Technology standards form the basis for clinical workflow in radiology. This article reviews 3 types of standards relevant for radiology: the DICOM standard for handling images; the Health Level 7 standard for communicating with the health care enterprise; and standards in coding and terminology such as International Classification of Diseases, Current Procedural Terminology, and RadLex. This third category has an impact on radiology reporting and practice management. Familiarity with all these standards can help radiologists optimize operations and plan for the future.

Key Words: DICOM, lexicon, ontology, medical coding

OVERVIEW
Technology standards serve as the basis for interoperability between imaging-related systems and across the health care enterprise. Thus, they are critical to a radiology department’s clinical workflow. Although the technical details of how these standards are set up and function is not of key importance for most radiologists, an informed perspective on the role of standards is critical to planning equipment purchases, managing relationships with hospital IT departments, optimizing imaging workflow, and developing strategies in the era of meaningful use of health IT. In addition, an understanding of the evolution and trends in standards development efforts will help radiologists prepare for future innovations in the practice of radiology. This article aims to provide a clinically oriented overview of relevant technology standards in imaging.

DICOM
Background
DICOM is a standard for the transmission, storage, and display of medical images [1-5]. DICOM has its roots in the early 1980s, when the clinical importance of digital medical imaging modalities was rapidly increasing. That time period was also one of widespread innovation in computer technologies, characterized by many competing proprietary products and designs. Although this proliferation ultimately culminated in many watershed technologies, such as the personal computer and graphical user interfaces, the lack of standards complicated the task of interconnecting equipment.

Within this environment, the ACR and the National Electrical Manufacturers Association (NEMA) began a collaboration in 1983 to define standards for the handling of digital medical imaging data. This collaboration initially produced ACR-NEMA 1.0 in 1985. The standard included a hardware-level network protocol specification (ie, a description of the physical cabling and electrical signals to be used in connecting 2 devices), an indicator of the technical challenges at that time [6]. The ACR-NEMA standard was renamed DICOM in 1993. Over time, certain portions of DICOM have been superseded by broader industry standards; other portions have been elaborated and refined. The DICOM committee has maintained its focus on facilitating the handling of medical imaging data, and the standard has broadened to address many emerging technology trends. The DICOM standard now represents the collective body of work of hundreds of medical and technical experts, performed over the course of many years, with participation from vendors, professional societies, government organizations, and other interested parties.

Today, DICOM is the universal standard for communications between medical imaging devices and applications. As such, DICOM constitutes the lingua franca for interoperability of medical imaging equipment. The ability of radiology departments to coordinate the use of many systems of varying ages from a wide range of manufacturers is due in large part to the DICOM standard.
However, although DICOM defines standard mechanisms for data interchange and handling, there are several things that DICOM is not. First, DICOM is not an implementation of the standard; there is no “official” piece of DICOM equipment or software. DICOM does not provide for enforcement of the standard, and no central body certifies DICOM compliance of imaging equipment. Rather, the onus is on equipment purchasers to understand what DICOM functionality they require and to determine whether specific pieces of equipment support that functionality. Vendor DICOM conformance statements provide the basis for making these assessments. Finally, DICOM does not specify the ways in which its mechanisms are used. For example, although DICOM allows for the use of various image-compression techniques, no one specific technique, or any compression at all, is required for a particular type of image transaction.

Technical Details and Practical Implications
The DICOM standard is continuously evolving, and updates to the standard are released periodically. As of this writing, the most recent release was in 2011. Each DICOM release consists of a series of documents, or “Parts,” each detailing a specific portion of the standard. In addition, corrections and supplements to a release may be published. The full set of documents defining the current DICOM standard is hosted by NEMA on its website [7] and may be accessed free of charge. To date, DICOM has 20 parts, which address a wide range of topics including the DICOM information model, network communications protocols, portable media, grayscale display, data security, and web technologies.

Areas of ongoing work, such as 3-D imaging, reporting, and the handling of images from non-radiology specialties and disciplines, are assigned to an overall total of more than 25 DICOM working groups. These working groups maintain relevant portions of the standard and develop material for possible future incorporation into the standard. Clearly, the scope of the standard and its ongoing efforts are broad.

