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Development and Representation of a Fall-Injury Risk Assessment Instrument in a Clinical Information System

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Abstract

The potential for informatics solutions to address inpatient safety issues is significant; however, several challenges are associated with the development of patient safety related informatics applications. These challenges include: 1) the identification and/or development of valid and reliable instruments; 2) adequate representation of key safety concepts, constructs, and associated concepts in the clinical information system; and 3) identification of data sources for instrument pre-population. As part of a larger project aimed at identifying and addressing the information needs of clinicians while using a clinical information system, an electronic fall and injury risk assessment instrument is in development to address a hospital-based fall and injury prevention initiative. The concepts contained in the instrument are well represented by Clinical LOINC and the UMLS. Associated concepts have been identified in the existing clinical information system data dictionary for pre-population of the instrument.

Keywords:

Accidental falls, Safety management, Decision-support, Information needs.

Introduction

Patient safety has become a focus of attention in healthcare in the United States, largely in response to the Institute of Medicine (IOM) publication, *To Err is Human*, which reported that annually in the United States there are between 44,000 and 98,000 deaths caused by *preventable* medical errors.[1] In a more recent report, *Patient Safety: Achieving a New Standard for Care*, the IOM highlights the importance of strengthening the information infrastructure that supports clinical care by including processes to provide immediate access to patient information and decision support tools for the prevention of medical errors.[2] Additional recommendations in this report include: 1) development of methods to capture patient related safety information and for risk assessment (including patient falls); 2) development of tools with data driven adverse events detection; and 3) the use of standardized health terminologies for the adequate representation of safety related concepts.

Patient falls are a persistent yet unsolved safety issue and are one of the highest causes of injury and subsequent morbidity and mortality in the inpatient healthcare environment.[3] Internationally, 2-3.5% of hospitalized patients are reported to experience falls.[4-7] Fall rates differ according to the type of unit, with geropsychiatric patients having the highest incidence.[8] In the inpatient environment, standardized assessment instruments have been developed to predict who will fall. These tools facilitate data collection and provide a consistent method of measuring patient risk status; however, the validity of these instruments is inconsistent across care areas and between institutions.[9] Standardized instruments have been adapted for nursing clinical information systems, unfortunately, the impact or use of these informatics-based instruments has not been reported.

A recent Australian general practice falls prevention project, Falls Risk Assessment and Management System (FRAMS**),** used Unified Modeling Language (UML) techniques to model fall risk assessment and prevention processes. The resulting system provides decision support and guidelines for general practice physicians to identify interventions tailored to specific risk factors.[10] Deficiencies were noted in the ability for terminologies to adequately represent many falls risk concepts, particularly those related to fall prevention. Unfortunately, the impact of this application has not yet been reported. Other informatics solutions addressing falls risk are limited to digital versions of paper-based community screening instruments, often time-consuming tools, even in electronic form. [11, 12] Although the above applications capture key components of falls risk, their focus is on elderly individuals in the community. As such, these processes are not entirely suitable for use in the acute care environment.

As part of a larger project designed to address the information needs of clinicians while they are using the clinical information system,[13] and as part of New York Presbyterian Hospital (NYPH) patient safety efforts, a point of care "Fall and Injury Risk Assessment" instrument is being developed. Challenges inherent to the development of an electronic version of the instrument include: development of an evidence-based, reliable and valid instrument; adequate representation of risk assessment concepts; and identification of data sources for instrument pre-population.

Background

New York Presbyterian Hospital (NYPH) is a large teaching hospital in Manhattan, New York. The existing clinical informa-

tion system (CIS) is a Web-based system that includes interfaces with pharmacy, laboratory and radiology systems and that enables clinicians to enter and to view clinical information. The data is housed in a clinical data repository which is a relational database containing information such as patient demographics, laboratory results, assessment and treatment reports, notes, pharmacy orders, discharge diagnoses as well as billing and administrative data.

Instrument Development

In response to an institution-wide fall and injury prevention initiative, a team was formed to assess and improve upon the existing hospital fall prevention policy. This team sought to develop an instrument that would not only include 'risk of injury' as a component of risk level but that also would provide a method for stratifying risk levels by which to tailor nursing interventions.

