

Leveraging the NLM map from SNOMED CT to ICD-10-CM to facilitate adoption of ICD-10-CM

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ABSTRACT

Objective Develop and test web services to retrieve and identify the most precise ICD-10-CM code(s) for a given clinical encounter. Facilitate creation of user interfaces that 1) provide an initial shortlist of candidate codes, ideally visible on a single screen; and 2) enable code refinement.

Materials and Methods To satisfy our high-level use cases, the analysis and design process involved reviewing available maps and crosswalks, designing the rule adjudication framework, determining necessary metadata, retrieving related codes, and iteratively improving the code refinement algorithm.

Results The Partners ICD-10-CM Search and Mapping Services (PI-10 Services) are SOAP web services written using Microsoft's .NET 4.0 Framework, Windows Communications Framework, and SQL Server 2012. The services cover 96% of the Partners problem list subset of SNOMED CT codes that map to ICD-10-CM codes and can return up to 76% of the 69 823 billable ICD-10-CM codes prior to creation of custom mapping rules.

Discussion We consider ways to increase 1) the coverage ratio of the Partners problem list subset of SNOMED CT codes and 2) the upper bound of returnable ICD-10-CM codes by creating custom mapping rules. Future work will investigate the utility of the transitive closure of SNOMED CT codes and other methods to assist in custom rule creation and, ultimately, to provide more complete coverage of ICD-10-CM codes.

Conclusions ICD-10-CM will be easier for clinicians to manage if applications display short lists of candidate codes from which clinicians can subsequently select a code for further refinement. The PI-10 Services support ICD-10 migration by implementing this paradigm and enabling users to consistently and accurately find the best ICD-10-CM code(s) without translation from ICD-9-CM.

Key words: ICD-10 Transition; ICD-10-CM; SNOMED CT; Medical Informatics Applications; Medical Informatics

INTRODUCTION

On October 1, 2015, after two postponements of the compliance deadline,^{1–2} claims submitted to payer organizations in the United States will be coded using the ICD-10-CM coding system. In anticipation of this change, intense dialogue within the healthcare industry has focused on the difficulty of translating between ICD-9-CM and ICD-10-CM.³ Because the concepts represented in ICD-10-CM are more granular than their ICD-9-CM counterparts and contain significant encoding of patient context, no straight-forward crosswalk between the two systems exists. Clinicians are concerned that, after the deadline, they will need to learn and remember roughly five times more concepts in order to properly code their cases and avoid reimbursement delays.^{4–5} Partners HealthCare System, Inc. (PHS) has a long history of using terminology services to provide controlled clinical terminologies to clinical systems. We wondered

whether it was feasible to provide services that could guide users to the “best” ICD-10-CM code(s) – the billable ICD-10-CM code(s) that have the attributes most relevant to a specific encounter.⁶ This article describes our initial efforts to develop PHS's ICD-10-CM Search and Mapping Services (PI-10 Services) to assist clinicians in finding the best ICD-10-CM code(s) for any given clinical context.

OBJECTIVE

The goal of PI-10 Services is to provide efficient methods to retrieve and identify the best ICD-10-CM code(s) for a specific clinical encounter. The data returned to consuming applications is intended to facilitate the creation of user interfaces that 1) provide an initial shortlist of candidate codes, ideally visible on a single screen, and 2) enable code refinement.

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BACKGROUND AND SIGNIFICANCE

The International Classification of Disease (ICD)

The International List of Causes of Death was created in the mid- to late-1800s and, by 1946, had evolved into the International Classification of Disease (ICD)⁷ (Table 1).

The World Health Organization (WHO) certifies ICD as “the standard diagnostic tool for epidemiology, health management and clinical purposes.”⁸ In addition to reporting national mortality and morbidity statistics to WHO, many countries use the ICD coding system for reimbursement and healthcare resource allocation. Countries that have created national extensions to ICD-9 or ICD-10 include the US (ICD-9-CM/ICD-10-CM), Australia (ICD-10-AM), and Canada (ICD-10-CA).

In 1975, the Ninth Revision of the International Classification of Diseases (ICD-9) was updated to classify conditions by anatomical site affected, rather than generalized disease. Four years later, in 1979, ICD-9-CM, the US clinical modifications to ICD-9, with approximately 14 000 codes, was adopted as the coding system physicians were required to use to report patient health conditions for reimbursement and

epidemiologic analysis.⁹ Prior to ICD-9’s adoption, WHO was simultaneously experimenting with alternative structures for ICD-10, which was ultimately adopted in 1994. ICD-10-CM, drafted in 1995, has over 69 000 codes and enables more precise and detailed encoding.¹⁰ Recommended to the US Secretary of Health and Human Services in 2003, ICD-10-CM was initially proposed to be implemented in 2011 and is currently mandated for use in 2015.