A comprehensive review of the entire DICOM standard is beyond the purview of this article. However, several areas are discussed that are relevant to practicing radiologists. In particular, those aspects of the standard that relate to DICOM conformance statements, grayscale image display, enhanced CT and MR objects, structured reporting, radiation dose tracking, and web technologies are briefly summarized.

Conformance Statements
DICOM represents a large body of work, addressing many aspects of imaging workflows. For example, DICOM currently defines 65 distinct types of data, or information “objects,” many of which extend beyond typical radiologic images. These include many objects related to radiation therapy treatments, waveform representations such as those for electrocardiogram data, visible light images such as those from endoscopic procedures, and dental images (see DICOM Part 3 for a complete listing). As a result, no single notion captures “DICOM compliance,” as any specific piece of equipment and any particular imaging workflow will use only a small subset of the full DICOM standard. For example, an MR scanner would not use the breast tomosynthesis DICOM information object.

Understanding DICOM conformance, then, requires an understanding of the specific DICOM data types, data services, and communication mechanisms supported by a particular device. A fundamental portion of the DICOM standard (ie, DICOM Part 2) defines a document format through which vendors describe these technical details. For a specific piece of equipment, this documentation is called the DICOM Conformance Statement, and careful review of this documentation and consideration of its details regarding the existing and planned local infrastructural environment should be an important part of any equipment purchasing process.

The information contained in DICOM Conformance Statements is by necessity technical, and familiarity with a few essential bits of jargon will make these documents more meaningful. The term “SOP Class,” or service-object-pair class, refers to a type of data and an associated function. For example, “CT Image Storage” is one example of an SOP Class. A device might use an SOP Class (in which case the device is a service class user [SCU]), provide an SOP Class (in which case the device is a service class provider [SCP]), or both. A CT scanner would be an SCU of the CT Image Storage SOP Class, and the archive used to store images from this scanner would need to be an SCP of this SOP Class.

The DICOM Conformance Statement for a particular piece of equipment, whether a modality, PACS, advanced visualization system, film printer, or other device, constitutes the manufacturer’s declaration of its intended DICOM functionality. Matching such functionality between devices is the key to achieving interoperability. Maintaining these documents as reference for installed equipment is important, as is review of such documents for equipment under consideration for purchase. IT staff and PACS administrators will generally be key collaborators in the close interpretation of these documents.

For a full description of the DICOM Conformance Statement format and relevant aspects of the DICOM information model, please see DICOM Parts 2-6 as well as the excellent text by Pianykh [5].

Grayscale Standard Display Function
Drawing upon extensive research in image display and human perception, Part 14 of the DICOM standard addresses issues related to consistent, optimized display of grayscale images. This portion of the standard provides a basis for the uniform display of images regardless of the medium or display technology. The DICOM grayscale standard display function (GSDF) constitutes a principal element of Part 14.
A digital grayscale image consists of a matrix of numerical values. Each value is an indicator of brightness at the corresponding point or pixel in the image. To display such an image involves mapping the range of these pixel values to the range of possible brightness values on a given display. Consider an image with 4,096 distinct possible pixel values ranging from $-2,048$ to $+2,047$, which would correspond to a “12-bit” grayscale image because $2^{12} = 4,096$. One approach to displaying this image is to assign the pixel value $-2,048$ to pure black, the pixel value $+2047$ to pure white, and the intervening pixel values to evenly spaced steps in between. This example is a linear display function, because of the even spacing.

Two issues arise regarding the physical properties of the display and the characteristics of the human visual system. First, consider the display. Image display technologies span a wide range of disparate physical forms, from printed film to cathode ray tube to flat panel, each with distinct properties. For any given display, achieving a desired level of grayscale brightness depends on these physical properties, embodied in the “characteristic curve” of the device. Through the characteristic curve, a display can specify levels of grayscale brightness based on pixel values.

