Workflow Lexicons in Healthcare: Validation of the SWIM Lexicon

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Abstract For clinical departments seeking to successfully navigate the challenges of modern health reform, obtaining access to operational and clinical data to establish and sustain goals for improving quality is essential. More broadly, health delivery organizations are also seeking to understand performance across multiple facilities and often across multiple electronic medical record (EMR) systems. Interpreting operational data across multiple vendor systems can be challenging, as various manufacturers may describe different departmental workflow steps in different ways and sometimes even within a single vendor's installed customer base. In 2012, The Society for Imaging Informatics in Medicine (SIIM) recognized the need for better quality and performance data standards and formed SIIM's Workflow Initiative for Medicine (SWIM), an initiative designed to consistently describe workflow steps in radiology departments as well as defining operational quality metrics. The SWIM lexicon was published as a working model to describe operational workflow steps and quality measures. We measured the prevalence of the SWIM lexicon workflow steps in both academic and community radiology environments using real-world patient observations and correlated that information with automatically captured workflow steps from our clinical information systems.

Our goal was to measure frequency of occurrence of workflow steps identified by the SWIM lexicon in a real-world clinical setting, as well as to correlate how accurately departmental information systems captured patient flow through our health facility.

Keywords Controlled vocabulary · Data mining · Computer systems

Introduction

In 2003, the Society for Imaging Informatics in Medicine (SIIM) launched a new initiative titled Transforming the Radiological Interpretive Processes (TRIP). This initiative was created as SIIM leadership recognized the sheer volume of data as the biggest challenge to contemporary radiology practice [1–4]. This effort was initiated at a time when numerous disruptive changes to practice were occurring: digital capture and storage of images, multislice computed tomography (CT), volumetric and functional magnetic resonance imaging (MRI), hybrid modalities, and increasing use of relative value and other productivity metrics. These events converged to create anxieties about how radiologists would function effectively in the future. TRIP's initial contribution was to define this problem and raise awareness of the need for research and analysis to be shared by the imaging community.

One of the major barriers to measuring performance metrics across practice settings was the absence of a common lexicon and format to describe even the broadest aspects of radiology practice, from the elements of workflow to common data items within imaging systems. This realization came at a time when researchers in both imaging and medicine in general were increasingly aware of the obstacles posed by a lack of common and agreed-upon terms that could enable metrics

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gathered at one institution to be comparable with those at another [5–12].

The last years of the twentieth century and the first years of this century saw extraordinary efforts to analyze and harmonize terms used to describe the activities of medical disciplines including SNOMED CT, Digital Imaging and Communications in Medicine (DICOM), BIRADS, and the RadLex initiative [13–22]. These lexicons sought to standardize terms around what was imaged (anatomy), how it was imaged (acquisition details), and findings. However, creating a unifying language for radiologic practice *workflows* proved more complex and elusive than generating sets of agreed-upon terms to describe imaging findings.

The creation of federally funded bodies such as the Cancer Bioinformatics Grid and the National Center for Biomedical Ontologies reflected a turn toward more complex ontological exploration of layers of meanings, relations between concepts, and the ways in which these concepts can be effectively imported into shared computational resources [23–44].

During these same years, radiology was pressured to provide evidence-based metrics that can underwrite new practice and performance standards. Earlier efforts to focus on workflow—from practical, economic, or patient-benefit viewpoints—had little traction in the field because they could not be replicated [45–71].

Despite wide and varied efforts at creating a unified language for radiology, each institution continues to have its own descriptors for almost every aspect of the patient's experience, every modality and picture archive and communication system (PACS) vendor continues to have its own set of names for various steps and the ways in which these steps are combined (even in the age of DICOM compatibility), and every radiologist continues to report with an idiosyncratic mix of non-standardized structured reporting and free-text / narrative dictation [72–80].

In 2010, the SIIM TRIP committee identified as a reoccurring theme the lack of a standard lexicon and minable repository as the single greatest barrier to development of the types of studies that will be needed to participate fully in meaningful use investigations, comparative effectiveness research, and business analytics [81–86]. Under the society president Bradley Erickson, MD PhD, an initial TRIP workflow lexicon was developed and christened “SIIM Workflow Initiative in Medicine” (SWIM). The society appointed the group to trial the lexicon at the SIIM 2011 annual meeting. Erickson, Christopher Meenan, and a team of IT experts from the University of Maryland Department of Diagnostic Radiology and Nuclear Medicine conducted a demonstration of a cloud-based test dataset based on the lexicon and proposed a model for consuming the SWIM test dataset via RESTful Web services.