ICD-10-CM Coding for Reimbursement

Reimbursable ICD-10-CM codes are between three and seven characters long and are grouped into chapters (Table 2 and Figure 1). The chapters are a collection of disease categories, sometimes called sections, and are represented by the first three characters of a code. For example, A00 identifies Cholera, one section or disease category in the chapter, “Certain infectious and parasitic diseases.” Character meaning beyond the third character varies by category. When the seventh character extension is required, its meaning is consistent within the entire category. For example, in the Injury and

Table 1: History of International Classification of Diseases (ICD) and Related US Events

Year	ICD-Related Event
1898	American Public Health Association recommend adoption of the Bertillon Classification of Causes of Death by Canada, Mexico, and the US, with suggested revisions every decade.
1900	French government holds the first International Conference for the Revision of the International List of Causes of Death. Subsequent decennial meetings are held in 1909, 1920, 1929, and 1938, for the second through the fifth revisions of the ICD.
1938	The Canadian delegate at the fifth International Conference proposes a modification for the list, as the basis of an international list of causes of illness.
1942	UK’s Committee on Hospital Morbidity Statistics of the Medical Research Council publishes <i>A provisional classification of diseases and injuries for use in compiling morbidity statistics</i> .
1944	US Surgeon-General introduces <i>The Manual for Coding Causes of Illness According to a Diagnosis Code for Tabulating Morbidity Statistics</i> to some hospitals, large voluntary insurance and medical care plans, and other US agencies.
1946	The International Health Conference commissions the WHO to create ICD-6, ultimately titled: <i>International Classification of Diseases, Injuries, and Causes of Death</i> .
1955	The WHO holds the International Conference for the Seventh Revision of the International Classification of Diseases in Paris.
1965	The WHO holds the eighth International Conference in Geneva. Changes were limited to essential additions and corrections of errors and inconsistencies.
1975	The WHO holds the ninth International Conference in Geneva.
1979	US adopts the ICD-9-CM for use in hospitals.
1995	CMS commissions draft a of ICD-10-CM, based on the WHO’s ICD-10.
2008	Health and Human Services (HHS) Secretary proposes adoption of the ICD-10-CM by October 1, 2011.
2009	HHS publishes the final rule on ICD-10-CM, with an October 1, 2013 deadline.
2013	ICD-10-CM implementation deadline delayed until October 1, 2014.
2014	ICD-10-CM implementation deadline delayed due to HR 4302 (PAMA), until at least October 1, 2015.

Table 2: ICD-10-CM Chapters and Descriptions

Chapter	ICD-10-CM Chapter Description
A00-B99	Certain infectious and parasitic diseases
C00-D49	Neoplasms
D50-D89	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism
E00-E89	Endocrine, nutritional, and metabolic diseases
F01-F99	Mental, behavioral, and neurodevelopmental disorders
G00-G99	Diseases of the nervous system
H00-H59	Diseases of the eye and adnexa
H60-H95	Diseases of the ear and mastoid process
I00-I99	Diseases of the circulatory system
J00-J99	Diseases of the respiratory system
K00-K95	Diseases of the digestive system
L00-L99	Diseases of the skin and subcutaneous tissue
M00-M99	Diseases of the musculoskeletal system and connective tissue
N00-N99	Diseases of the genitourinary system
O00-O9A	Pregnancy, childbirth, and the puerperium
P00-P96	Certain conditions originating in the perinatal period
Q00-Q99	Congenital malformations, deformations, and chromosomal abnormalities
R00-R99	Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified
S00-T88	Injury, poisoning, and certain other consequences of external causes
V00-Y99	External causes of morbidity
Z00-Z99	Factors influencing health status and contact with health service

External Causes chapters (S00-T88 & V00-Y99), the seventh character documents the episode of care, whereas, in Obstetrics (O00-O9A), the seventh character documents the affected fetus.¹¹ In addition to the seventh character extension, category-specific patient context – eg, laterality, severity, etc. – is frequently required to assign a more specific code for a specific encounter.

General Equivalency Maps (GEMs)

The Center for Medicare and Medicaid Services (CMS) and the Centers for Disease Control and Prevention (CDC) designed General Equivalency Maps (GEMs) to provide maps between ICD-9-CM and ICD-10-CM where organizational and formatting conventions in the two code sets are similar. CMS has published updates to GEMs every year since 2007.¹² Unlike a simple crosswalk, GEMs link an ICD-9-CM code to all valid ICD-10-CM alternatives,¹³ which is ideal for creating sets of related codes but not for automated mapping between ICD-9-CM and ICD-10-CM. Use of GEMs to recode a patient record from ICD-9-CM to ICD-10-CM typically requires additional

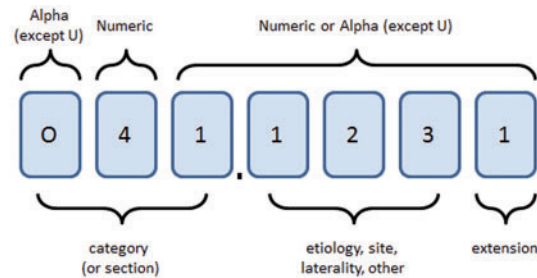
information – eg, laterality, site, severity, etc. – to assign the best code(s) to the record.¹⁴ If that information is not documented, a coder cannot accurately choose between related ICD-10-CM codes.

Problem List Usage, SNOMED CT, and NLM's Cross-Map

SNOMED CT, owned and maintained by the International Health Terminology Standards Development Organization (IHTSDO), is a comprehensive nomenclature used to capture clinical patient data, such as clinical problems.^{15–16} SNOMED CT is being used to code clinical problems more frequently now that it has been specified as the required terminology for patient problems in the Electronic Health Record (EHR) Meaningful Use (MU) Certification Criteria.^{17–19} In 2008, IHTSDO and WHO collaborated on a project to programmatically create a map between SNOMED CT and ICD-10, with the goal of enhancing interoperability between international applications of the two systems.²⁰ In 2010, the National Library of Medicine (NLM) started a project to programmatically map SNOMED CT to ICD-10-CM by leveraging IHTSDO's cross-map.^{21–22} NLM has a reference

Figure 1: ICD-10-CM Code Character Description and ICD Version Comparison.