The question is then: “Given a particular pixel value, what brightness level should be displayed?” The human visual system is less sensitive to changes at lower, versus higher, levels of brightness. In other words, it takes a greater increment of physical luminance between 2 dark shades of gray to be discernible by a human observer; to differentiate between 2 light shades of gray does not take as much incremental luminance. This property of the human visual system may be termed “perceptual nonlinearity.” If we simply used the linear display approach described earlier, 2 similar but distinct dark pixels in an image may appear indistinguishable to a human observer; similarly, distinct light pixels may seem disproportionately different from one another, leading to perceptual distortion.

DICOM Part 14 and the GSDF provide a mechanism to account for this perceptual nonlinearity. The GSDF is a mapping function, which assigns a greater difference in luminance to darker pixels and a lesser difference in luminance to brighter pixels. The result is an image with less perceptual distortion between dark and light shades; as a byproduct, image display also becomes more uniform and consistent across devices.

Leveraging the advantages of the GSDF within a PACS-based workflow requires an imaging chain (eg, viewing software, driver software, graphics hardware, monitor hardware) capable of applying the GSDF, as well as a monitor calibration program. Refer to the ACR Technical Standard for Electronic Practice of Medical Imaging [8] for detailed guidance with regard to display technologies.

**DICOM-Enhanced CT and MR Objects**

Enhanced CT and MR objects were incorporated into DICOM in the early 2000s. These enhancements created formal mechanisms for handling the growing complexities of these key modalities and included improvements to the recording of sequence type and contrast-phase information. The creation of these enhanced objects was designed to allow more consistent presentation states, or “hanging protocols,” in PACS applications, among other objectives.

The enhanced CT and MR objects have the additional ability to handle “multiframe” image data. Whereas images were traditionally handled in DICOM as individual 2-D slices, the advent of techniques such as 3-D/isotropic CT imaging, volumetric MR acquisition, and dynamic postcontrast MR led to large amounts of multidimensional data. In a multiframe approach, an entire set of images can be packaged as a single DICOM object rather than as a sequence of separate objects. This functionality streamlines image handling and enables storage, transfer, and display efficiencies.

The diffusion of these innovations into clinical use has been relatively slow. Radiologists may not be well informed about the relationships among specifications in the DICOM standard, conformance of devices to these specifications, and the impact of these on functionality. For example, for one vendor’s PACS to provide the hanging protocol advantages of the enhanced CT DICOM object, another vendor’s source CT scanner must support this object. Neither vendor can be expected to solve this problem alone. Radiologists who understand the role of the DICOM standard in solving such problems are thereby equipped to make more-informed purchasing decisions.

**DICOM Structured Reporting and Radiation Dose Tracking**

Although the theory and methods of structured documents represent another large field beyond the scope of this discussion, the increasing prevalence of structured reporting in radiology makes the topic of structured documents clinically relevant. The standardized formats and vocabularies of structured reporting have been promoted as a means to reduce variability and increase quality of radiology reports [9,10], although some controversy exists as to the efficacy of structured reporting [11]. In addition, such reporting standards promote the accessibility of radiology report contents to data-mining applications. The RSNA Reporting Committee, organized in 2008, has published more than 100 radiology reporting templates that address many organ systems, body parts, and imaging modalities [12].

DICOM defines information objects to support the handling of structured documents. This portion of the standard is referred to as DICOM SR (SR for structured reporting) [13-15]. Although DICOM SR may be used to store and transmit radiology reports, its application to radiation dose tracking has been developed additionally in the form of the radiation dose structured report (RDSR). Aside from the RDSR, DICOM is used in other ways to record radiation dose information.
Radiation dose related to imaging procedures has been the subject of increasing interest for physicians and patients. The ACR, for example, has developed its Image Wisely® campaign [16] to promote the judicious use of radiation in radiologic exams. This interest in radiation dose leads naturally to a need for systematic recording of radiation exposure information associated with individual exams. Furthermore, in the era of radiology analytics [17], the collection of such dose information within information systems promises to enable automatic dose-related tracking, such as cumulative, patient-specific dose over time, conversion of exposure data into size-specific dose estimates [18], and quality management initiatives based on assessment of ongoing departmental dose reduction efforts.