Materials and Methods

The initial version of the SWIM workflow lexicon created in September 2011 is described in Table 1 and enables tracking major workflow events over the lifetime of an imaging study. Two vendors (GE Healthcare, Chicago, IL; AGFA Healthcare, Belgium) participated with academic researchers (University of Maryland—Radiology) in the event to demonstrate they could retrieve this SIIM-hosted data and achieve matching results in their own respective business intelligence software packages. SWIM also defined calculations for several performance metrics; these are seen in Table 2.

One requirement identified by the committee was to determine how many SWIM workflow elements were actually captured in the various information systems that might exist in a typical diagnostic imaging department. Systems such as the radiology information system (RIS), PACS, or digital dictation system each play a critical part in the clinical team workflow, with no one information system containing a comprehensive picture of operational metrics. The committee's goal was to conduct a comprehensive analysis that followed two groups of patients through their experience in our department, and measured each step of the patient's experience with observationally recorded timestamps, and correlated that observational data with data captured automatically in the vended clinical information systems. Completeness of the SWIM implementation was measured by how frequently each step occurred in disparate information systems, and correlates automatically captured data with real-world observational data.

A group of 100 patients were observed as they experienced a typical appointment in a radiology department at one academic medical center in downtown Baltimore. Two medical students enrolled patients in two different care settings: fifty (50) patients were observed in an outpatient imaging center and fifty (50) were observed in an academic medical center outpatient environment. Observers followed patients as they progressed through various workflow steps including arrival, check-in, and begin and ending of diagnostic exams. Each patient visit was tracked using a checklist of SWIM terms with times manually recorded using a mobile device. As patients moved through each area of the department, observers noted the time that they experienced each described workflow step on their checklists. Technologists and other members of the department including front desk staff were made aware that observers were part of a workflow study.

After manually collecting the observed patient data, analysts reviewed digital records for the same patients that were automatically captured in several of department's information systems including the PACS, RIS, and digital dictation system. Timestamps were reviewed to compare observers' collected data with automatically captured information system data. Observed and automatically captured data were

Table 1 Initial SWIM lexicon version 2011-09 describing workflow steps

No.	Step name	Description
1	<i>Order</i>	An electronic order is entered into the order placer system requesting an imaging exam
	OrderReceived	An order was received from OrderPlacer into the Orderfiller
2	TimeScheduled	When the appointment is determined (not the actual appointment time)
	ApptTime	The planned time for the procedure
	MobileLvDept	The time when a technologist leaves department to acquire images in a location outside the department
	MobileArrivePt	The time when a technologist arrives to acquire images in a remote location
3	PtNotify	Patient is notified of the scheduled exam
	PrecertRequest	
4	Precert	Exam is approved by reviewer/third party payor
5	Enterprise ID Remap	Look up and maybe generate enterprise ID for this order and patient
6	PtAccept	Patient accepts appointment or may modify scheduling
	TransportOrdered	Transportation ordered for a patient
7	ClinHx	PACS retrieves configurable list of elements from EMR of ordering physician
8	Protocol	Based on history and indication, the specific image acquisition methods (or cancelation) are specified
9	<i>Arrived</i>	Patient check-in at the imaging facility
	DeskInfo	Patient has returned materials to registration desk
	ReqLabsOrdered	Required lab tests (e.g., Cr, Pg) ordered
	ReqLabsReported	Required lab tests available in medical record
	ReqLabsReviewed	Required lab tests reviewed by performing physician or nurse
10	Changed	The patient has changed into attire required to perform exam
	RoomAssigned	Time when the room is assigned to a patient and procedure
	RoomCleaned	Time when room is cleaned and ready to accept next patient (this happens at end of procedure)
	RoomAvailable	Time when room is clean, and preparation for a specific case begins
	ProcedureReady	Time when patient, room, and others are ready for proceduralist ready to start procedure
	PatientIn	Time when the patient enters the procedure room
	PatientOut	Time when the patient leaves the procedure room
	OralContrastAdmin	Oral contrast given to patient
	Discharge	Time when the patient leaves the imaging department
	PreImageConsult	Discussion with ordering physician for selection of appropriate exam
	<i>FirstImage</i>	The time when the imaging device begins to collect data that will be used to create the first image.
11	NursePrep	Any required steps by nursing completed (e.g., sedation, IV start)
	PatientReady	Patient is in the room and ready for procedure to begin (? dup with ProcedureReady#25)?
12	ImportImage	Import any relevant images from external media or network
13	SafetyCheck	Confirm correct patient, exam, body part
	OrderSupplies	Order any needed supplies / medications for procedure
14	ProcPause	In case of intervention, physician must confirm correct Pt, Proc, Part
15	Consent	Confirm that patient has given informed consent
	SampleSent	Send acquired samples for testing
	BaseImagesComplete	All images are acquired and the routine base images are reconstructed (e.g., CT axials)
16	<i>Complete</i>	All images are acquired and reconstructed (including routine special reconstructions done on the imaging device) on the imaging device
	Alert	Technologist alerts appropriate person (usually the interpreting radiologist for JC crit notification requirements) that images are available (e.g., post-op, stroke)
17	Talk	Physician talks with patient about imaging findings or to confirm imaging findings (e.g., in ultrasound, may also scan)
18	Transfer	All images are transferred out of imaging device to a designated target (image export)
19	Transform	<<Delete—duplicate with automated processing or human processing>>
20	Review	Review that images are complete, no additional/unexpected required to complete diagnosis—performed by interpreting physicians