Representation of Fall-Injury Risk Concepts

Accurate representation of fall and injury risk concepts facilitates data sharing and re-use in the CIS. Bates advocates for improved representation of quality concepts in standardized terminologies to provide the necessary infrastructure for such data sharing and re-use.[14] The capability of existing terminologies to provide coverage for safety-related concepts is unclear, however, recent efforts are working towards the establishment of data standards. The feasibility of representing standardized assessment instruments in concept-oriented terminologies is well established.[15, 16] Concept-oriented terminologies are those in which each concept has unique characteristics that are defined by an explicit semantic structure, facilitating unambiguous concept representation. Ideally, the fall and injury risk items will be represented in a concept-oriented terminology, providing a method for data sharing and re-use, for example, for the analysis of aggregate fall-injury risk data.

UMLS Metathesaurus

The Unified Medical Language System (UMLS) Meta-thesaurus is a database of concepts derived from existing biomedical terminologies. Concepts from existing terminologies that are incorporated into the UMLS are each assigned a concept unique identifier (CUI), a string unique identifier (SUI) and a language unique identifier (LUI).

The UMLS also includes a Semantic Network, consisting of a set of semantic types that are interconnected by semantic relations. Each concept in the Metathesaurus is identified as being of one or more semantic types and has the potential to relate to other concepts, based on the semantic relations allowed by its semantic types. The relationships within the existing terminologies, and the relationships between concepts in different terminologies, are represented using this method.

LOINC

The Logical Observation Identifiers Names and Codes (LOINC) database is a concept-oriented, public domain terminology originally developed to represent laboratory and clinical test results. Clinical LOINC provides extensions to laboratory LOINC that capture clinical observations and measures. Table 1 outlines Clinical LOINC semantic structure adapted for standardized assessment measurements.[16]

Table 1: Elements of the Clinical LOINC semantic structure for standardized assessment measurements

Element	Definition
Component	Attribute of a patient; name of scale item
Property	Kind of quantity related to a substance: i) Finding - atomic clinical observation OR ii) Impression - diagnostic statement
Timing	Interval of time: i) Point - single point in time OR ii) Interval - more than one point in time e.g. 24 hrs
System	Individual or group who is object of measurement: i) Patient/Client; ii) Family; iii) Caregiver; iv) Child; v) Community; vi) Parent-Child dyad; and vii) Patient-Caregiver dyad
Scale	Type of scaling used: i) Quantitative; ii) Ordinal; iii) Nominal; iv) Narrative
Method	Method of completing the measurement: i) Observed; ii) Reported

Existing Data Sources and Infrastructure

ICD9-CM

The *International Classification of Diseases, 9th Edition, with Clinical Modifications* is a standard coding system for healthcare encounters. Identification of ICD9-CM concepts related to fall-injury risk provides a method to pre-populate the electronic risk assessment instrument based on stored patient data.

Medical Entities Dictionary (MED)

The Medical Entities Dictionary (MED), a concept-oriented metadata dictionary in use at NYPH, is a repository of medical terms arranged in a semantic network. The concepts contained in the MED include those from ICD-9CM, the UMLS, and LOINC. These concepts represent terms and processes that capture the meanings associated with healthcare-related observations, procedures, functions and therapies.[17, 18]

The entities in the MED are defined in a frame-based format in which the attributes of an item are characterized by the frame slots and their values. The slots can be one of two types, semantic or string. Semantic slots are those that define relationships and thus are able to represent meaning between concepts. Some slots are hierarchical, such as 'sub-class of' (which identifies the immediate parent of the concept) and 'descendant-of' (which identifies the concept's ancestors). Other semantic slots are nonhierarchical, such as 'has-parts' and 'part-of', a reciprocal pair. String slots provide textual information related to concepts, such as preferred names, synonyms, and codes in other terminologies.[15, 17, 18]

Concepts related to standardized assessment instruments have been incorporated into the MED in earlier work. This was accomplished by representation of non-laboratory concepts in Clinical LOINC, specification of semantic relationships between concepts, and identification of the most suitable location for the concepts in the MED.[15]

Clinical Data Repository

The clinical data repository (CDR) is a centralized repository that stores patient data. The data are represented using MED codes in addition to LOINC codes, ICD-9 CM codes and other codes from related terminologies.

