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Research and Applications

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The LOINC RSNA radiology playbook - a unified terminology for radiology procedures

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ABSTRACT

Objective: This paper describes the unified LOINC/RSNA Radiology Playbook and the process by which it was produced.

Methods: The Regenstrief Institute and the Radiological Society of North America (RSNA) developed a unification plan consisting of six objectives 1) develop a unified model for radiology procedure names that represents the attributes with an extensible set of values, 2) transform existing LOINC procedure codes into the unified model representation, 3) create a mapping between all the attribute values used in the unified model as coded in LOINC (ie, LOINC Parts) and their equivalent concepts in RadLex, 4) create a mapping between the existing procedure codes in the RadLex Core Playbook and the corresponding codes in LOINC, 5) develop a single integrated governance process for managing the unified terminology, and 6) publicly distribute the terminology artifacts.

Results: We developed a unified model and instantiated it in a new LOINC release artifact that contains the LOINC codes and display name (ie LONG_COMMON_NAME) for each procedure, mappings between LOINC and the RSNA Playbook at the procedure code level, and connections between procedure terms and their attribute values that are expressed as LOINC Parts and RadLex IDs. We transformed all the existing LOINC content into the new model and publicly distributed it in standard releases. The organizations have also developed a joint governance process for ongoing maintenance of the terminology.

Conclusions: The LOINC/RSNA Radiology Playbook provides a universal terminology standard for radiology orders and results.

Key words: LOINC, RadLex, radiology, vocabulary, controlled

INTRODUCTION

Despite continuous advances in biomedical imaging technology and growing adoption of electronic health record systems (EHRs),[1] imaging information often lacks interoperability across systems. Ubiquitous adoption of the DICOM standard in hospitals has solved an important challenge by providing a universal structure for storing and exchanging medical image exams.[2] Yet, each radiology facility typically still creates its own nomenclature to identify the imaging procedures it performs.[3] The effort required to make use of

Table 1. Attributes of the RadLex Playbook naming model

Model Attribute	Description	Multiplicity Allowed
MODALITY	Radiologic procedure modality, eg *Computed Tomography* or *Magnetic Resonance Imaging*.	Yes
MODALITY_MODIFIER	Indicates subtypes of an imaging modality (eg *Angiography* for CT angiography exams).	Yes
PROCEDURE_MODIFIER	Indicates key distinguishing aspects of a procedural technique (eg *Transjugular* for biopsies by that route).	Yes
POPULATION	By default, Radiologic procedures are presumed to be applicable to patients of all ages, unless this attribute is populated by a value such as *Neonatal, Infant*, or *Pediatric*.	No
BODY_REGION	Indicates which broad portion(s) of the body are to be imaged by a given procedure (eg *Head*, *Chest*, *Abdomen*) .	Yes
ANATOMIC_FOCUS	Secondary indicator of the imaged area, more specific than *BODY_REGION* and often referring to an organ or organ system (eg *Ankle*, *Pancreas*, *Thyroid gland*).	Yes
LATERALITY	Body site laterality, where applicable, may take any of the following values: *Right, Left, Bilateral, Unilateral.*	No
REASON_FOR_EXAM	Where necessary for making key distinctions among procedures, this attribute specifies a specific indication (eg *Screening*) or a specific goal of the exam (eg *Biopsy*).	Yes
TECHNIQUE	Specifies any key technical factors in image acquisition (eg *Dual energy CT*, *Rectal coil*)	No
PHARMACEUTICAL	Indicates administration of contrast including route of administration (eg *With IV Contrast*), or other diagnostic or therapeutic materials.	Yes
VIEW	Specifies patient positions and maneuvers occurring during the exam (eg *Cross Table Lateral*, *Decubitus*).	Yes

idiosyncratic codes from many institutions hinders data exchange and aggregation. As a result, it is challenging to integrate images and reports in a health information exchange,[4] to benchmark radiation doses,[5] to develop cross-site alerts of potentially avoidable repeat exams,[6] or to re-use imaging information for research.