CT imaging is a primary source of medical radiation, and DICOM facilitates the systematic storage of CT dose information through several mechanisms. Perhaps the most widespread approach is to store a captured dose screen along with the images of an exam. Modern CT systems generate a dose sheet, which contains information about dose-related parameters for a given exam, such as CT dose index volume and dose-length product. This dose sheet can be captured as an image (Fig. 1). Storing dose information in such a way is advantageous for its simplicity: the dose sheet screen-capture constitutes one more DICOM image to archive as part of the study, and review of the dose information requires only the image to be displayed. However, recording numerical data in this fashion precludes the automatic processing which is needed for dose-tracking applications unless the screen-captures are first reprocessed and converted back to numerical form. Cook et al [19] have described an automated system that applies optical character recognition to CT dose sheets to enable automatic dose tracking.

Although the use of screen-captures is convenient, it is certainly indirect and limiting, and DICOM also provides for more direct storage of dose-related parameters. DICOM allows many kinds of data to be associated with medical images via “attributes.” An attribute consists of a tag (a unique pair of numbers) and its value. For example, the attribute “kVp” is denoted by the tag “0018,0060” and may be used to mark an image with the relevant tube voltage value. Many systems allow users to display the “DICOM header” of an image, which is simply a listing of all its tags and their values. Several radiation dose-related attributes are defined in the DICOM standard, such as tube voltage, tube current, and exposure time. For dose information stored in such a manner, automated retrieval for subsequent analysis is straightforward. However, with increasing scanner and protocol sophistication, dose-related attributes become insufficient. Particularly with multiphase CT exams, dynamic kVp and mAs optimization, new CT reconstruction algorithms, and dual-source CT systems, the nature of radiation exposure information is becoming increasingly complex and is not easily captured with a simple set of parameters.

Fig 1. This image displays radiation exposure information for a CT exam. Such images, or “dose sheets,” are generated by modern CT systems and typically contain 1 line per exam phase in which each line indicates dose parameters such as CTDIvol and DLP. The image shows a line pertaining to the initial CT topogram, another for the noncontrast imaging phase, 2 lines related to contrast bolus tracking, and 3 subsequent lines for arterial, venous, and delayed imaging phases, respectively. One common approach to storing CT radiation exposure information is to store the dose sheet image along with the CT images, essentially storing dose data as a “picture of numbers.” Although easy to implement, this approach precludes further computation of exposure data, unless additional processing is subsequently performed to convert the dose sheet image back into numerical form (as described by Cook et al [19]). cSL = collimated section length; CTDIvol = CT dose index volume; DLP = dose-length product; H-SP = head first, supine; L = large; ref. = reference; S = small; s = seconds; TI = time.
For such cases, the structure afforded by DICOM SR can be used to record such complex dose information in a more organized and appropriate fashion. The RDSR consists of a DICOM SR template that defines a standardized hierarchy of data elements capable of capturing dose information associated with modern equipment and protocols. Although this approach is certainly more comprehensive than others discussed, adoption is in its early stages.

Web Access to DICOM-Persistent Objects
The computing landscape has changed in many ways since the initial days of the ACR-NEMA collaboration. Although ACR-NEMA version 1.0 specified a networking protocol, including the details of an electrical connector cable to be used between 2 devices, this protocol was superseded by the emergence of Ethernet and the Transmission control protocol/Internet protocol (TCP/IP) as the dominant networking standard. Another more recent example of ongoing DICOM evolution is in the area of web technology and the introduction of Part 18: Web Access to DICOM-Persistent Objects (WADO).

WADO provides DICOM functionality through a web-based interface [20]. The term “persistent objects” refers to long-lived data such as medical imaging exams. The new capabilities of WADO enable DICOM-based imaging within web browsers, and WADO is emerging in some vendors’ thin-client and “zero footprint” [21] viewing applications. WADO is poised to become an important technical component of imaging workflows in the era of mobile computing, although this portion of the DICOM standard is still evolving.