Infobutton Manager

The Infobutton Manager (IM) is a common gateway interface (CGI) application that can extract relevant 'context' information from a location in the CIS in which a clinician is working. Context information includes user data such as ID, location, and type, patient data such as date of birth and gender, and MED Codes associated with the specified location in the CIS. The IM then links the 'context' information to several Web-based resources that can provide answers to any of several clinical questions. [13]

Methods

Instrument Development

The fall and injury prevention team identified thirty fall and injury predictor variables and conducted a case-control study to examine the predictive validity of these items. The case-control study was carried out via a retrospective chart audit for 90 patients who had fallen and 90 patients who had not fallen, controlling for admission unit and time period. Stepwise logistic regression statistical analysis was used to identify the best fitting fall prediction model. Cutoff points for risk levels were determined based on ROC curves.

Representation of Patient Safety Concepts

The UMLS Knowledge Source Server was used to identify CUIs for each item in the risk assessment instrument. For items that were not exact matches, the concept was deconstructed to search for possible post-coordination terms. Fall and injury risk assessment concepts were represented in LOINC semantic structure for future integration into the MED.

Existing Data Sources and Infrastructure

ICD-9CM codes for the fall and injury risk concepts were identified via a web-based instrument developed to search the MED. The semantic structure for standardized assessment in the MED was examined to determine the need for extensions to adequately represent the fall and injury risk assessment items.

Results

Instrument Development

Logistic regression statistical analysis identified a best fitting model that includes five items: history of a fall in the past seven days, male gender, unsteady gait and not using an assistive device, impaired cognition, and the use of one or more sedatives. The items in the model have been incorporated into a new instrument such that each item will be represented as a Yes/No value. Risk level was stratified into four groups - low, moderate, high and very high. The final model has a sensitivity of 67.4%, and a specificity of 60%.

Representation of Patient Safety Concepts

Eleven of the eighteen relevant concepts (61%) were exact matches in the UMLS. The remaining concepts can be represented by post-coordination. (See Table 2)

Table 2: UMLS Representation of Fall & Injury Risk Concepts

Fall Risk Item		**UMLS Concept**
Fall(s) in past 7 days		Fall + Temporal Code
Gender = Male		Gender Male
Impaired Cognition		Impaired Cognition
Unsteady Gait and NOT using Assistive Device		Unsteady Gait + Assistive Device
1 or more Sedatives		Sedatives
Injury Risk Item		**UMLS Concept**
History of adult fracture		History + Fracture + Age
Metastatic bone disease		Secondary Malignant Neoplasm of the Bone
Osteoporosis		Osteoporosis
Frailty		Frailty
Antiplatelet therapy		Antiplatelet therapy
Anticoagulant therapy		Anticoagulant therapy, NOS
Thrombolytics		Thrombolytic Therapy
Increased Prothrombin Time		Prothrombin Time + Increased
Increased Partial Thromboplastin Time		Partial Thromboplastin Time + Increased
Increased International Normalized Ratio		International Normalized Ratio + Increased
Decreased Platelet Count		Platelet count + Decreased
Coagulopathy		Blood Coagulation Disorders
Thrombocytopenia		Thrombocytopenia

Concepts with "+ " will require post-coordination

Existing Data Sources and Infrastructure

Figure 1 highlights the processes and relationships between components necessary to develop and integrate the instrument into the CIS. First, the paper-based instrument is validated and tested for reliability. Next, the items are represented in the MED using LOINC semantic structure and UMLS concepts.