Table 1 (continued)

No.	Step name	Description
21	<i>Acquired</i>	All raw image data is acquired (reconstruction time is not included). This means that the patient may exit the imaging device
	<i>Prepared</i>	All steps required for reporting completed (images acquired, transmitted to reporting device, post-processing done)
22	AutomatedPProcessingStart	Start of Automatic algorithmic manipulation of images (VOI LUTs, SCIC, AutoWL)
	AutomatedPProcessingComplete	Automatic/algorithmic manipulated images transmitted to reporting system
23	QC	Delete unacceptable images, adjust W/L, confirm correct patient, etc. Typically done by a technologist
24	Split	Separate one large acquisition into two or more examinations using PGP step or otherwise split acquisition into exam sets
25	?algoProc duplicate?	Computer automated processing of image data (e.g., CAD)
	HumanProcStart	Start of human processing of images (e.g., 3D) to be included in examination
26	HumanProcComplete	Completion of human processing of images
27	QC of Proc	Review of the images created or manipulated by either automatic algorithms or humans
	TriageRpt	Report created by non-radiologist (e.g., emergency department physician)
28	PrelimDic	Time when non-final report is captured in electronic audio format
29	PrelimTrx	Non-final report is transcribed into text Physician “claims” a case for interpretation
30	PrelimView	Non-final report is viewed by referring physician
31	Dictated	Physician reviews image and renders a report in electronic audio format Audio transmitted to “speech-to-text” system (human transcriber or speech recognition)
32	Transcribed	The final report is in electronic text format and ready for approval by interpreting physician into final form
33	Reported	Final electronic text report is approved (signed) by the interpreting physician
34	Markup	interpreter labels important features of exam
35	TeachingFile	Create a teaching file entry for current exam
36	Education	Search configurable materials for information relevant to current case
37	ReqConsult	Request another physician to consult on case
38	RespondConsult	Respond to a request from another for a consultation
39	HoldSame	Put current exam in a hold buffer pending more information—same physician will interpret
40	Sendback	Put exam back in the queue of those ready to be interpreted
41	FinalPublish	Final report is sent to ordering physician (EMR confirmation of receipt)
42	DelayedAddl	Additional delayed images are added to an exam
43	CorrectedDic	A corrected report is dictated
44	CorrectedTrx	Correct report is transcribed
45	Corrected	Correct report is reviewed and approved and published
46	Export	An exam is sent to CD or network for export
47	ArchiveCommit	Exam is transferred to an external archive
48	Billed	Information on exam has been transferred to billing system
49	PatientMerge	Exams of a patient with two IDs are merged to one of the IDs
50	ExamReassigned	Change the patient ID for an exam to a new ID
51	DeleteExam	A record entry for an exam and any associated images are deleted
52	ClinFollow	Time when required or recommended clinical follow-up step (e.g., mammo follow-up letters)
53	PersFollow	Trigger by an individual to check on a patient for professional interest
55	Coded	The CPT or ICD codes for the procedure are assigned
56	CodeCorrection	The CPT or ICD codes are updated
57	BillRejection	Time when payor notifies billing system that requested payment has been rejected
	PersonalNotification	The time when important findings are communicated to physician taking care of patient
	CritNotification	The time when a critical finding (JC definition) is communicated to physician taking care of patient
	ResultsViewed	The time when the report is viewed by the ordering physician or their designate
	ResultsAcknowledged	The time when the report is has been viewed and the ordering physicians acknowledges the content