DICOM Summary
DICOM is a mature standard that is now the lingua franca for the interoperability of medical imaging equipment. DICOM is extensive in scope, addressing issues ranging from image transmission to image storage and display. DICOM continues to evolve, addressing many current concerns in radiology. Users, especially purchasers, in radiology should be aware of interoperability issues and technological trends as they interact with vendors and assess new equipment.

HEALTH LEVEL 7: INTEROPERATING IN THE BROADER MEDICAL ENTERPRISE

Background
Mirroring the need for interoperability of imaging systems within radiology departments, health care enterprises depend critically on the ability of many different clinical information systems to exchange data reliably. These systems include physician order entry systems, electronic medical record (EMR) applications, the RIS, and laboratory information systems, to name just a few. This interoperability is enabled by the Health Level Seven (HL7) technical standard, and HL7 is to the health care enterprise as DICOM is to radiology. The HL7 standard is maintained and updated by an international organization named Health Level Seven International [22]. With respect to imaging workflows, the most common transactions carried out over HL7 are registration, ordering, and results dissemination.

Technical Details and Practical Implications
Two main versions of HL7 are currently in use: version 2.x and version 3.0. The vast majority of systems currently use version 2.x for integration. These version numbers suggest a comparison with the ubiquitous universal serial bus (USB) connectors found on personal computers and other devices, designed so that USB 3.0 is backward-compatible with USB 2.0. However, unlike USB, HL7 2.x and 3.0 differ dramatically from each other and are not easily interoperable. Information formatting varies greatly between 2.x and 3.0, rendering them incompatible. Messages with 2.x are comprised of segments that start with a 3-letter descriptor and end in a line break (Fig. 2). However, the vocabulary, as well as the element structure, of 2.x messages is different from that of 3.0 messages. This difference makes it difficult to interoperate between systems using different versions of HL7.

Fig 2. An example of an HL7 version 2.x message. These messages are composed of pieces, or segments, each of which begins with a 3-letter code to indicate segment type (eg, MSH, PID, and PV1 on the first 3 lines in this case corresponding to message header, patient identification, and patient visit information, respectively). Within each segment, the segment type code is then followed by data fields separated by the pipe (|) character. On the first line, the field “ORU-R01” indicates that this is an “observation result unsolicited” (ORU) message, which is used to communicate radiology results and other clinical data. HL7 = Health Level 7; MSH = message header; ORU = observation result unsolicited; PID = patient identification; PV1 = patient visit information.

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notoriously loosely defined. Many vendors place unique limitations on field length and specify how information should be provided within the pipe and caret structure. Consequently, the way a specific application uses HL7 2.x may be somewhat idiosyncratic. This situation led to the technical adage, “If you’ve seen one HL7 interface, you’ve seen one,” because the interface between 2 specific systems may not generalize well to other systems.

In contrast, HL7 3.0 messages are formatted using the Extensible Markup Language (XML) standard (Fig. 3). The XML format is certainly easier to read, but it comes with significant restrictions as the available fields are strictly defined by a set of rules called the reference implementation model, also published by Health Level Seven International. Because HL7 3.0 messages are structured more formally than 2.x messages, and the same structure is shared among vendors, 3.0 is frequently used for data interchange between health care enterprises.

Another key concept of HL7 is that it is nearly entirely event based, meaning that HL7 messages are triggered as events occur across the health care enterprise. For example, when a radiology report is made available by an RIS, this event is transmitted, or “broadcast,” over the network as an HL7 message. Any interested applications receiving this message, such as an EMR, may then process the event accordingly. This functionality is in contrast to the targeted “point-to-point” request/response communication in DICOM, such as query and retrieve operations.

Registration. Registration messages share patient names, demographics, and insurance information with numerous systems across the hospital. In HL7 2.x parlance, they are known as admission, discharge, transfer (ADT) messages. In addition, ADT messages can trigger merge operations in downstream systems if a single patient has multiple medical record numbers. This setup ensures data quality and consistency.