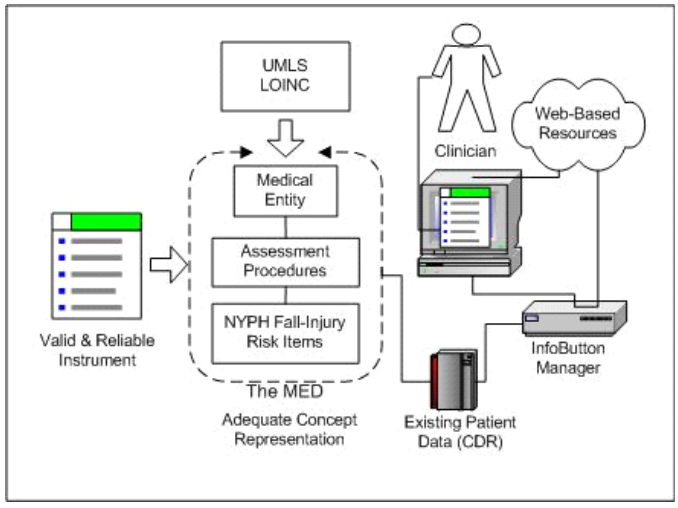

Figure 1 - Development Components for Risk Instruments

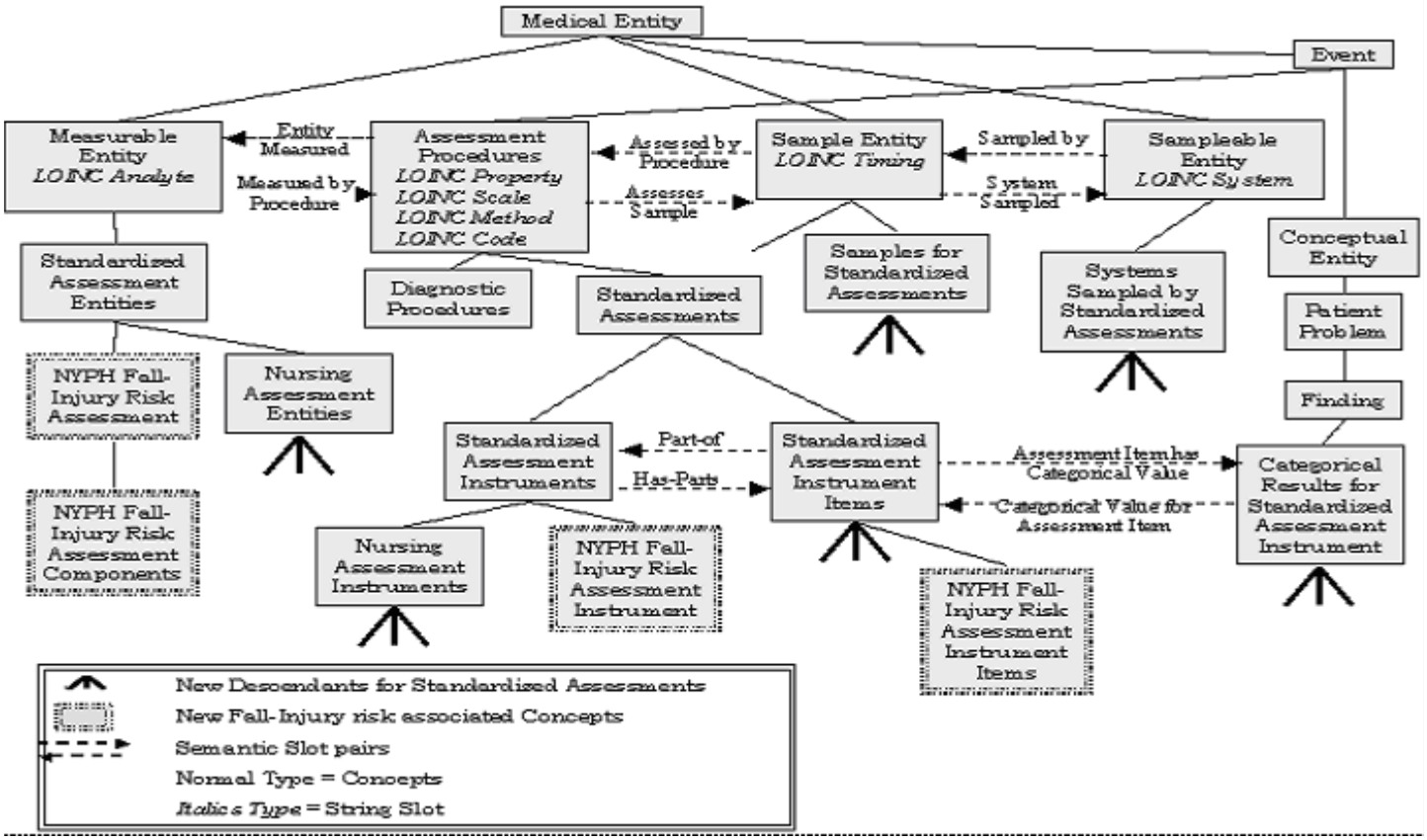

Figure 2 - Relevant Hierarchy Representation in the MED of Fall-Injury Rosk Concepts