Unlike ICD-9-CM codes, which are mostly numeric, ICD-10-CM codes are alphanumeric, and characters 4–7 have variable meanings. If “X” is used in an ICD-10-CM code, it is there as a place holder for shorter codes requiring a seventh character extension.



ICD Version Comparison At-A-Glance		
	ICD-9-CM	ICD-10-CM
Billable Codes	14,567	69,823
Chapters	19	21
Code Length (excl. period)	3-5 characters	3-7 characters
First Character	E, V, or 0-9	A-Z, excl. U
Other Characters	Numeric	See above
Ability to Add New Codes	Very Limited	Unrestricted
Ability to Provide Detail	Limited	Unrestricted

application, Interactive Map-Assisted Generation of ICD Codes (I-Magic), which demonstrates the use of these mapping rules. I-Magic, written in Java, “simulates a problem list interface in which users enter problems with SNOMED CT terms, which are then used to derive ICD-10-CM codes.”²³

Terminology Services at Partners HealthCare System, Inc. (PHS)

Partners Enterprise Terminology Services (PETS) provide clinical application developers with a set of web services to enable use of controlled terminologies in their applications. For example, a SNOMED CT-based service is used in systems that track patient problems, such as the ambulatory EHR and the inpatient order entry and discharge systems. In order to provide an enterprise-wide standard, PHS has adopted and actively curates a set of approximately 4600 SNOMED CT concepts as its problem list subset (PPLS). The PPLS originated from an earlier list of local terms²⁴ and was extended through reviews of NLM’s Core Problem List Subset and the Veteran’s Health Administration/Kaiser Permanente Problem List Subset. The PETS Problem Lookup service allows users to search by text for SNOMED CT codes from the PPLS. The Problem Lookup service is used in production systems throughout departments within Brigham and Women’s and Massachusetts General Hospitals and in the ambulatory EHR system.

Because PHS uses SNOMED CT for encoding the patient problem list, we hypothesized that NLM’s mapping rules might provide an opportunity to facilitate ICD-10-CM migration for PHS applications that use SNOMED CT for problem lists or scenarios in which clinicians currently search for ICD-9-CM codes using text. We also hypothesized that we could build a web service that would enable code refinement through questions and answers, while requiring only a single, stateless web service call from applications.

MATERIALS AND METHODS

PI-10 Services Use Cases

The PI-10 Services address these three high-level use cases:

1. A clinician wants to encode a patient encounter for a condition recorded on the patient’s problem list as a SNOMED CT concept;
2. A clinician wants to encode a patient encounter for a condition not on the patient’s problem list and searches using a free-text clinical term;
3. A clinician wants to encode a patient encounter using a template of standard conditions and needs to be guided to the most specific ICD10-CM code.

The following freely-available content sets were used during analysis, design, and development:

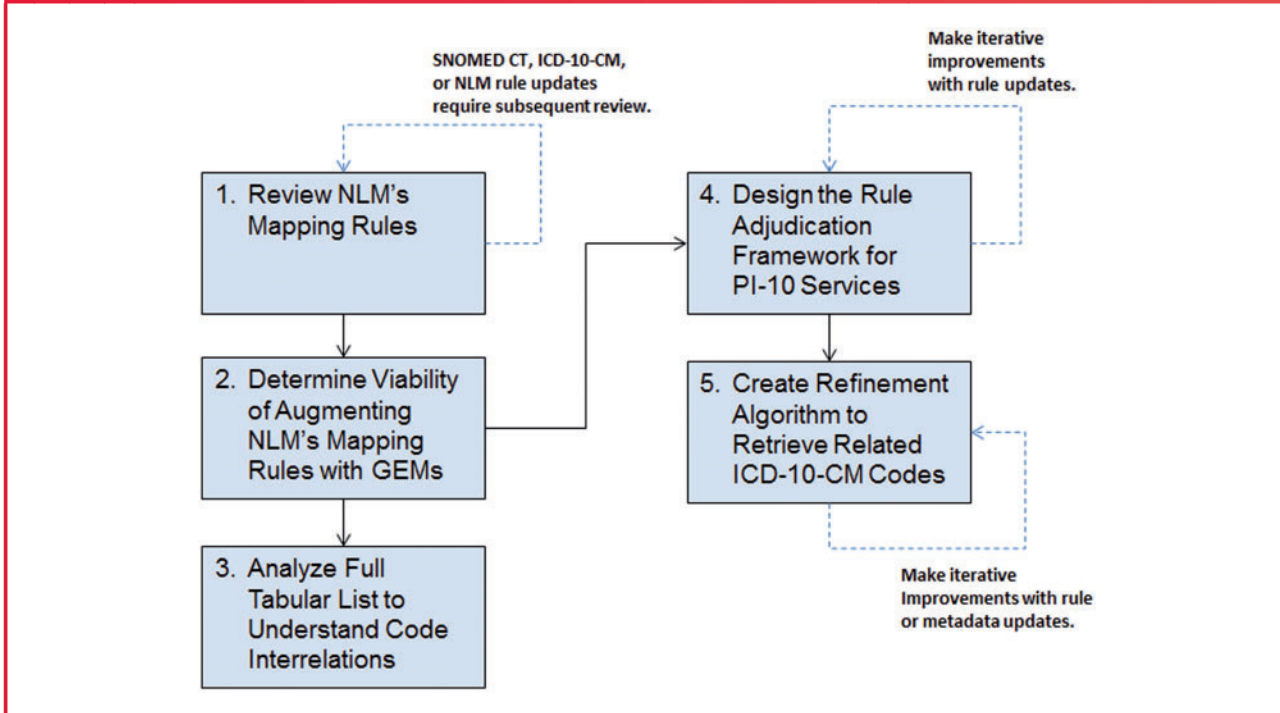
- SNOMED CT core subset (January 2014 International Release);
- ICD-9-CM and ICD-10-CM (FY2015 releases);
- NLM SNOMED CT to ICD-10-CM Mapping Rules (July 2012 preview release, July 2013 release);
- CMS Tabular List of Diseases and Injuries (FY2015 ICD-10-CM release);
- SNOMED CT to ICD-9-CM crosswalk (September 2013 US Edition); and
- CMS GEMs (FY2015 release).