To address these problems, both the Regenstrief Institute, Inc. and the Radiological Society of North America (RSNA) undertook separate efforts to standardize nomenclature for radiology procedure names. Regenstrief expanded and enriched Logical Observation Identifiers, Names, and Codes (LOINC®) to include radiology terms.[7] RSNA developed the RadLex® Playbook,[8] an outgrowth of its RadLex terminology that focuses specifically on procedures names.

The Regenstrief Institute and the RSNA were on parallel standardization paths, but shared many common perspectives. They both were creating a standardized nomenclature for naming radiology procedures, used the method of empiric analysis of local procedure names to derive a model for naming procedures, and made their standards available at no-cost under a license that promotes widespread use. Both organizations also recognized that health data standards demonstrate the network effect: they become more valuable as more people use them. Given the overlapping goals, the organizations sought to harmonize their efforts and produce a single unified terminology: the LOINC/RSNA Radiology Playbook.

With funding support from the National Institute of Biomedical Imaging and Bioengineering (NIBIB), in 2013 the Regenstrief Institute and the RSNA began to unify LOINC radiology content and the RadLex Playbook into a single integrated terminology. The goal of this joint effort was to provide a common information model, a unified terminology, and a single governance process for terms that describe radiology orders and results.

Objective

This paper describes the unified LOINC/RSNA Radiology Playbook, and the process by which it was produced. Specifically, we describe our approach to unifying LOINC radiology content and the RadLex Playbook, the shared governance model, and the structure and content of the jointly distributed LOINC/RSNA Radiology Playbook file.

METHODS

The RadLex Playbook

The RadLex Playbook began in 2011 with a subcommittee of the RSNA RadLex project. RadLex is a comprehensive lexicon of radiology terms for indexing and retrieval of radiology information resources, specifically aimed at representing clinical content associated with radiology reports.[9] RadLex includes more than 75 000 terms organized in 9 main categories such as anatomical entity, clinical finding, imaging modality, etc. The RadLex Playbook[8] aims to provide a standard system for naming radiology procedures, based on the elements that define an imaging exam. By providing standard names and codes for radiologic studies, the RadLex Playbook can facilitate a variety of operational and quality improvement efforts, including workflow optimization, chargemaster management, radiation dose tracking, enterprise integration and image exchange.[3]

The RadLex Playbook is comprised of two components: 1) the model used to generate names (the grammar), and 2) the names generated from that grammar. The RadLex Playbook grammar describes how to create the pre-coordinated Playbook terms across the defining name attributes. Each such term is comprised of several RadLex clinical terms. The unique combination of RadLex clinical terms makes a unique Playbook term and is given a unique identifier (the RadLex Playbook ID, or RPID). Thus, for each RPID there is a corresponding set of RadLex IDs that link to the associated RadLex clinical terms. Table 1 gives the list of attributes used to construct RadLex Playbook names.

The initial version of the RadLex Playbook was released in 2011. As several institutions independently contributed exam codes to the evolving Playbook, a large, heterogeneous set of codes was developed. With the release of RadLex Playbook version 2 (June 2015), a curated subset has been identified as a core set of exams (ie Core Playbook) with broad applicability for new adopters.

LOINC

LOINC is a freely available international standard for health measurements, observations, and documents. Presently, LOINC