Existing patient data from the CDR and the Web-based resources are captured via the IM [13] which then inserts the appropriate and available data or links into the instrument. The clinician then has access to the instrument containing real-time patient information relevant to the risk assessment and links to appropriate associated resources.

An ICD9-CM search yielded matches for four of the eighteen concepts (22%) including metastatic bone disease, coagulation defects, osteoporosis and thrombocytopenia. Fall and fracture-related concepts were also represented, though without capturing temporal meaning. Overall ICD-9CM representation was 33%.

Table 3 provides an example of the LOINC semantic structure used to explicitly represent these items. All of the items are ascribed a *value set* of '0' or '1', which adequately represents the Yes/No nature of the instrument. Additionally, the *property* of each item is characterized as a finding because the data will be based on clinical observations rather than on diagnostic processes.

Building on earlier work,[15] Figure 2 demonstrates the relevant hierarchies and LOINC semantic relationships of NYPH fall and injury risk assessment concepts. No new extensions were required; instead, four new concepts were added as children of the existing concepts.Discussion

Several challenges are inherent to the development of a patient safety related informatics application. First, the application must reflect the best available evidence, which in this case should be demonstrated by a valid and reliable risk assessment instrument. Second, the concepts related to the application must be adequately represented by existing terminologies which can provide the opportunity for data sharing and data re-use. And third, existing data sources must be identified to streamline informatics processes which can ultimately enhance the clinical decision making process.

Table 3: LOINC representation of one risk concept

Element	Category
Component	Falls in past 7 days
Property	Finding
Timing	Point in Time
System	^Patient
Scale	Nominal Scale
Method	Observed NYPH Fall-Injury Risk Assessment
Value Set	0 = No; 1=Yes

We have developed and validated a standardized fall and injury risk assessment instrument, which will ultimately be integrated into the CIS. The UMLS adequately represented the fall and injury risk concepts although some terms will require post-coordination, particularly those that reflect temporal nuances of the risk assessment items (e.g. fall in past 7 days, history of adult fracture). This is related to the deficiencies noted by the Australian general practice group, which accentuates the need to standardize the representation of quality concepts. Identification of ICD9-CM related codes demonstrates that items in the CDR are available for integration into the instrument. This will provide a method for the instrument to pre-populate the elements using

data available in the CIS such as 'metastatic bone disease'. However, the ICD9-CM covered only 33% of the items, which indicates that these codes alone do not provide sufficient relevant information; consequently other data sources must be utilized to capture the complete information.

LOINC semantic structure was effectively used to represent fall and injury risk items. This is consistent with the concept-oriented nature of both LOINC terminology and the MED in that the explicit representation of a concept allows for atomic deconstruction and subsequent mapping to a related concept-oriented terminology. Subsequent integration into the local data dictionary will require minimal work because of earlier representation of standardized assessment instrument concepts. This project also supports previous work that identified the usefulness of using the LOINC semantic structure as a method of representing standardized assessment instruments, thereby facilitating integration of those concepts into the MED.

Conclusion

Integration of a standardized fall and injury risk assessment instrument is an example of a patient safety related informatics solution in which informatics challenges needed to be addressed. We have developed and validated a risk assessment instrument that will be integrated into the CIS. We successfully represented the risk assessment items in Clinical LOINC, ICD9 and the UMLS. Locations for the items have been identified in the local concept-oriented data dictionary. Additional items in the clinical data repository were identified and further work in that area will likely provide more options for pre-population of the electronic instrument. The adequate representation of patient safety related concepts and processes can only but improve clinical decision-making and thus improve patient safety in the care delivery environment.

Acknowledgments

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