The service analysis and design process followed an iterative, multi-step process. We analyzed the NLM mapping rules, in order to understand the rule structure, data input requirements, and content coverage ratio of the PPLS. I-Magic²⁵ was used to demonstrate the instantiation of the NLM rules and their relationship to sets of attributes that differentiate related ICD-10-CM codes. We then evaluated the feasibility of augmenting the NLM mapping rules with custom rules derived from the SNOMED CT to the ICD-9-CM crosswalk and CMS GEMs, to close any gaps in the NLM rules. Finally, we analyzed the CMS Tabular List of Diseases and Injuries (the “full tabular list” or FTL) to determine how codes were related to one another. We performed a preliminary analysis to judge the effort required to derive a set of attributes whose values would be repurposed to guide a user to a specific ICD-10-CM code.

These analyses led us to understand that the pre-population of the vast amount of ICD-10-CM codes and attribute metadata would be critical to the design of the rule adjudication

Figure 2: The PI-10 Services Analysis and Design Process.

Steps 1–3: The various analyses used to decide whether to build the proof of concept rule adjudication framework. **Step 4:** The framework returns ICD-10-CM base codes referenced by the input SNOMED CT code(s). **Step 5:** Each base code in the initial shortlist of results is a reference to a set of related code siblings. The code refinement algorithm uses attribute meta-data of each ICD-10-CM code to determine sibling relationships and organize associated questions and answers.



framework and the code refinement algorithm. The rule adjudication framework uses the pre-populated data structures so that it can:

- Quickly parse the input parameters and collection of rules (whether NLM, GEMs-augmented, or custom); and
- Determine ICD-10-CM code targets that need to be processed by the code refinement algorithm.

The code refinement algorithm uses base codes and attribute metadata in the pre-populated data structures to collect all code siblings (codes related to each other through the derivable attribute metadata) and enable the rule adjudication framework to assemble output. Empiric findings provided feedback to the process to allow iterative improvement (Figure 2).

RESULTS

Analysis and Design

We reviewed NLM's July 2012 preview release of its SNOMED CT to ICD-10-CM mapping rules (2012 pre-release) to analyze the format and structure of the rules²⁶ and to gauge whether the rules would be sufficient for the PPLS. We noticed that an individual rule's target (ICD-10-CM code) is dependent on any specific data in the mapRule field that could indicate the need to check input parameters for the existence of age,²⁷ gender, or other specific SNOMED CT codes from the patient's problem list. The July 2013 release of the mapping rules (2013 release)

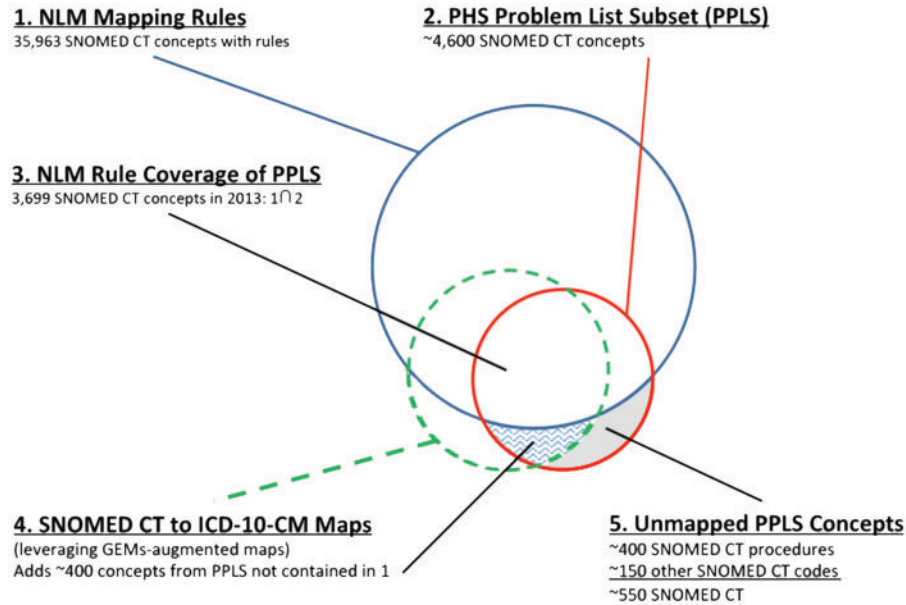
increased the number of PPLS codes with maps to ICD-10-CM codes from 2560 to 3699. Despite the increase, there were SNOMED CT codes in the PPLS that were not covered by NLM's rules. We subsequently leveraged maps from SNOMED CT to ICD-9-CM and GEMs to provide additional PPLS codes with maps to ICD-10-CM codes (Figure 3).