Table 2. Attributes of the LOINC Radiology naming model

Major: Minor Attribute	Radiology procedure use	Description	Multiplicity Allowed
Component: Analyte	Syntax pattern: <descriptor> [<number of views>] [<projection beam orientation>] [<body position>]	Delineates the projections and spatial conditions that are present during image acquisition. For radiography procedures, typically either a counted number of views (eg *3*) or the specific named views are specified (eg *AP* & *Lateral*).	Yes (within each syntax set)
Component: Challenge	Syntax pattern: [<existence>] <challenge>	Describes chemical, physical, and/or functional challenges, including existence (*W*, *WO*, *W&WO*). The naming convention for chemical challenges such as administration of contrast agents follows the general pattern in LOINC, including identifying the substance or challenge given, and an abbreviation for route of administration (eg *W Contrast IV*).	Yes
Property	Fixed value: Find	In LOINC, the *Property* distinguishes between different kinds of quantities for the same substance (eg Mass versus molar concentrations). For radiology procedures, the *Property* is always specified as *"Find"* (for Finding).	No
Time Aspect	Fixed value: Pt	In LOINC, the *Time Aspect* distinguishes between measures made at a moment (point) in time from those over a time interval that are integrated, in the mathematical sense, over time. For radiology procedures, the *Time Aspect* is always specified as *"Pt"* (for point in time).	No
System	Anatomic area	Identifies the anatomical area that is the focus of the imaging (eg *Ankle*, *Abdomen*, *Liver*).	Yes
System: Supersystem	Patient is the default, otherwise subject is specified	Identifies the subject of the observation, if not the patient (eg *Fetus*).	No
Scale	Fixed value: Doc	Distinguishes between quantitative, ordinal, nominal and other kinds of observations. For radiology procedure names, the *Scale* is always specified as *"Doc"* (for Document).	No
Method	Syntax pattern: <Modality>.[<Submodality>]	Radiologic procedure modality (eg *CT*, *XR*). Optionally, it can also specify a sub-modality such as "Angio" for angiography separated from the main modality by a period.	Yes

is used in more than 170 countries by many kinds of organizations, including large reference laboratories, healthcare organizations, insurance companies, regional health information networks, and national health programs.[10,11] Over 30 countries, including the United States, have adopted LOINC as a national standard. The Meaningful Use program requires that LOINC be used in messages that report laboratory test results, exchange medical summaries, and send data to cancer registries and public health agencies.

LOINC began representing radiology procedures by forming a special subgroup of committee members and a collecting exam names from diverse clinical sites. As is LOINC's usual approach, the naming model was derived by empirically analyzing the patterns and levels of granularity in names from operational systems. The first LOINC radiology codes were released in 2000 (Version 1.0O), and since then, radiology procedures have continued to be an active area of growth. The current LOINC release (version 2.61) contains more than 5800 active radiology terms. LOINC's primary scope is diagnostic radiology exams, but through new submission requests is also expanding into interventional radiology. Two independent analyses[7,12] have demonstrated that LOINC has good coverage (91-92%) of the procedures found in local radiology systems.

LOINC names radiology procedures within the 6 major, and up to 4 minor attributes of the LOINC concept model.[13] Within these core LOINC attributes, some specialized conventions were developed for radiology.[14] Table 2 summarizes the radiology-specific naming conventions in LOINC.

UNIFICATION OF LOINC AND RADLEX PLAYBOOK

Overall approach

In 2013, Regenstrief Institute and the RSNA agreed to cooperate on developing a single, unified standard for radiology procedure names, bringing together Regenstrief's globally-recognized terminology experience and the RSNA's preeminent domain expertise. The unified, jointly developed terminology is called the LOINC/RSNA Radiology Playbook.

Early on, the organizations agreed that a unified naming model was needed, but that perpetuating dual identifiers (LOINC codes and RPIDs) for procedures in the unified terminology would be duplicative work and introduce unnecessary confusion for users about which code to use in which circumstance. They agreed that LOINC codes would be the primary identifiers for procedures in the unified terminology. They also agreed to map existing RRIDs to corresponding LOINC codes, but that new RPIDs would not be created. This approach would achieve the goal of having universal codes for radiology procedures. To fully leverage the strengths of both terminologies, the attribute values used in the model would be represented as LOINC Parts linked to RadLex clinical terms. Users could then organize, query, and reason against the procedures codes via the concept relationships in RadLex.

The organizations developed a unification plan consisting of 6 main objectives: 1) develop a unified model for radiology procedure names with attributes represented as an extensible set of values, 2) transform existing LOINC procedure codes into the unified model representation, 3) create a mapping between all the attribute values

used in the unified model as coded in LOINC (ie, LOINC Parts) and their equivalent concepts in RadLex, 4) create a mapping between the existing procedure codes in the Core Playbook (a subset of the RadLex Playbook) and the corresponding codes in LOINC, 5) develop a single integrated governance process for managing the unified terminology, and 6) publicly distribute the terminology artifacts.