Table 1 (continued)

No.	Step name	Description
	CorrelationReview	Time when pathology or other external results are returned to radiologist
	PrefetchIssued	A request for transfer from archive to PACS is issued
	PrefetchCompleted	When the prefetch request images are completely transferred to PACS
	Opened	Time when the examination is opened on viewing application
	DicatationStartTime	Time when first word of report is recorded (or macro selected, etc.)
	LaunchApplicationForInterpretation	Time when a third party application (e.g., 3D) is launched from the main viewing application
	CloseApplicationForInterpretation	Time when the third party application is closed
	ImagesStoredInArchive	Time when images are copied to the image archive (second copy)
	ClinicalImageView	Time when ordering physician views the images
	PeerReview?	
	IVContastStart	Time when intravascular contrast agent injection was begun
	IV injection contrast ended	Time when intravascular contrast material was completed (what about saline chaser?)
	StatOrder	Ditto for order, except high priority acquisition
	ExamCancelled	
	ChangedCPTOrderedProcedure	For example, change from CT Abd to ABD/Pelvis
	ChangedProtocol	For example, from with IV contrast to no IV contrast or without/with
	ClinicianOpinion	
	PrelimPublish	Time when a preliminary report has been received by a referring physician viewer
	AttemptedCritNotify	Time when critical event notification is begun

compared with the SWIM lexicon to analyze for occurrence frequency, completeness, and timestamp consistency.

Results

We measured the frequency of occurrence of SWIM lexicon workflow steps (lexicon version 2011–09) for 100 patients as they traveled through our department and found that of the 127 proposed lexicon workflow steps, only 46% of those steps were populated by formal timestamps across both manually observed and automatically captured data points.

When calculating which of the 127 lexicon workflow steps were being captured automatically by information systems alone, we found that the rate of occurrence of captured timestamps by our information systems alone was 26%.

Furthermore, different information systems in the department seemed to capture different and unique parts of the workflow. Across the main three information systems in the department (RIS, PACS, dictation), the occurrence of lexicon steps that were only captured by only one information system was an average of 20.5%, the occurrence across two different types of information systems was an average of 4.7%, and the occurrence of workflow steps across all three unique information systems was an average of only 1.6%.

For those lexicon workflow steps that were automatically captured by information systems, we found little overlap with different information systems capturing different parts of the workflow. The RIS captured the majority of lexicon workflow timestamps (18.5%), followed by PACS (11%) and dictation (2%). These results are summarized in Table 3.

Table 2 Sample workflow metrics from initial SWIM lexicon version 2011-09

Index name	Formula
ReportTurnAroundTime	Reported prepared
RoomUtilization	$\text{Sum}(\text{RoomCleaned} - \text{RoomReady}) / \text{Sum}(\text{RoomUnavailable} - \text{RoomAvailable})$
ModalityUtilization	$\text{Sum}(\text{Complete} - \text{ProcedureStarted}) / \text{Sum}(\text{ModalityScheduledUnavailable} - \text{ModalityScheduledAvailable})$
PatientWait	ProcedureStarted Arrived
RoomDuration	PatientOut PatientIn
AcquisitionDuration	Acquired ProcedureStarted
TimeFromStatOrderToAcquisition	Acquired Order
ModalityToPACSTransferTime	Prepared – Complete