NLM's rules frequently point to either an "unspecified," non-billable, or incomplete code that requires a user to supply additional patient- or encounter-specific information for the seventh character, at a minimum, to obtain the appropriate ICD-10-CM code. These "hints" are present in the NLM rules as "advice" statements (eg, "consider laterality specification," "episode of care information needed," "consider trimester specification," "consider which fetus is affected by the maternal condition," etc.), but the rules do not provide any data or insight into how to apply the suggested advice.

Experimentation with I-Magic and analysis of the FTL led us to better understand the attribute relationships between ICD-10-CM codes and how those relationships could be leveraged within the PI-10 Services. We conceived of the notion of a "base code" as the root of a set of related codes. We define a base code as the top-most non-billable parent code of a collection of related codes. We use the term "code siblings" to describe a collection of codes related to one another through the derivable attribute metadata. In addition to enabling the selection of the required code refinement for seventh characters, the PI-10 Services' output permits applications to prompt users

Figure 3: Increasing Map Coverage of SNOMED CT Codes in the PPLS in Stages.

Analysis of [1] the set of NLM mapping rules and the [2] PPLS revealed [3] a coverage ratio of ~80%. Adding [4] GEMs-augmented maps increased the coverage ratio to ~89%. Analysis of the remaining SNOMED CT codes in the PPLS [5] uncovered procedures that could be excluded. This leaves ~150 codes that are candidates for custom mapping rules.



to answer code refinement questions to find the best ICD-10-CM code (Figures 4, 5).

Service Description

The PI-10 Services are Simple Object Access Protocol (SOAP)²⁸ web services written using Microsoft's .NET 4.0 Framework, Windows Communications Framework, and SQL Server 2012. They are deployed on a clustered IIS application server with load balancing. We used publicly available content sets for all content artifacts other than the attribute metadata, for which we used a proprietary derivation of the metadata curated by our content vendor, Health Language, Inc. (Denver, CO).

There are three PI-10 Services that address the use cases previously described. The services and their inputs are:

- **SnomedToICD10Mapping:** A SNOMED CT code and patient context data, eg, gender, date of birth and SNOMED CT codes, from the patient's problem list.
- **SnomedToICD10Lookup:** Clinical terms (text) and patient context as in SnomedToICD10Mapping.
- **GetICD10CodeRefinement:** A list of full or partial ICD-10-CM codes.

SnomedToICD10Lookup augments **SnomedToICD10Mapping** with the clinical problem search algorithm from the PETS library. All three services return a list of ICD-10-CM base codes with their associated refinement questions and answers and are provided by the **GetICD10CodeRefinement** service. The following examples highlight features of the PI-10 Services and

the characteristics of the XML output that applications will render and display to users.

The PI-10 Services are intended to provide all necessary data for a client application to implement the desired functionality and user interface. The PI-10 Services have been designed to retrieve as many of the possibly appropriate mapping rules and provide the associated ICD-10-CM code targets when patient context is not available. This allows consuming applications to obtain all related ICD-10-CM codes from the PI-10 Services, when an application is unable to provide the optional context that could aid in adjudicating NLM's mapping rules. This design enables stateless interactions with the services and delegates interactive refinement to the client application.

PPLS Coverage Ratio Analysis

The 2012 pre-release, with 23 893 rules for 15 613 SNOMED CT concepts, covered approximately 55% of the SNOMED CT codes in the PPLS. The 2013 release, with 58 931 rules for 35 963 SNOMED CT concepts, covered 80% of the SNOMED CT codes in the PPLS. The additional ICD-10-CM targets achieved by using the GEMs-augmented maps covers approximately 400 more SNOMED CT codes in the PPLS, leaving roughly 550 SNOMED CT codes (12%) requiring review to determine why they did not map to ICD-10-CM (Figure 3).

Review of those 550 SNOMED CT codes showed that roughly 400 were procedures that were included in the PPLS. Procedures would need to map to ICD-10-PCS, which is not in the scope of this work. Fewer than 200 SNOMED CT codes

Figure 4: Consolidation of Output Example Using Chorioamnionitis. The NLM mapping rule for Chorioamnionitis points to 1 ICD-10-CM code (O41.1290) within a set of 28 billable sibling codes. Also pictured (right) is the PI-10 Services' alternative to displaying long lists of codes by leveraging questions and answers. The list of 28 codes is represented as a single base code (O41.12) with two code refinement questions and their answers.