The unification plan was divided into 3 phases. The first phase spanned 2 years ending September 2015 and was funded by the National Institute of Biomedical Imaging and Bioengineering (NIBIB). In Phase I, a unified model (objective 1) and governance process (objective 5) for the entire collaboration were created, and the unified model and mappings were implemented for computed tomography (CT). The second phase, from October 2016 through September 2017, was also supported by the NIBIB. In Phase II, the organizations expanded the content modeling and mapping work to all other radiologic imaging modalities and interventional procedures (objectives 2-6). Non-radiologic images, such as endoscopic images, or optical dermatology images, were not included in this work's scope. In the process, they iteratively improved the unified model and its application with lessons learned (objective 1 continued). By the end of Phase II, all existing LOINC content was transformed to the unified model and all objectives completed. Phase III has transitioned this work into a sustained maintenance activity of the two organizations.

In the following, we describe the technical aspects of the unification.

Developing a Unified Model for Radiology Procedure Names

We began the unification process by reviewing the axes of the LOINC radiology naming model and the RadLex Playbook naming grammar with the goal of creating a common grammar/model. The developers of both vocabularies shared their design decisions and attribute definitions. We also generated lists of the attribute values from each terminology used in existing procedure terms.

Reviewing the set of attribute values for each attribute informed the unification process in several ways. It helped to identify axes that had a direct correspondence between LOINC and RadLex Playbook. It also helped identify attributes with overlapping but not identical meanings, and where the boundaries between attributes were not crisply delineated or applied in existing terms.

Through iterative discussions, we developed resolutions for unifying and untangling the core attributes for the unified LOINC/RSNA Radiology Playbook. Some issues were resolved by revising attribute definitions, others by migrating attribute values from one attribute to another, and still others by agreeing that a particular distinction would not be carried forward into the unified model. As we moved through the unification process for each attribute, we iteratively documented our design decisions in the LOINC/RSNA Radiology Playbook User Guide (User Guide).[15]

Transform Existing LOINC Procedure Codes into the Unified Model

Once an initial draft of the unified model was complete, we began to apply it to existing content. The LOINC/RSNA Radiology Playbook is expressed as procedure terms with unique identifiers, formal names, and links to attributes that form a unified model instance. The attribute values that make up the model instance are populated with coded entities from both LOINC (Parts) and RadLex clinical terms (RadLex concepts). The first step of the transformation was updating the LOINC fully specified name to reflect the new naming conventions.

In Phase I, we focused on CT procedure terms as a pilot domain. Later, in Phase II, we expanded to the other imaging modalities. For each modality, the Regenstrief LOINC team reviewed and modified the LOINC names to conform with the unified model. Some changes involved updating to new preferred names (eg from thoracic outlet to brachial plexus), some revised syntactic styles, and others moved information from an old attribute to a new one. These changes were jointly reviewed and approved by the Regenstrief and RSNA teams. The detailed review also uncovered cases where the existing term name was ambiguous or the exam itself was obsolete. In such cases, the LOINC term status was changed to either *deprecated* or *discouraged*.

Creating a Mapping of Attribute Values between LOINC and RadLex

The Regenstrief LOINC team created a software algorithm that takes the formal naming syntax (as expressed in the main 6 axes of the LOINC name[13]) and parses it into the collection of coded attributes values. In LOINC, the coded attribute values are called Parts. For example, the LOINC term for a basic *CT Head [24725-4]* is broken down into a list of attributes containing "Rad.Modality.Modality type" of *CT [LP200067-9]* and "Rad.Anatomic Location.Region Imaged" of *Head [LP199977-2]*. After updating the LOINC term names of a particular modality to the new conventions, we ran the parser to generate the list of LOINC Parts for mapping to RadLex.

We used expert review, assisted by searching and browsing tools like NCBO BioPortal[16] and ART-DECOR[17] to locate corresponding concepts in RadLex. For example, LOINC Parts *CT [LP200067-9]* and *Head [LP199977-2]* were mapped to RadLex terms *computed tomography [RID10321]* and *head [RID9080]*, respectively. Each mapping was reviewed by a team of 6 domain experts from both Regenstrief and the RSNA. When no equivalent concept was found in RadLex clinical terms, a new RadLex term was created by the RSNA team. We stored these mappings in LOINC so that they were reused for all terms linked to those Parts.