Orders. In outpatient radiology workflow, after a patient registers and reports to radiology, an administrative assistant, or a technologist, creates an order for the patient within the RIS. The demographics for the patient are already available in the RIS from processing an ADT message and do not need to be typed again. This order is sent via an order message to the PACS as well as the voice recognition system. Information in the order message includes: the accession number for the exam, the exam type, and patient demographics. Most RISs send additional order messages to indicate status changes (eg, exam completed), informing the PACS and the voice recognition system of changes. This model helps reduce the number of times that information is entered, thus decreasing error rates.

Results. Results messages in most departments are generated via voice recognition and are typically sent into the RIS. In the HL7 2.x specification, results messages are known as “observation result.” The RIS then sends another results message out to the PACS, the electronic health record, and other downstream systems. In addition, the RIS typically sends results messages to billing for processing.

Interface engines. Historically, HL7 interfaces were point-to-point interfaces integrating 2 systems. As hospitals added additional systems, the point-to-point model was no longer sustainable. Most hospital systems employ an interface engine to act as a real-time router, directing ADT messages to all systems, sending results to the PACS and the EMR, and billing messages from the RIS and lab information systems to billing. In addition, most interface engines support rearranging of HL7 messages and reformatting of fields as needed. One example is an RIS that creates accession numbers that are longer than the DICOM specification and need to be truncated before orders are sent to PACS.

Current and Future Directions

Just as DICOM has incorporated web technologies, as with the WADO mechanism described earlier, Health

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  <typeId root="2.16.840.1.113883.1.3" extension="PCCO_MD000040" />
  <templateId root="2.16.840.1.113883.10.20.1" />
  <id root="OB736647-EC99-424c-a864-7e33da82e703" />
  <code code="34133-9" codeSystem="2.16.840.1.113883.6.1" display="Kaiser Health Record" />
  <title>Kaiser Permanent</title>
  <effectiveTime value="20081008124536" />
  <confidentialityCode code="F" codeSystem="2.16.840.1.113883.6.25" />
  <languageCode code="en-US" />
  <recordTarget>
    <patientRole>
      <id />
      <patient>
        <name>
          <family>Doe</family>
          <given>John</given>
        </name>
        <administrativeGenderCode code="M" />
        <birthTime value="19600131" />
      </patient>
    </patientRole>
  </recordTarget>
</ClinicalDocument>

Fig. 3. An example of an HL7 version 3.0 message fragment. Unlike HL7 2.x, version 3.0 messages are structured using XML. The meanings of specific portions of the message are explicitly defined by tags in the message. Here, the hierarchical tags “patient,” “name,” and “family” lead to the value “Doe.” HL7 = Health Level 7; XML = extensible markup language.
Level Seven International is developing a standard for using HL7 via the web. This standard, called Fast Healthcare Interoperability Resources (FHIR, or “fire”), is currently in draft form and offers the potential to further facilitate health care interoperability by lowering barriers to implementation.

**HL7 Summary**

HL7 is the standard by which information systems communicate within and even between health care enterprises. HL7 version 2.x is currently used most commonly within health care systems, whereas version 3.0 is more commonly found in health information exchanges. Web-based HL7, in the form of the pending Fast Healthcare Interoperability Resources standard, promises further advancements in enterprise-level interoperability.

**VOCABULARIES, ONTOLOGIES, CODING**

**Background**

A long history of terminologies and classification systems in medicine have been designed to structure and standardize communication of relevant information. The International Classification of Diseases (ICD) diagnostic coding system has its origins in the Bertillon Classification of Causes of Death introduced in 1893 [23]. The Terminologia Anatomica [24] standard for anatomic terms originated as the Basle Nomina Anatomica, which was first released in 1895. For clarification, such a list of standardized terms may be referred to as a controlled terminology, vocabulary, or lexicon; these terms, for the purposes of this discussion, will be used synonymously. The ACR first published its ACR Index in 1955 [25]. The College of American Pathologists first published its Systematized Nomenclature of Pathology (SNOP) and Systematized Nomenclature of Medicine (SNOMED) in 1965 and 1974, respectively [23]. SNOMED underwent several subsequent revisions before it was combined in 2002 with Clinical Terms Version 3, from the United Kingdom’s National Health Service, to produce SNOMED Clinical Terms (SNOMED CT) [26].

