Toward the Creation of an Ontology for Nursing Document Sections: Mapping Section Headings to the LOINC Semantic Model

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Abstract
Clinical documents consist of groups of information (e.g., sections, panels, batteries). In order for clinical information to be shared, consistent formal naming principles for document components are desired. The purposes of this study were 1) to identify the components of existing electronic nursing documents, and 2) to represent them with Logical Observation Identifiers, Names, and Codes (LOINC) semantic model to examine the sufficiency of LOINC for non-ambiguously defining nursing document components as a prerequisite step toward the creation of an ontology for nursing document components. Section headings (n=308) were retrieved from the Eclipsys CIS; 38% were successfully represented with an inter-rater reliability of 0.73. Inconsistency exists in the names of the current section headings. In order for LOINC to better represent the document components, currently missing nursing section headings need to be added and extension of the attributes is desired.

Keywords Electronic Nursing Document components, Electronic Health Records, Document Ontology, LOINC, Document Section Headings

Introduction

Clinical documents consist of groups of information, which is a set of data that are expected to be relevant [(1)]. Definition of the content and structure of electronic clinical documents has been challenging since the granularity of information is irregular, the topics of information are various, and there is no predefined order among the topics [(2)]. Organization of clinical documents is a part of clinical information system (CIS) modeling. However, the standardization of document component names using formal semantic principles has less been focused [(2-4)]. In order for clinical information to be shared by different healthcare professionals and different information systems, consistent formal naming principles for document components (e.g., section headings, panels, batteries, data items) are desired [(5)].

Natural language processing may support the extraction and interpretation of clinical information from electronic health records (EHRs), however, it might be not as effective to reuse the particular information for other purposes, if the names of sections are not standardized [(2)]. The categorization of the document components may support the navigation of EHRs and specification of an appropriate level of granularity for the record components [(6)]. In addition, there is increasing need to filter the most meaningful information from EHRs in simple and effective ways.

Nurses are major EHR users as they provide twenty-four hour patient care and coordinate the patient care provided by other clinicians [(7)]. Nursing documents provide an overview of clinical progress of a patient and may be reviewed by other clinicians.

The Health Level 7 (HL7)/LOINC document ontology was developed for clinical document exchange specifications across various systems[(8, 9)]. The ontology specifies clinical document names and provides their LOINC codes. The LOINC database includes some codes for document components; however, the sufficiency of LOINC to define the components of nursing documents needs to be examined. The purposes of this study were 1) to identify the components of nursing documents from an existing electronic nursing documentation system, and 2) to map them into LOINC to examine whether LOINC can non-ambiguously define the components of nursing document as a prerequisite step toward the creation of an ontology for nursing document components.

Background

Related Research

European Committee for Standardization (CEN)
CEN ENV13606 [(6, 10)] studied categorization of clinical document components for supporting the navigation of EHRs and specifying an appropriate level of granularity for the record components [(6)]. The names of document components were selected from multiples sources (e.g., computer screen forms, clinical data templates, standard reports and summaries) [(6)]. The project team grouped and described the component of documents in a 4-level of hierarchy: 1) folder (e.g., GP record, Diabetes Care Record), 2) composition (e.g., Vital Sign Chart, Discharge Summary), 3) headed section (e.g., Past Medical History), and 4) cluster (e.g., Heart Sounds, White Blood Cell Count)[(11)]. The sections headings include Former Patient History, Ongoing Problems & Lifestyle, Present Findings, Regular Interventions, Present Interpretations, Planned Activities, etc. How-

ever, they are not broadly used since they are not easy to understand and possibly too coarse grained [11].

British Heading Project In the United Kingdom, a national research project, "Heading project," was conducted on the national standards of clinical information structures in order to facilitate the effective communication of clinical information. A specified set of headings were proposed through consultation and expert forums from the clinical professions, system vendors, and academics in health informatics [5]. The naming of the section headings was focused to standardize the communication of EHRs. The proposed headings are categorized into Health Characteristics (e.g., Family History, Social Circumstances, Examination Findings, Test Results, Diagnosis, and Outcome), Actions (e.g., Assessment, Treatment, Clinical Administration, and Participation), and Views (e.g., Problems, Alerts, Reason for Encounter). The headings reflect clinician activities with respect to clinicians' functions over time. While the headings are expected to be an standard for all clinical systems within the UK health system, they are not considered to capture the fine detail of clinical terminology [4].