Mapping existing RadLex Playbook procedures to LOINC

Our goal was to map every term in the Core Playbook to a LOINC term, and have every LOINC radiology term represented in the unified model. As we progressed through the imaging modalities, updating the LOINC names and mapping the attribute values, we also mapped each procedure term in the Core Playbook to a LOINC term.

To perform the mappings, we used expert review, assisted by custom software and by searching using the freely available Regenstrief LOINC Mapping Assistant (RELMA) program (available from loinc.org/downloads). When mapping, we used information from both terminologies, including the term names, the specified attribute values, and expert knowledge from the terminology developers. The mappings were jointly reviewed and approved by the Regenstrief and RSNA team of domain experts. If an exactly equivalent LOINC term was not found for a given Playbook term, a new LOINC concept was created and a mapping established. The detailed review also uncovered cases where the existing Core Playbook term was ambiguous or duplicative. In such cases, the Core Playbook term status was changed to *deprecated*.

Develop an Integrated Governance Process

The RSNA and Regenstrief also shared similar values in standards development. These shared values included a commitment to openness, free distribution, and consensus-driven decision-making. The organizations

held a strong desire to avoid duplicative work. They viewed the ideal model for cooperation as one that would not only leverage the strengths of each terminology, but also the strengths of each organization.

In Phase I, the organizations worked together on a term sheet outlining the core principles of how they would cooperate on developing and managing the unified terminology. In September 2015, the RSNA and Regenstrief signed a collaboration agreement that instantiated these principles and created a single integrated governance process for managing the unified LOINC/RSNA Radiology Playbook. In Phase II, the organizations used the agreement as the framework for their collaboration. They have now transitioned from unification to ongoing maintenance in Phase III.

Publicly Distribute the Terminology Artifacts

As the unification progressed through each modality, Regenstrief and the RSNA published the completed work with the established LOINC and RSNA Playbook release cycles that occur twice yearly. Beginning with the June 2015 LOINC release (version 2.52), the unified naming conventions were incrementally implemented in LOINC term names, starting first with CT. By the end of Phase I, the organizations had defined a release file format for the LOINC/RSNA Radiology Playbook that included mappings between LOINC and the RSNA Playbook at the procedure code level, and a connection between procedure terms and their attribute values expressed as LOINC Parts and RadLex IDs.

In December organizations published 2015, the first version of the LOINC/RSNA Radiology Playbook with the LOINC version 2.54 release. In that same release, the organizations also published the first version of the LOINC/RSNA Radiology Playbook User Guide. This document is the definitive documentation of the unified model for representing radiology procedures in the LOINC/RSNA Radiology Playbook. Subsequent bi-annual releases contained progressive updates to the terminology, mappings, and documentation.

RESULTS

The process of unifying the two terminologies is now complete. Here, we summarize the key outcomes of our main objectives.

Developing a Unified Model for Radiology Procedure Names

In December 2015, we published the first version of the unified model. The User Guide serves as the definitive documentation of the unified model, and is included as an Annex in the LOINC Users' Guide published by Regenstrief and in releases of the RadLex Playbook from the RSNA. The User Guide contains a definition and description of each attribute. A summary of the unified model attributes is given in Table 3.

Throughout the unification process, we iteratively updated the User Guide with detailed usage notes about how the attributes are applied in the terminology. For example, we recorded the following usage note about mammography subtypes:

> *Obsolete mammography subtypes: We originally included* ***MG.analog*** *and* ***MG.full field digital (FFD)*** *in the list of allowed* ***MG*** *Subtypes to specify analog mammography and digital mammography, respectively, while* ***MG*** *without a Subtype signified a procedure that could be done with digital or analog equipment. However, given that over the past several years digital mammography has become standard practice, we recommend that moving forward,* ***FFD*** *does not need to be specified as a Subtype of* ***MG****. Instead, the generic* ***MG*** *LOINC codes should be used for 2D mammography, which in most cases will be digital images but may also include analog images.*

We also recorded decisions for some of the key issues that were debated and resolved. For example, LOINC previously used the pattern "W & WO" in denoting contrast administration whereas RadLex used the "WO & W" pattern. The governance committee resolved to use the more chronologic "WO & W" pattern in the unified model and noted this in the User Guide. We expect the User Guide to continue being a "living" document reflecting the current state of the terminology as it evolves.