Table 3 Results summary manually observed and automatically captured datasets

Total lexicon steps (version 2011)	Count 127	Rate (%)
Manually observed lexicon steps—academic	60	47.2
Manually observed lexicon steps—private practice	56	44.1
Information system automatic capture—academic	32	25.2
Information system automatic capture—private practice	36	28.3
% occurrence of lexicon in all three systems (average)	2	1.6
% occurrence of lexicon in two systems	6	4.7
% occurrence of lexicon in one system	26	20.5
RIS only—prevalence of lexicon workflow steps	23.5	18.5
Dictation only—prevalence of lexicon workflow steps	3	2
PACS only—prevalence of lexicon workflow steps	13.5	11

No single system had a complete view of the entire patient experience or departmental workflow. The RIS contained the majority of populated data points (18.5% of potential lexicon workflow steps), with the PACS (11%) and dictation (2%) following behind. There was very little overlap or redundancy in individual system ability to capture department workflow. When looking at how many of the workflow steps were duplicated in more than one system, we found that only 4.7% of timestamps existed in two systems, and only 1.6% existed in all three. These results are summarized in Table 3. Clearly, these three different systems were capturing different parts of the workflow, and none was a comprehensive source for the entire workflow picture.

Discussion

The goal of SWIM is to help departments improve their workflow and quality initiatives through better access to and better understanding of their own data [87]. Our validation of the SWIM lexicon provided some important insights into current generation information systems and their ability to capture data about patient workflows.

One interesting observation is the prevalence of lexicon workflow steps captured by information systems alone. In real-world environments outside of our manual observation and analysis for this project, the majority of clinical departments will rely on automatically captured timestamps to measure performance. If only 26% of current departmental workflow is captured automatically in information systems, then the majority of workflow steps might not be easily measured and a department's ability to direct continuous quality improvement efforts may be hampered without manual process monitoring.

We should note that it is not realistic to expect that 100% of steps be collected for any particular examination. A number of the steps are specific for invasive and interventional procedures. So are specific for error correction steps (e.g., report

revisions). Nevertheless, there are a number of important steps that occur in nearly all examinations that are not routinely collected by any system.

The SWIM initiative has made significant progress since the 2011 event. In June 2013, the Radiological Society of North America (RSNA) incorporated SWIM workflow steps into their existing RadLex lexicon for radiology information resources, assigning RadLex IDs to SWIM terms (see Table 4) [88].

However, there have also been some complications. Our team faced several challenges while collecting and analyzing the data. Vendor databases were difficult to access and required permission or assistance from vendors to discover. Once databases were made available, we found that understanding data structures and mapping data tables to workflow timestamps was difficult without vendor guidance. Some procedures were grouped together in our information systems, making it difficult to isolate steps. For some cases, there were numerous timestamps for one single event (e.g., when an exam is opened, it also receives a “viewed” timestamp, although only one step is actually performed). Understanding which user performed which workflow step is critical to measuring these data points, and complete understanding of user IDs mapped to technologist or physicians was essential.

The accumulation of the above experience led two of the authors in 2015 to approach the Integrating the Healthcare Enterprise (IHE) consortium with a proposed work item to define a new profile called Standardized Operational Log of Events (SOLE) [89]. The concept of SOLE is to use existing mechanisms that medical device vendors have such as HIPAA logs, and redirects those logs—in SWIM format—to a common log server. This mechanism already exists for an existing IHE profile, Audit Trail and Node Authentication (ATNA). In 2016, SIIM's Hackathon committee published a SWIM test dataset via a REST-based SOLE proof of concept server as part of their Annual Meeting Hackathon event, with the prize winner incorporating SWIM workflow steps in their project [90]. As of October 2016, IHE-SOLE has been approved for development.