NLM's code target for 11612004

#	ICD-10-CM Description	Code
1	Chorioamnionitis, first trimester, not applicable or unspecified	O41.1210
2	Chorioamnionitis, first trimester, fetus 1	O41.1211
3	Chorioamnionitis, first trimester, fetus 2	O41.1212
4	Chorioamnionitis, first trimester, fetus 3	O41.1213
5	Chorioamnionitis, first trimester, fetus 4	O41.1214
6	Chorioamnionitis, first trimester, fetus 5	O41.1215
7	Chorioamnionitis, first trimester, other fetus	O41.1219
8	Chorioamnionitis, second trimester, not applicable or unspecified	O41.1220
9	Chorioamnionitis, second trimester, fetus 1	O41.1221
10	Chorioamnionitis, second trimester, fetus 2	O41.1222
11	Chorioamnionitis, second trimester, fetus 3	O41.1223
12	Chorioamnionitis, second trimester, fetus 4	O41.1224
13	Chorioamnionitis, second trimester, fetus 5	O41.1225
14	Chorioamnionitis, second trimester, other fetus	O41.1229
15	Chorioamnionitis, third trimester, not applicable or unspecified	O41.1230
16	Chorioamnionitis, third trimester, fetus 1	O41.1231
17	Chorioamnionitis, third trimester, fetus 2	O41.1232
18	Chorioamnionitis, third trimester, fetus 3	O41.1233
19	Chorioamnionitis, third trimester, fetus 4	O41.1234
20	Chorioamnionitis, third trimester, fetus 5	O41.1235
21	Chorioamnionitis, third trimester, other fetus	O41.1239
22	Chorioamnionitis, unspecified trimester, not applicable or unspecified	O41.1290
23	Chorioamnionitis, unspecified trimester, fetus 1	O41.1291
24	Chorioamnionitis, unspecified trimester, fetus 2	O41.1292
25	Chorioamnionitis, unspecified trimester, fetus 3	O41.1293
26	Chorioamnionitis, unspecified trimester, fetus 4	O41.1294
27	Chorioamnionitis, unspecified trimester, fetus 5	O41.1295
28	Chorioamnionitis, unspecified trimester, other fetus	O41.1299

➔

#	ICD-10-CM Description	Code
1	Chorioamnionitis	O41.12

Specify affected fetus:

- Not applicable or unspecified
- Fetus 1
- Fetus 2
- Fetus 3
- Fetus 4
- Fetus 5
- Other fetus

Specify trimester:

- First trimester
- Second trimester
- Third trimester
- Unspecified trimester

in the PPLS (4%) will require review to determine what, if any, custom rules should be created to map them to ICD-10-CM codes.

Analysis of Returned ICD-10-CM Codes

The FY2015 release of ICD-10-CM has 69 823 reimbursable codes. There are 15 991 unique ICD-10-CM codes that are targets of either NLM mapping rules or the GEMs-augmented maps. When those targets are expanded to include all of the related billable code siblings, the total becomes 52 740 indicating that 76% of all ICD-10-CM codes are accessible through the PI-10 Services prior to creating PHS-specific custom mapping rules or creating additional attribute metadata.

Use Case 1 Example: Mapping from a SNOMED CT Code on a Patient Problem List

This example references Chorioamnionitis, an inflammation of the fetal membranes due to a bacterial infection.²⁹ Assuming SNOMED CT code 11612004 (Chorioamnionitis) is on a patient's problem list, the information in Table 3 indicates that NLM's target ICD-10-CM code for Chorioamnionitis, O41.1290, is 1 of 28 code siblings and can be refined by specifying two pieces of information encoded in the metadata associated with each of the sibling codes – “affected fetus” and “trimester.”

The metadata indicates four allowable values for trimester – “first,” “second,” “third,” and “unspecified” – and seven

allowable values for affected fetus – “not applicable”/ “unspecified,” the values 1–5, and “other fetus” (Figure 4).

Use Case 1 Example: Mapping from a Single SNOMED CT Code to Multiple ICD-10-CM Codes

There are scenarios in which a patient problem, represented as a single SNOMED CT concept, requires multiple ICD-10-CM codes in order to be properly expressed. This example references Knuckle pads, deafness, and leukonychia syndrome (ie, Bart-Pumphrey syndrome), a condition characterized by nail and skin discolorations, skin growths, and hearing loss.

The NLM targets for SNOMED CT code 1271009 (Knuckle pads, deafness, and leukonychia syndrome) are three ICD-10-CM codes that are all required to accurately capture the meaning of the original SNOMED CT concepts. They are M72.1 (Knuckle pads), H91.90 (Unspecified hearing loss, unspecified ear), and Q84.4 (Congenital leukonychia).

The service output contains these codes, along with a code refinement question and answers (to specify laterality) for H91.90 and an XML-represented mechanism that enables applications to identify that the codes are required together.

Use Case 2 Example: Searching with the Clinical Term “Femur Fracture”

A search of “femur fracture” against ICD-10-CM code descriptions returns an unmanageable list of over 2500 codes.

Figure 5: Consolidation of Output Example Using “Femur fracture.” In this example, a search on “femur fracture” would return a list with over 2500 results. Alternatively (right), the PI-10 Services’ paradigm transforms that long list into an initial shortlist of four resulting base codes. The selected answer choices (lower right) result in ICD-10-CM code: S72.92XE - Unspecified fracture of left femur subsequent encounter for open fracture type I or II with routine Healing.