We instantiated the unified model in a new LOINC release artifact that contained the LOINC codes and display name (ie *LONG_COMMON_NAME*) for each procedure, mappings between LOINC and the RSNA Playbook at the procedure code level, and connections between procedure terms and their attribute values that are expressed as LOINC Parts and RadLex IDs. As the unification progressed, finalized content was published in this format with each bi-annual LOINC release.

Transform Existing LOINC Procedure codes into the Unified Model

As the unification progressed through each modality, we transformed all existing LOINC terms into the unified model. This process has iteratively improved the unified model and its application. Table 4 shows the attribute values from the unified model for an example term.

Within LOINC, the transformation involved edits to the formal name, as well as the Long Common Name and Short Name. The iterative development of the unified model resulted in many changes over time. In the major LOINC releases from June 2015 to December 2017, 888 new LOINC radiology terms were created, 180 existing terms were deprecated, and edits were made to more than 5600 existing LOINC terms. (Many terms were actually edited several times over that period). The current LOINC release (version 2.63) contains unified modeling of more than 5800 active terms covering all radiologic imaging modalities and modality-agnostic interventional procedure terms.

Creating a Mapping of Attribute Values between LOINC and RadLex

For these 5800+ terms, there are over 40 000 attribute value relationships linking more than 900 LOINC Parts to RadLex clinical terms. During the period of collaboration, more than 200 new RadLex clinical terms were created to fulfill the attribute values.

Mapping existing RadLex playbook procedures to LOINC

All terms from the RadLex Core Playbook have been mapped to LOINC codes. The current LOINC version (version 2.63) contains mappings to more than 1000 RadLex Playbook procedure codes. The detailed review and mapping efforts led to decisions to deprecate more than 30 RadLex Core Playbook terms.

Develop an Integrated Governance Process

With the unification phases completed, we have now transitioned into Phase 3, which represents an ongoing maintenance of the united terminology as a sustained activity that is jointly maintained and governed by the two organizations. Users can request additions to the terminology through the existing LOINC submission process.[18] We have developed a specialized submission template for users requesting new radiology procedure terms.[18]