Initially, such nomenclature system development was motivated by a desire to clarify medical communication, to enable population-based studies of disease, and to facilitate information retrieval. Within the past several decades, efforts have been directed at formulating these systems to leverage computer-based techniques of data management, as exemplified by medical coding based on the ICD and CPT systems. Over time, this approach has evolved to include more-sophisticated methods of knowledge representation, characterized by concepts and their relationships, and referred to as “ontologies.” These representations allow machine-based reasoning and offer the potential for computer-assisted knowledge discovery.

These developments have an impact on radiologists in several ways. First, in the area of reporting, term standardization promotes clarity. The RSNA RadLex project represents work to develop a “single source for medical imaging terminology” [27]. Second, standard coding and classification systems including RadLex play a role in practice management issues, such as billing, exam ordering, and scheduling.

**Technical Details and Practical Implications**

**RadLex and radiology reporting.** The ACR Index system classified radiological cases by anatomy and pathology. It utilized a numerical coding scheme, much akin to the Dewey Decimal library classification system [28], whereby specific digits and place values were assigned particular meanings. The ACR Index was used for several decades, with its third edition published in 1986. However, it was characterized by a relative lack of anatomic and pathologic detail and was, at times, inflexible [27]. Beginning in 2005 and using the ACR Index as a starting point, the RSNA embarked on the RadLex project to address these shortcomings and provide a common reference for imaging-related terms.

To leverage other related work, RadLex derives portions of its content from other sources. Anatomic content is based in part on the Foundational Model of Anatomy, a large ontological model of human anatomy [29]. Similarly, RadLex derives material in the realm of pathology from the SNOMED CT system. RadLex now contains more than 30,000 terms relating to anatomy, pathology, imaging observations, and radiologic workflow.

Although RadLex may be used in many ways, ranging from data mining to assisted web searching to teaching file organization [30-32], one primary role for RadLex is in reporting. In the era of computerized reporting systems and the RSNA’s Structured Reporting Templates [12], RadLex supplies standardized names and descriptors for imaging findings (see the DICOM Structured Reporting and Radiation Dose Tracking section). For the interested reader, RadLex content is accessible through the RSNA [33] or through the National Center for Biomedical Ontology [34].

Although RSNA reporting templates and RadLex terminology have been adopted by vendors to some extent, further diffusion of these standards into clinical practice will depend on ongoing vendor engagement and user demand. The current drive for quality improvement may motivate increased usage of standardized templates and terminology in radiology reporting [35]. Such reports would facilitate large-scale automated processing of performance metrics relating to areas such as report turnaround time, malignancy staging, and critical results communication, among many others, thereby allowing practices and departments to measure and demonstrate quality.

**Practice management.** Medical reimbursement in the United States, especially under CMS, is predicated on ICD and CPT coding. For the purposes of reimbursement claims, ICD codes are used to specify diagnoses. These diagnostic codes in turn support the provision of particular medical services, which are specified using CPT codes. As noted briefly earlier, the ICD coding system...
originated in the late 19th century and is now managed by the World Health Organization. The ninth revision of ICD (ICD-9) was required for CMS claims starting in the late 1970s. Although ICD-10 was released in the early 1990s, a nominal CMS deadline for adoption of this revision (ie, October 2015) has not been reached as of this writing. Note that ICD-11, currently still pending, will incorporate concepts and content from SNOMED CT, as an indicator of the shared history and evolution of these classification systems.

CPT codes, on the other hand, were developed by the AMA. First released in 1966, CPT is updated on an annual basis and codifies medical services such as consultations, nonsurgical procedures, imaging exams, and surgical interventions. However, the potential for ambiguity in CPT radiology codes led to the RSNA RadLex Playbook project [36], first released in November 2011. This effort, part of the larger RadLex framework, specifies radiology exam names and codes using a structured approach to facilitate exam ordering and scheduling. These exams are then mapped to CPT codes through an institution’s “charge master” for billing purposes. Standardized Playbook codes may also be transmitted via DICOM attributes (ie, properties associated with DICOM images) to facilitate interoperability between sites and institutions.