#	ICD-10-CM Description	Code
1	Age-related osteoporosis with current pathological fracture, right femur, initial encounter for fracture	M80.051A
2	Age-related osteoporosis with current pathological fracture, right femur, subsequent encounter for fracture with routine healing	M80.051D
3	Age-related osteoporosis with current pathological fracture, right femur, subsequent encounter for fracture with delayed healing	M80.051G
4	Age-related osteoporosis with current pathological fracture, right femur, subsequent encounter for fracture with nonunion	M80.051K
5	Age-related osteoporosis with current pathological fracture, right femur, subsequent encounter for fracture with malunion	M80.051P

Code	ICD-10-CM Description	Refinement
M80.05	Age-related osteoporosis with current pathological fracture, femur	Required <input type="radio"/>
M84.45	Pathological fracture, femur and pelvis	Required <input type="radio"/>
S71.1	Open wound of thigh	Required <input type="radio"/>
S72	Fracture of femur	Required <input checked="" type="radio"/>

Specify laterality:

- Left
- Right
- Unspecified

Specify encounter information:

- initial encounter for closed fracture
- initial encounter for open fracture type I or II
- initial encounter for open fracture type IIIA, IIIB, or IIIC
- subsequent encounter for closed fracture with routine healing
- subsequent encounter for open fracture type I or II with routine healing
- subsequent encounter for open fracture type IIIA, IIIB, or IIIC with routine healing
- subsequent encounter for closed fracture with delayed healing
- subsequent encounter for open fracture type I or II with delayed healing
- subsequent encounter for open fracture type IIIA, IIIB, or IIIC with delayed healing
- subsequent encounter for closed fracture with nonunion
- subsequent encounter for open fracture type I or II with nonunion
- subsequent encounter for open fracture type IIIA, IIIB, or IIIC with nonunion
- subsequent encounter for closed fracture with malunion
- subsequent encounter for open fracture type I or II with malunion
- subsequent encounter for open fracture type IIIA, IIIB, or IIIC with malunion
- sequela

Close

Table 3: SNOMED Code for Chorioamnionitis, NLM’s Target ICD-10-CM Code, and Metadata Attributes

SNOMED CT Code & Term	11612004	Chorioamnionitis
NLM Map Target(s)	041.1290	Chorioamnionitis, unspecified trimester, not applicable or unspecified
Attribute:		Trimester (6 th character)
Attribute:		Affected fetus (7 th character)
Base Code:		041.12 (28 billable ICD-10-CM codes in hierarchy)

The PI-10 Services output facilitates a two-step process for applications to lead users to the best ICD-10-CM code(s).

The PI-10 Services make use of the data shown in Table 4 to return output to the application, enabling the initial display of a much more manageable list of 4 items instead of a list of 2556 ICD-10-CM codes (Figure 5).

Once the user selects the most appropriate initial result – the base code S72, for this example – the application can prompt the user with the list of questions and answers associated with that base code, in order to enable the selection of the best ICD-10-CM code. Using the selections shown in Figure 5 (lower right), the application can display the corresponding ICD-10-CM code (S72.92XE) to users.

DISCUSSION

We have designed and implemented a set of services that facilitates the ICD-10-CM encoding of clinical encounters by clinical

users without translation from ICD-9-CM. Our method is novel, in that we 1) use SNOMED-CT codes as entry points into ICD-10-CM, and then 2) guide the end-user to a final code using attribute-driven questions and answers. Our initial implementation is able to cover 96% of the PPLS (after excluding procedures) and 76% of all ICD10-CM concepts. In addition, the PI-10 Services are novel in that they provide the framework to implement this search-and-refine approach and leave the user interface design to the consuming application. By better aligning the transition to ICD-10-CM with clinical thinking and workflow, we suspect the PI-10 Services will minimize the impact to users as applications move to the large, new set of ICD-10-CM concepts.

As stated previously, CMS never intended GEMs to be used as crosswalks or as a substitute for native coding of clinical encounters in ICD-10-CM after the implementation deadline.^{30–31} The industry seems to have erroneously concluded

Table 4: Selection of SNOMED CT Terms Associated with “Femur Fracture” and Their Corresponding ICD-10-CM Target Codes

SNOMED CT Code & Term	431031001	Pathological fracture of neck of femur associated with osteoporosis
NLM Map Target(s)	M80.059?	Age-related osteoporosis with current pathological fracture, unspecified femur
	Attribute:	Laterality (6 th character)
	Attribute:	Episode of care (7 th character)
	Base Code:	M80.05 (18 billable ICD-10-CM codes in hierarchy)
SNOMED CT Code & Term	409667007	Pathological fracture of femur
NLM Map Target(s)	M84.453?	Pathological fracture, unspecified femur
	Attribute:	Laterality (6 th character)
	Attribute:	Episode of care (7 th character)
	Base Code:	M84.45 (18 billable ICD-10-CM codes in hierarchy)
SNOMED CT Code & Term	79978005	Open supracondylar fracture of femur
NLM Map Target(s)	S71.109?	Unspecified open wound, unspecified thigh
	Attribute:	Wound type (5 th character)
	Attribute:	Laterality (6 th character)
	Attribute:	Episode of care (7 th character)
	Base Code:	S71.1 (54 billable ICD-10-CM codes in hierarchy)
SNOMED CT Code & Term	71620000	Fracture of femur
NLM Map Target(s)	S72.90X?	Unspecified fracture of unspecified femur
	Attribute:	Fracture Type (4 th character)
	Attribute:	Laterality (5 th character)
	Attribute:	Episode of care (7 th character)
	Base Code:	S72 (2466 billable ICD-10-CM codes in hierarchy)

Note: In S72.90X the “X” in character 6 is a place holder and, therefore, has no attributes associated with it.

that the existence of GEMs means that translation between ICD-9-CM and ICD-10-CM is necessary or required to achieve compliance. By avoiding translation between terminologies, we anticipate that the PI-10 Services will help ameliorate transition anxiety, by demonstrating that they can quickly return the best ICD-10-CM codes to users without materially impacting their current workflow. Anecdotally, in demonstrations using a local, custom-developed reference application to call the PI-10 Services, clinical users have been receptive to the PI-10 Services’ results and the introduction of this paradigm shift. We have explained that the services provide a shorter initial list of results with application-rendered pop-ups or other mechanisms to display associated refinement questions and answers that enable users to select the best ICD-10-CM code without having to know the intricacies of ICD-10-CM.