Table 3. Attributes of the unified LOINC/RSNA Radiology Playbook model

Attribute Group	Attribute	Description	Multiplicity allowed
Modality		Represents the device used to acquire imaging information and includes sub-attributes *Modality.type* and *Modality.subtype*.	
	Modality.Modality type	Indicates the type of modality, which is primarily represented using the two-letter DICOM modality codes.	Y
	Modality.Modality subtype	Signifies a particularly common or evocative configuration of the modality.	Y
Anatomic Location		The *Anatomic Location* attribute specifies the body part or body region that is imaged and includes the sub- attributes *Region Imaged* and *Imaging Focus*. Our goals are to populate both the *Region imaged* and *Imaging focus* sub-attributes for all terms, except where the *Region Imaged* is the focus of the study.	
	Anatomic Location. Region Imaged	*Region imaged* is used in two ways: as a coarse-grained descriptor of the area imaged and a grouper for finding related imaging exams; or, it is used just as a grouper.	Y
	Anatomic Location. Imaging Focus	*Imaging focus* is defined as a more fine-grained descriptor of the specific target structure of an imaging exam. In many areas, the focus should be a specific organ.	Y
	Anatomic Location. Laterality.Presence	Exams requiring laterality to be specified will be signified with an *Anatomic Location.Laterality.Presence* attribute set to **True**.	N
	Anatomic Location. Laterality	For terms with *Laterality.Presence* = **True**, the Laterality attribute must not be null. Valid values of the *Laterality* attribute are: **Left**, **Right**, **Bilateral**, **Unilateral**, **Unspecified**.	N
View		Indicates the orientation of the patient in the image. This may reflect a combination of patient position and x-ray beam direction, or may alternatively be captured in a named, or eponymous, View.	
	View.Aggregation	Describes the extent of the imaging performed, whether in quantitative terms (eg, 3 or more views) or subjective terms (eg, **Complete**).	N
	View.View type	Names specific views, such as **Lateral** or **Prone**. *View type* is an indicator of the orientation of the patient in an image, often carrying an implication of passive positioning (ie positioning which is not unduly onerous for the patient). This may reflect a combination of patient position and imaging direction (eg x-ray beam direction), and may be captured in a named or eponymous term (eg **Norgaard view**).	Y
Timing		This attribute may be used in conjunction with both the *Maneuver* and *Pharmaceutical* attributes. It specifies the existence of a *Maneuver* or a *Pharmaceutical*, or, in some cases, the existence of one *Maneuver* (or *Pharmaceutical*) and the absence of another. The *Timing/Existence* attribute can be either simultaneous (ie **WO**, **W**) or a combined "before and after" notation that denotes separate sets of images (ie **WO & W**).	Y
Maneuver		Maneuvers relate to a challenge presented to a patient, often with the goal of elucidating or testing some dynamic aspect of anatomy or physiology. They often carry an implication of patient exertion.	Y
	Maneuver.Maneuver type	Identifies the type of maneuver. Used in conjunction with the *Timing/Existence* attribute.	
Pharmaceutical		Specifies the presence or absence of administered contrast agents, radiopharmaceuticals, medications, or other clinically important agents and challenges during the imaging procedure.	
	Pharmaceutical.Substance Given	Specifies the pharmaceutical at a clinically important level (eg It is often sufficient to simply indicate "**Contrast**" without identifying the actual substance).	Y
	Pharmaceutical.Route	Route of administration is denoted by abbreviations, where possible, for medication routes (eg **PO**, **IV**) as specified in the LOINC Users Guide.	Y
Reason for Exam		Describes a clinical indication or a purpose for the study. This may refer to a patient diagnosis, a clinical indication, a clinical status (eg, **Post op**), an intended measurement, altered anatomy (eg, **Endograft**), or some other indicator of the purpose of the exam (eg **Screening**). We have no intention of populating this for all exams, but rather only when necessary for making clinically important distinctions in test names.	Y
Guidance		Identifies image-guided interventions that are modeled with sub-attributes.	
	Guidance for.Presence	Label (ie **Guidance for**) to identify image-guided interventions.	N
	Guidance for. Approach	Identifies the primary route of access used, such as **Percutaneous**, **Transcatheter**, or **Transhepatic**.	Y
	Guidance for.Action	Indicates the intervention performed, such as **Biopsy**, **Aspiration**, or **Ablation**.	Y
	Guidance for.Object	Specifies the target of the *Action*, such as **Mass**, **Abscess** or **Cyst**. For complex procedures, operators may be used to combine instances of the *Guidance* attribute.	Y

Table 4. Example of attributes and mappings for LOINC [36244-2] MR Prostate W contrast IV

Attribute	LOINC Part	LOINC Part Name	RID	RadLex Display Name
Region Imaged	LP199998-8	Pelvis	RID2507	Pelvis
Imaging Focus	LP200001-8	Prostate	RID343	Prostate
Modality type	LP206549-0	MR	RID10312	Magnetic resonance imaging
Timing	LP200088-5	W	RID49853	W
Pharmaceutical.Substance given	LP200085-1	Contrast	RID11582	Contrast agent
Pharmaceutical.Route	LP200078-6	IV	RID11160	Intravenous

Publicly Distribute the Terminology Artifacts

Beginning with June 2015 LOINC release, the LOINC/RSNA Radiology Playbook has been updated and distributed with each LOINC release published by Regenstrief. The RadLex Playbook distributions published by RSNA were updated to include mappings to corresponding LOINC codes and to reflect terms deprecated as part of the review process.