Table 4 SWIM Version 2014–03 with RadLex ID's defined

RadLex ID	Name	Description
RID45826	DataAcquired	All raw image data is acquired (reconstruction time is not included). This means that the patient may exit the imaging device
RID45827	AdmitIRPtRounds	The IR consultant and/or physician extender performs daily rounds on IR hospital admits
RID45828	AdmitPtRecovery	Hi-IQ update of ptn admit to the patient recovery area (“patient arrival”)
RID45829	Alert	Technologist alerts appropriate person (usually the interpreting radiologist for JC crit notification requirements) that images are available (e.g., post-op, stroke)
RID45815	ApptTime	The planned time for the procedure
RID45830	ArchiveCommit	Exam is transferred to an external archive
RID45825	Arrived	Patient check-in at the imaging facility
RID45831	AttemptedCritNotify	Time when critical event notification is begun
RID45832	AudioTransmit	Audio transmitted to “speech-to-text” system (human transcriber or speech recognition)
RID45833	AutomatedProcessingComplete	Automatic/algorithmic manipulated images transmitted to reporting system
RID45834	AutomatedProcessingStart	Start of automatic algorithmic manipulation of images (VOI LUTs, SCIC, AutoWL)
RID45835	BaseImagesComplete	All images are acquired and the routine base images are reconstructed (e.g., CT axials)
RID45836	Billed	Information on exam has been transferred to billing system
RID45837	BillRejection	Time when payor notifies billing system that requested payment has been rejected
RID45838	PtChanged	The patient has changed into attire required to perform exam
RID45839	ChangedCPTOrderedProcedure	For example, change from CT Abd to ABD/Pelvis
RID45840	ChangedProtocol	For example, from with IV contrast to no IV contrast or without/with
RID45841	ClinFollow	Time when required or recommended clinical follow-up step (e.g., mammo follow-up letters)
RID45842	ClinHx	PACS retrieves configurable list of elements from EMR of ordering physician
RID45843	ClinicalImageView	Time when ordering physician views the images
RID45844	CloseApplicationForInterpretation	Time when the third party application is closed
RID45845	CodeCorrection	The CPT or ICD codes are updated
RID45846	Coded	The CPT or ICD codes for the procedure are assigned
RID45847	ImagingComplete	All images are acquired and reconstructed (including routine special reconstructions done on the imaging device) on the imaging device
RID45848	ConfirmConsent	Confirm that patient has given informed consent (done in recovery and re-confirmed at proc pause)
RID45849	Consult	Outpatient IR clinic with clinical note entered into EMR
RID45850	ReportCorrected	Correct report is reviewed and approved and published
RID45851	CorrectedDic	A corrected report is dictated
RID45852	CorrectedTrx	Correct report is transcribed
RID45853	CorrelationReview	Time when pathology or other external results are returned to radiologist
RID45854	CritNotification	The time when a critical finding (JC definition) is communicated to physician taking care of patient
RID45855	DelayedAddl	Additional delayed images are added to an exam
RID45856	DeleteExam	A record entry for an exam and any associated images are deleted
RID45857	DeskInfo	Patient has returned materials to registration desk
RID45858	DictationStartTime	Time when first word of report is recorded (or macro selected, etc.)
RID45859	Dictated	Physician reviews image and renders a report in electronic audio format
RID45860	DischargeTime	Time when the patient leaves the imaging department
RID45861	EducationSearch	Search configurable materials for information relevant to current case
RID45820	Enterprise ID Remap	look up and maybe generate enterprise ID for this order and patient
RID45862	ExamCancelled	Examination is canceled
RID45863	ExamReassigned	Change the patient ID for an exam to a new ID
RID45864	ExamExported	An exam is sent to CD or network for export
RID45865	FinalPublish	Final report is sent to ordering physician (EMR confirmation of receipt)
RID46000	FirstImage	The time when the imaging device begins to collect data that will be used to create the first image.
RID46001	ProcedureStart	

Table 4 (continued)