**Summary**

Standardized medical lexicons, ontologies, and coding schemes have a long history. Several of these relate to the practice of radiology, such as in the areas of reporting and practice management, in which these standards promise to promote report clarity and improve efficiency. Standards of particular importance include RadLex, ICD-9, ICD-10, and CPT. RadLex Playbook may become increasingly important in coming years. As in other areas of imaging standards, engagement of vendors and users will be important for the ongoing development of these efforts.

**TAKE-HOME POINTS**

- DICOM is the universal standard for interoperability of imaging equipment in radiology.
- DICOM continues to evolve in areas such as radiation dose tracking and web technology.
- HL7 is the ubiquitous standard for communicating information across the health care enterprise.
- ICD and CPT form the basis for billing in radiology. A nominal deadline for the adoption of ICD-10 (ie, October 2015) remains pending as of this writing.
- RadLex Playbook provides a mechanism for standardized radiology procedure naming and facilitates data interchange between sites and institutions.

**GLOSSARY**

Abstract syntax: another term for “SOP Class.”

Application entity (AE): a specific DICOM device on a network, named by its “AE Title.”

Attribute: a DICOM tag or property that may be attached to an image, such as patient name, study date, and ordering physician name.

Characteristic curve: an intrinsic physical property of an image display device indicating how pixel values must be transformed into digital driving levels to achieve a desired grayscale brightness level.

Controlled terminology: for purposes of this discussion, synonymous with “lexicon” and “vocabulary.”

DICOM: Digital Imaging and Communications in Medicine.

Digital driving level (DDL): an electrical signal within an image display device used to create a specific grayscale brightness level.

Lexicon: standardized set of terms; unlike an ontology, does not encode relationships between terms.

Metadata: “data about the data”; in DICOM, each image is marked with properties, or attributes, such as patient name, study date, etc., which constitute the metadata.

National Electrical Manufacturers Association (NEMA): an industry consortium, which in 1983 began a collaboration with the ACR to develop the imaging standard now known as DICOM.

Object: an encapsulation of the ACR to develop the imaging standard now known as DICOM.

Ontology: a computer-based representation of a body of knowledge consisting of concepts and the relationships between these concepts; such relationships may be hierarchical (eg, the lingula “is a part of” the left lung), or associative (eg, Helicobacter pylori “is a causative factor of” peptic ulcer disease).

RadLex: originally a lexicon of terms relevant to medical imaging; has more recently evolved into an ontology that incorporates anatomic terms, pathologic concepts, imaging observations, and radiology workflow terms (including standardized exam names, contained in the RadLex Playbook component).

Service class provider (SCP): DICOM acronym; a DICOM device may declare itself capable of supplying a particular DICOM service with respect to a particular type of DICOM data. For example, an imaging archive intended for use in storing CT images would need to be an SCP of the CT image storage function.

Service class user (SCU): DICOM acronym; a DICOM device may declare its intention to utilize a particular DICOM service with respect to a particular type of DICOM data. For example, a CT modality would need to send images to an archive for storage. The CT modality would thus be an SCU of the CT image storage function.

Service-object pair (SOP) class: a particular type of data, and a specific function that operates on that data; also called an abstract syntax. For example, “CT Image Storage” constitutes an SOP Class.

Systematized Nomenclature of Medicine Clinical Terms (SNOMED-CT): introduced in 2002, representing...
a harmonization of the preceding SNOMED Reference Terminology and Clinical Terms Version 3 systems, which had been published by the College of American Pathologists, and the United Kingdom’s National Health Service, respectively.

Transfer syntax: a DICOM specification of the data encoding format to be used by 2 communicating DICOM devices.

Unique identifier (UID): a numerical value assigned to a DICOM object; DICOM UID’s are globally unique. For example, any particular DICOM image will be assigned a numeric code, which will uniquely identify that image.

Vocabulary: for purposes of this discussion, synonymous with “lexicon” and “terminology.”

REFERENCES