition) associated with the highest image quality scores. These, in turn, can be presented to the technologist as default acquisition parameters at the time the examination is performed. If, on the other hand, a patient is having the same exam (portable chest radiograph) 60 min after completion of a previous radiographic exam for the purpose of line detection, the referring clinician may request that the exam be optimized to reduce radiation exposure. In this scenario, the database can be referenced to determine the acquisition parameters that maximize dose reduction while maintaining the predefined threshold level of image quality. In addition, the computer can

present the technologist/radiologist with the specific image processing algorithm for that given exam type, patient body habitus, and clinical indication (e.g., line placement).

CONCLUSION

The common thread is that data begets data and, if used properly and prospectively, can serve as a valuable tool to improve clinical practice, elevate the quality of care, and differentiate service providers based on objective performance measures. This need not be a punitive exercise but can instead be used to point out existing deficiencies and provide an objective means to enhance ongoing education and training initiatives while promoting data-driven new technology development. In the end, it is not essential that practicing radiologists understand the intricacies of medical informatics. What is important is that they realize the intrinsic value of objective data to enhance everyday clinical practice and use this to prevent their own medical specialty from becoming a commodity, devoid of objective, quality-oriented performance measures.

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