RadLex ID	Name	Description
RID45866	GeneralAnesthesiaEnded	
RID45867	GeneralAnesthesiaStarted	
RID45868	HoldSame	Put current exam in a hold buffer pending more information—same physician will interpret
RID45869	HumanProcComplete	Completion of human processing of images
RID45870	HumanProcStart	Start of human processing of images (e.g., 3D) to be included in examination
RID45871	ImagesStoredInArchive	Time when images are copied to the image archive (second copy)
RID45872	ImportImage	Import any relevant images from external media or network
RID45873	InformedConsent	Informed consent form completed
RID45874	InterpStarted	Physician “claims” a case for interpretation
RID45875	IRPre-Procedure	Patient has entered procedure room and prior to procedure initiation
RID45876	IRImageSelect	IR room techs manually selects and annotates images for transfer from IR fluoro suites to designated target
RID45877	IRMaterialUsage	IR Techs id equipment used during the procedure (and serial numbers where necessary)
RID45878	IRNursePrep	Sedation RN administers medication (if required, anesthesia prepares airway)
RID45879	IRPatientAdmitHospital	Certain IR patients are admitted to the hospital with coord completed by IR physician extenders
RID45880	IRPostProcMonitoring	Recovery RNs monitor patient recovery status
RID45881	IRProcedureComplete	Hi-IQ update that specific IR procedure is complete
RID45882	IRProcedureStart	Hi-IQ update that IR procedure has started
RID45883	IRPtRecovery	IR patients transferred to patient recovery area post-procedure
RID45884	IRRoomReady	Hi-IQ update of “room ready” that denotes IR room is ready for the patient to be transferred from the recovery area to the IR room
RID45885	IRRoomTurnover	Hi-IQ update that room is ready for cleaning
RID45886	IRTechRoomPrep	IR Tech acquires all material/equipment anticipated for intended procedure
RID45887	IRTechSterilePrep	IR Tech undertakes sterile preparation and draping of patient as well as preparation of sterile work table
RID45888	IVInjectionContrastEnded	Time when intravascular contrast material was completed (what about saline chaser?)
RID45889	IVContrastStart	Time when intravascular contrast agent injection was begun
RID45890	LaunchApplicationForInterpretation	Time when a third party application (e.g., 3D) is launched from the main viewing application
RID45891	Markup	Interpreter labels important features of exam
RID45816	MobileArrivePt	The time when a technologist arrives to acquire images in a remote location
RID45817	MobileLvDept	The time when a technologist leaves department to acquire images in a locaiton outside the department
RID45892	NursePrep	Any required steps by nursing or other allied health person completed (e.g., sedation, IV start)
RID45893	Opened	Time when the examination is opened on viewing application
RID45894	OralContrastAdmin	Oral contrast given to patient
RID45813	Order	An electronic order is entered into the order placer system requesting an imaging exam
RID45895	OrderReceived	An order was received from OrderPlacer into the Orderfiller
RID45896	OrderSupplies	Order any needed supplies/medications for procedure
RID45897	PatientIn	Time when the patient enters the procedure room
RID45898	PatientMerge	Exams of a patient with two IDs are merged to one of the IDs
RID45899	PatientOut	Time when the patient leaves the procedure room
RID45900	PatientReady	Patient is in the room and ready for procedure to begin
RID45901	PeerReviewCompleted	End of a case being reviewed for peer review purposes
RID45902	PeerReviewStarted	Start of a case being reviewed for peer review purposes
RID45903	PersFollow	Trigger by an individual to check on a patient for professional interest
RID45904	PersonalNotification	The time when important findings are communicated to physician taking care of patient
RID45905	PostProcCoord	Physician extender follow-up to confirm patient post-procedure status and any need for follow-up consult
RID45819	Precert	Exam is approved by reviewer/third party payor

Table 4 (continued)