VIPS Model (a Swedish acronym for well-being, integrity, prevention and safety) developed to support the systematic documentation of nursing care, consists of keywords on two levels: 1) The first level of the keywords, such as Nursing History (e.g., Health history), Nursing Status (e.g., Understanding of health and illness), Nursing Intervention (e.g., Interventions to identify social network); and 2) the second level of keywords consisting of subdivisions for Nursing History, Nursing Status, and Nursing Interventions. The model focuses on the content with relevance for patient care rather than the structure and format of records [12, 13].

HL7 Clinical Document Architecture (CDA)

A CDA document is a defined information object that can include text, images, sounds, and other multimedia content [14]. CDA documents are encoded in eXtensible Markup Language (XML). Using XML, CDA makes electronic documents both machine-readable and human-readable [14]; thus, they can be processed electronically and can also be retrieved by clinicians. Recently, the HL7 CDA Release 2 explicitly specified the body of a CDA document. The body of a CDA document consists of one or more segment tagged with <section>. Section has two subcomponents: 1) tagged with <text> for narratives (unstructured data), and 2) tagged with <entry> for coded representation (structured data) that corresponds to the <text> information [8]. Non-ambiguous document component names for inclusion in CDA-based documents will facilitate data reuse and sharing of documents among institutions.

LOINC Semantic Model

LOINC is a publicly available database that provides the names and codes for identifying laboratory and clinical observations [15]. LOINC codes are used for transmitting clinical information by being included in the HL7 messages. Currently, LOINC contains nursing assessments from standardized nursing vocabularies recognized by American Nurses Association (ANA) [16]. The LOINC semantic model consists of six major elements: Component, Property, Method, Time, Scale, and System/Sample [17]. Table 1 summarizes the elements of LOINC semantic model and shows an example of representation of a nursing document section heading. The semantic model was shown to be adequate for representing standardized assessment measures in a previous study [15].

Table 1 LOINC semantic model (e.g., Travel Assessment)

Element	Description	Travel Assessment
Component	Characterizes the substance or entity that is measured, observed, or educated.	HISTORY OF TRAVEL
Property	Characterizes the feature or attribute of the component	FIND
Method	Characterizes the procedure used to make the measurement or observation.	REPORTED
Time	Is the interval of time which the observation or measurement made over.	PT
Scale	Is the scale of the measure, such as quantitative, ordinal, nominal, or narrative.	NOM
System /Sample	Characterize the system or body part about which the observation was made.	PATIENT

Methods

All types of nursing documents from the Eclipsys CIS [18] at Columbia University Medical Center, New York, were used as sample for this study. In the Eclipsys CIS, the computer screen form of each nursing document type is composed of two parts: 1) document navigation area on the left hand side frame and 2) data entry area on the right hand side frame. The document navigation area consists of labels in a two-level hierarchy and each label is linked to a collection of information in the data entry area. The names of labels were considered as document section headings. The names of section headings were extracted from all nursing documents

types, and then mapped into LOINC using RELMA, the LOINC mapping assistant. The mapping was completed by the primary author and then validated using inter-rater reliability. Inter-rater reliability between two investigators was calculated by using the kappa statistic on a random sample of 15 % of the section headings.

Results

Forty-three different types of nursing documents were retrieved from the Eclipsys CIS. The nursing documents include Nursing Adult Admission History; Nursing Anesthesia Miscellaneous Note; Nursing Mammography; Nursing Pre-Op Checklist; Nursing Progress Note, Psychiatric; Nursing Central Line Dressing Change Procedure; Nursing Discharge Note; Transfer/Sending Unit Note, etc. Three hundred and eight section headings were identified. The section headings mostly exist in a two-level hierarchical structure (Table 2).

Table 2 Section headings of Nursing Adult Admission History

Example Section Heading
.Admitting Diagnosis & Health Issues
.Allergies
.Admission
..Past Medical History
..Pain Assessment
.Medication, Herbals, and Nutrition Supplements
..Current Medication
..Medication Comment
.Self Care & Functional Screens
..Self Care History and Functional Screen
.Social History
.Belongings and Unit Orientation
.Education Assessment
.Advanced Directives

.: level 1 section; ..: level 2 section

Some section headings exist in multiple documents; for instance, Nursing Adult Admission History and Nursing OB Patient History share a section heading, Self Care History. Nursing Adult Admission History, Nursing CT Scan, and PACU Discharge Criteria share a section heading, Allergies. In addition, nursing procedure documents have identical section headings (Table 3).