The current LOINC release (version 2.63) is a milestone release because all of the radiology content in LOINC has been transformed into the unified model. In addition, all of the RadLex Core Playbook terms have been linked to corresponding terms in LOINC.

The LOINC/RSNA Radiology Playbook is available for download at no cost from the LOINC website. All of the radiology procedure terms are included in the main release.[19] The specialized LOINC/RSNA Radiology Playbook File containing the detailed attribute values and mappings is available as a standalone download file from the LOINC website.[19]

The LOINC/RSNA Radiology Playbook is published under the LOINC license, which permits its use at no cost worldwide in both commercial and non-commercial applications.[20] The license grants usage rights in perpetuity, and encourages translation into other languages. The license carries only one major prohibition: users cannot use the licensed material to develop or promulgate a different terminology standard for orders or observations. That, of course, would defeat the purpose of having a universal standard in the first place.

DISCUSSION

Together, the Regenstrief Institute and the RSNA have created a unified terminology standard for radiology procedures that builds on the strengths of LOINC and the RadLex Playbook. The LOINC/RSNA Radiology Playbook represents a complete resource of standardized imaging procedure codes and a significant advancement for interoperability.

The Office of the National Coordinator for Health IT lists the unified LOINC content as the standard for imaging procedures in its 2017 Interoperability Standards Advisory.[21] The DICOM part 20 standard for sending Imaging Reports using HL7 Clinical Document Architecture[22] requires a LOINC code for labeling the imaging procedure report, as does the Diagnostic Imaging Report template in HL7's Consolidated CDA standard.[23] Additionally, several authors have described the benefits of using LOINC for radiology procedures.[3,5,7,24,25]

Throughout the unification, we sought to balance semantic clarity and pragmatic application. Local procedure terms are notoriously imprecise, ambiguous, and many are oriented towards naming for reimbursement purposes rather than the broader goal of clinically-relevant interoperability.[3] In general, we tried to avoid unnecessary complexity but did accommodate pervasive "billing-derived" patterns such as "3 or more views." Future work to evaluate techniques for efficiently mapping local terms to LOINC/RSNA Radiology Playbook terms could leverage the enhanced semantics provided by the structured model.

Enhanced by the detailed term metadata in the unified model, health IT applications have greater ability to aggregate and compute across terms for purposes such as determining relevant prior exams, alerting for possible duplicate studies, and organizing procedure reports from multiple institutions. For example, any prior study of the same region of interest could be easily identified using the anatomic location attributes.

Our approach to developing the LOINC/RSNA Radiology Playbook was similar to other terminology alignment efforts[26–30] in that we developed mapping protocols, used semi-automated tools to assist with lexical matching, and established a multi-step content validation plan. Although the sequence of review by different experts varied at times, the team remained consistent. We did not formally study inter-rater reliability. Our approach differs from prior studies in several aspects. First, our overall approach is novel because it represents a true unification rather than an ongoing mapping effort. As such, we did not employ broader-than or narrow-than mappings. We only established mappings between equivalent concepts, and used the RadLex ontology relationships and software tools like RELMA to confirm. If no equivalent term was found, new concepts were added to LOINC (procedure terms) or RadLex (attribute values).

Going forward, the jointly managed LOINC/RSNA Radiology Playbook will be the single, definitive source of standardized radiology procedure terms produced by the Regenstrief Institute and the RSNA. As more institutions map their local codes to the LOINC/RSNA Radiology Playbook and the science of imaging continues to evolve, we expect that we will need to add new terms. Such requests are welcomed as an essential input to an evolving, openly developed standard.

CONCLUSION

The LOINC/RSNA Radiology Playbook provides a universal terminology standard for radiology orders and results. By unifying separate standard terminologies, making the combined product available at no cost, and developing it in an open manner, this work represents a significant advancement for interoperability.

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CONTRIBUTORS

DJV drafted and finalized the article for publication. All authors contributed to the design, application, and publication of the unified terminology. DJV and CC coordinated the organizational agreements between Regenstrief and RSNA. All authors reviewed and approved the final version of the manuscript.

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