RadLex ID	Name	Description
RID45906	PrecertRequest	A request is sent to a third party payor to precertify payment for a procedure
RID45907	PrefetchCompleted	When the prefetch request images are completely transferred to PACS
RID45908	PrefetchIssued	A request for transfer from archive to PACS is issued
RID45909	PreImageConsult	Discussion with ordering physician for selection of appropriate exam
RID45910	PrelimDic	Time when non-final report is captured in electronic audio format
RID45911	PrelimPublish	Time when a preliminary report has been received by a referring physician viewer
RID45912	PrelimTrx	Non-final report is transcribed into text
RID45913	PrelimView	Non-final report is viewed by referring physician
RID45914	ImagesPrepared	All steps required for reporting completed (images acquired, transmitted to reportin device, post-processing done)
RID45915	PreProcCoord	Physician Extender follow-up to coord ptn status along with date/time of procedure
RID45916	ProcedureReady	Time when patient, room, others are ready for proceduralist ready to start procedure
RID45917	ProcPause	In case of intervention, physician must confirm correct Pt, Proc, Part, <i>allergies, informed consent</i>
RID45824	ProtocolSpecified	Based on history and indication, the specific image acquisition methods (or cancelation) are specified
RID45821	PtAccept	Patient accepts appointment, or may modify scheduling
RID45918	PtInfoFormGivenToPatient	The form used to collect information about a patient is given to the patient
RID45818	PtNotify	Patient is notified of the scheduled exam
RID45919	PtSentToChangeAttire	The patient is sent to dressing room to change into appropriate attire for the examination
RID45920	PtSentToNursingCheck	The patient is sent/transferred to meet with nursing
RID28816	QC	Delete unacceptable images, adjust W/L, confirm correct patient, etc. Typically done by a technologist
RID45921	RemapDICOMID	Replace Patient Identifiers in DICOM header—such as for research or teleradiology
RID45922	RemapHL7ID	Replace patient identifiers in an HL7 message such as for teleradiology
RID45923	RemapProcedureName	Replace procedure name/identifier such as for teleradiology
RID45924	Reported [Final report approved]	Final electronic text report is approved (signed) by the interpreting physician
RID45925	ReqConsult	Request another physician to consult on case
RID45926	ReqLabsOrdered	Required lab tests (e.g., Cr, Pg) ordered
RID45928	ReqLabsReported	Required lab tests available in medical record
RID45927	ReqLabsReviewed	Required lab tests reviewed by performing physician or nurse
RID45929	RespondConsult	Respond to a request from another for a consultation
RID45930	ResultsAcknowledged	The time when the report is has been viewed and the ordering physicians acknowledges the content
RID45931	ResultsViewed	The time when the report is viewed by the ordering physician or their designate
RID45932	Review [image review]	Review that images are complete, no additional/unexpected required to complete diagnosis—performed by interpreting physicians
RID45933	RNSafetyCheck	Confirm correct patient, exam, body part
RID45934	RoomAssigned	Time when the room is assigned to a patient and procedure
RID45935	RoomAvailable	Time when room is clean, and preparation for a specific case begins
RID45936	RoomCleaned	Time when room is cleaned and ready to accept next patient (this happens at end of procedure)
RID45937	SampleSent	Send acquired samples for testing
RID45938	SedationEval	Sedation versus anesthesia evaluation complete pre-procedure (patient eval, IV placed)
RID45939	Sendback	Put exam back in the que of those ready to be interpreted
RID45940	SplitAcquisition	Separate one large acquisition into two or more examinations using PGP step or otherwise split acquisition into exam sets
RID45941	StatOrder	Order with high priority acquisition
RID45942	TalkToPt	Physician talks with patient about imaging findings or to confirm imaging findings (e.g., in ultrasound, may also scan)
RID45943	TeachingFileCreated	Create a teaching file entry for current exam
RID45814	TimeScheduled	When the appointment is determined (not the actual appointment time)
RID45944	Transcribed	

Table 4 (continued)

RadLex ID	Name	Description
		The final report is in electronic text format and ready for approval by interpreting physician into final form
RID45945	Transferred	All images are transferred out of imaging device to a designated target (image export)
RID45822	TransportOrdered	Transportation ordered for a patient
RID45946	TriageRpt	Report created by non-radiologist (e.g., emergency department physician)
RID45947	VitalsMonitor	Patient vitals obtained (+/– monitor)
RID45948	Apptconfirmation	Pt called 24 hours in advance for appt confirmation and preimaging instructions (insulin, fasting, etc.)
RID45949	techdosedetails	tracer injection time, dose and site recorded on patient's medical record
RID45950	Tracerinject	IV line placement and tracer injection
RID45951	TracerOrder	Order/confirmation of tracer supply and dose (body weight related) 24 hours prior to imaging
RID45952	PatientSurvey	Patient survey information collection

Conclusion

Lexicons are useful tools that provide a uniform language and foster a shared understanding of knowledge domains. They have been shown to be effective in a variety of industries when used to standardize terms and improve understanding of common components. In healthcare, where the stakes are much higher and where a shared understanding of workflow and performance is paramount, the use of lexicons such as SWIM can be an important and essential part of quality improvement efforts.

We would encourage the clinical imaging industry to adopt lexicons such as SWIM to make it easier for hospitals to improve their operational efficiency. Our group struggled to obtain data timestamps as part of our project but believe that with adoption of SOLE, the SWIM lexicon will fully come into use to enable administrative, practice, and research data mining never before possible.

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