Table 3 Section headings in multiple nursing procedure documents

Nursing Document	Common Section Heading
Nursing Ultrasound	Radiology Procedure
Nursing Nuclear Medicine	Allergies
Nursing MRI	Lab Results
Nursing Mammography	Pre-Transport Vitals
Nursing IVP	Procedure
Nursing CT Scan	

Thirty-eight percent of section headings were mapped to LOINC (Table 4). Inter-rater reliability was 0.73 ($p<.0001$) with a 95% confidence interval (0.4564, 1.0092).

The components of a nursing document were compared with those of the previous research (Table 5).

Table 5 Comparison of the document sections with UK headings in a discharge note

Eclipsys Section Headings	British Section Headings
Nursing Discharge Needs	Discharge Note
.Discharge	.The patient's needs
..Discharge Needs	.Interventions performed to date
Nursing Discharge Note	.Outcomes of interventions
.Patient Discharge	.The patients present status
..Discharge Information	
..Patient Status	

.: level 1 section; ..: level 2 section

Table 4 Section headings mapped to LOINC codes

Section Heading	Scale	Component	Method	Property	Time	System	LOINC
Allergies	NAR	HISTORY OF ALLERGIES	REPORTED	FIND	PT	^PATIENT	10155-0
Braden Scale	-	BRADEN SCALE SKIN ASSESSMENT PANEL		-	PT	^PATIENT	38228-3
Past Medical History	NAR	HISTORY OF PAST ILLNESS	REPORTED	FIND	PT	^PATIENT	11348-0
Social History	NAR	SOCIAL HISTORY		FIND	PT	^PATIENT	29762-2
Stated Reason for Admit	NAR	CHIEF COMPLAINT	REPORTED	FIND	PT	^PATIENT	10154-3
Prior Illness	NAR	HISTORY OF PAST ILLNESS	REPORTED	FIND	PT	^PATIENT	11348-0
Family Health History	NAR	HISTORY OF FAMILY MEMBER DISEASES	REPORTED	FIND	PT	FAMILY	10157-6
Smoking History	NAR	HISTORY OF TOBACCO USE	REPORTED	FIND	PT	^PATIENT	11366-2
Feeding	NAR	FEEDING AND DIETARY STATUS	REPORTED	FIND	PT	^PATIENT	11320-9
Breast	NOM	PHYSICAL FINDINGS	OBSERVED	FIND	PT	BREASTS	10193-1
Dressing	ORD	DRESSING	OBSERVED.QAM	FIND	PT	^PATIENT	28409-1
Ambulation	ORD	AMBULATION	OBSERVED.QAM	FIND	PT	^PATIENT	28413-3
Emotional Status	ORD	EMOTIONAL STABILITY.STATUS	OBSERVED.OMAHA	FIND	PT	^PATIENT	28274-9

Table 6 Examples: redundancy

Section Heading	Scale	Component	Method	Property	Time	System	LOINC code
Allergies	***NAR***	HISTORY OF ALLERGIES	REPORTED	FIND	PT	^PATIENT	10155-0
	NOM	HISTORY OF ALLERGIES	REPORTED	FIND	PT	^PATIENT	8658-7
Breast	NOM	PHYSICAL FINDINGS	OBSERVED	FIND	PT	***BREAST***	32422-8
	NOM	PHYSICAL FINDINGS	OBSERVED	FIND	PT	***BREASTS***	8696-7

Table 7 History of Mental Illness

Scale	Component	Method	Property	Time	System	LOINC code
NOM	HISTORY OF PSYCHIATRIC SYMPTOMS & DISEASES	REPORTED	FIND	PT	^PATIENT	8685-0
NOM	HISTORY OF SYMPTOMS & DISEASES	REPORTED	FIND	PT	PSYCHIATRIC	11365-4

Discussion

Various kinds of inconsistency across various documents exist in current section headings from our data set: 1) inconsistent naming of section headings with identical content (e.g., 'Self Care & Functional Screens' and 'Self Care History and Functional Screen', 'Nutritional Screen' and 'Nutrition Assessment'); 2) inconsistent distribution of section headings (e.g., Table 5); and 3) inconsistent levels of specification in a hierarchical structure of section headings (e.g., 'Blood Type' and 'Functional Screen'). Especially, some section headings look more like a name of data item than a name of section heading (e.g., Parity; Location of Pain; Have you had close contact with someone who had a contagious distress?; AFP).

Some section names were ambiguous, thus, they can be interpreted in different ways (e.g., 'Gonorrhea' for 1) a name of a lab test or 2) history of gonorrhea as a nursing assessment). Several section headings were almost the same name with its document name, e.g., Delivery Transfer Note (a section heading) and Nursing Delivery Transfer Note (a document name). In addition, a section, 'Admission Data' was possibly mapped to 'ADMISSION EVALUATION NOTE' while it could be counted as no match because 'ADMISSION EVALUATION NOTE' was considered as a document name rather than a section name. There is a hierarchy among the components of the nursing documents, e.g., a section heading, Bedside Procedure, has its sub-components, such as Procedure Performed, Medication Given, and Bedside Tests. It is challenging to represent the hierarchy of document components using LOINC semantic model. Currently, LOINC distinguishes document names and document section names by using different values for an attribute Scale, i.e., DOC and NAR; however, there is no difference among sections, subsections, and data elements.

Therefore, a formal ontology for structuring document components (e.g., sections, sub-sections, data items) is necessary for naming the components consistently in the aspects of categorization of information, granularity of the information, and internal hierarchy of the information. This issue might influence the degree of markup for CDA document template.

Several issues were found in LOINC mapping process. First of all, some LOINC codes appear to be redundant, i.e., some of section headings can be mapped in different ways (Tables 6 and 7). For instance, a section heading, Allergies was mapped to two different codes, HISTORY OF ALLERGIES with NOM and HISTORY OF ALLERGIES with NAR. Separate codes exist for Breast, such as PHYSICAL FINDINGS with BREAST [system] and PHYSICAL FINDINGS with BREASTS [system].

Second, the level of specification between a section heading and its corresponding LOINC concept is not equivalent in some cases (i.e., either one is broader concept). Sometimes, a section heading is less specific than its corresponding LOINC concept, e.g., for Fetal Position, two different LOINC codes exist: FETAL POSITION with PALPATION [Method] and FETAL POSITION with US [Method], while sometimes a section heading is more specific than a LOINC concept, e.g., Current Pregnancy and Past Pregnancy, can be mapped to the same LOINC code, PREGNANCY STATUS. In addition, the matching was partially completed in several cases, e.g., 'Sleeping Pattern' mapped to SLEEP AND REST PATTERN.STATUS; 'Upright Balances/Safety' mapped to ASSESSMENT OF SAFETY SECTION.

Third, some section headings conveying nursing assessments are currently missing in LOINC, such as Edema; Burn; Advance Directives; Religion; Culture (meaning, socially transmitted behavior/thought patterns); and Understanding of Meds. These section headings need to be added LOINC to improve the expressiveness of LOINC to define the components of nursing documents.

Finally, there is no match for the section headings conveying nursing interventions, such as Education;

Emotional Care; Observation; Anxiety Prevention and Reduction; Belongings and Unit Orientation; Central Line Dressing; Oriented to Unit; Other treatments used to relieve pain; and Patient Education Functional Status. Nursing interventions are beyond the scope covered by LOINC. In this case, other formal semantic models might be needed to represent the section headings expressing nursing intervention and care plan for more complete representation of nursing document sections in EHR.

Extension of the values for the attributes of LOINC semantic model might be an applicable resolution for LOINC to better represent the document components in a manner consistent with current document structures, e.g., Property may be used to define the class of information, such as sections (Family Health History), panels (e.g., Glasgow Coma Scale), batteries (e.g., Blood Pressure), and data elements (e.g., differential White Blood Cell Count). In addition, some section headings have different meanings among diverse healthcare professionals. For instance, 'activity' is used 1) by physiotherapists to record the patient's degree of full-time work, 2) by dieticians to record advice regarding physical activity, and 3) by nurses to record information on the levels of patient's functional status [(1)]. Extension of values for Method might be a possible solution to deal with this issue.

The major limitation of our study is that the sample documents were from only one institution, which limits the generalizability of our findings.

Conclusion

Inconsistency exists in the names of nursing document components from a current electronic nursing documentation system. Some names were ambiguous. We need a formal consistent way of stating the components of nursing documents in EHRs. LOINC supports standardized document section names. In order to be more useful for representing nursing document components, currently missing nursing section headings need to be added and extension of the attributes in LOINC semantic model is desired. Better representing the names of categories of clinical information may support the creation of document templates by providing non-ambiguously defined document components.

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