There are some limitations to our initial work.

1. We are not aware of any investigation of the application of the NLM rule maps to clinical problem lists in the field,

so we are unsure how well-correlated the concepts used to represent disease entities in problem lists are to the antecedent concepts used in the NLM maps. This is a potential area for study.

2. Our method guides the selection of ICD-10-CM code(s) relevant to a specific encounter, but does not necessarily incorporate the logic to fully encode all of the various situation-dependent codes (eg, CODE ALSO) that might be required, according to CMS coding guidelines, for a single encounter.
3. SnomedToICD10Lookup relies on a free-text search to identify entry points into ICD-10-CM. The ability of the PETS search algorithm to locate appropriate SNOMED CT codes for the shortlist of entry points may be a limiting factor in the acceptance of our services. This is another area for potential study.

Increasing the Upper Bound of Returned ICD-10-CM Codes

Ensuring that the PI-10 Services can return all valid, billable ICD-10-CM codes will require ongoing extensions

of the current content, which may be addressed by the tasks that follow:

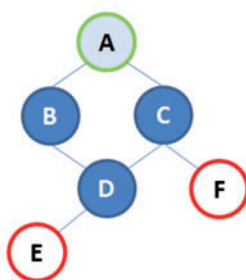
- The SNOMED CT concepts that could be associated with an ICD-10-CM code are not all covered by NLM's mapping rules. Continued expansion of the PPLS will require maintenance processes to maintain a coverage ratio as close to 100% as possible.
- In order to ensure that all ICD-10-CM codes can be returned by the services, there need to be rules that link to all ICD-10-CM categories.
- The metadata that describes individual ICD-10-CM codes, enabling the P-10 Services' code refinement strategy, needs to be complete and monitored for changes to ICD-10-CM that might necessitate updates.

Task 1: Introduce Transitive Closure of SNOMED CT into PI-10 Services

The transitive closure on a set of data with binary relations (in this case, SNOMED CT and its member codes' parent-child relationships) provides ancestral hierarchy data. Computing and pre-populating the transitive closure of SNOMED CT enables the PI-10 Services to take advantage of that data without calculating ancestral hierarchies at runtime. When using SNOMED CT's ancestral hierarchy data with NLM's mapping rules, one can apply existing rules to a set of descendant SNOMED CT codes by implication.³² The implementation of transitive closure should increase the map coverage ratio of the PPLS. As can be seen in Figure 6, if A transitively closes E and F, and A has an NLM mapping rule, those rules are candidate rules for E and F. So, we can extend mapping rules to E and F because of their ancestor, A. All PPLS codes that acquire rules due to the programmatic application of transitive closure will need to be manually reviewed.

Figure 6: The transitive closure of SNOMED CT. The transitive closure of SNOMED CT applied to NLM's mapping rules can increase Partners Problem List Subset (PPLS) coverage by extending maps to SNOMED CT concepts (without rules) that are descendants of those that already have rules.

Ancestral Hierarchy of SNOMED CT Concepts



A is a SNOMED CT concept not in PPLS with NLM Mapping Rule(s)

E & F are SNOMED CT concepts in PPLS without NLM Mapping Rules

Through A, E & F are candidates for inheriting NLM Mapping Rules from A

Task 2: Custom Rule or Metadata Creation

Custom rules address two different mapping deficiencies:

1. SNOMED CT codes in the PPLS without any NLM rules pointing to any ICD-10-CM code; and
2. ICD-10-CM categories that are not the targets of any NLM rule.

For those codes for which the application of transitive closure does not provide a rule, custom rules will need to be created. The current coverage ratio of PHS's PPLS is approximately 96%, leaving fewer than 200 SNOMED CT codes without a rule. With future releases of NLM rules, the need for custom rules for SNOMED CT codes in the PPLS may decrease.

Additionally, of the 1900 ICD-10-CM categories that contain billable codes, over 200 categories (~10%) have no codes that are map targets and, therefore, they could not be returned to a user without custom maps. Though creating custom rules such that they emulate NLM's format is, technically, very simple, ongoing review of the PPLS SNOMED CT codes will still be necessary. As new codes are added to the PPLS, it will be important to validate that a rule exists or is created at the time of inclusion. Further, when modifying existing rules with additions or replacements, coordinating those changes with subsequent updates to terminologies, NLM mapping rules, or GEMs will require a rigorous data management process, version control, and ongoing review by clinical subject matter experts.

Task 3: Code Refinement Strategy and Metadata Improvement

The PI-10 Services use ICD-10-CM attribute metadata to return code refinement data in the output. Currently, the metadata describes many attributes, such as laterality, trimester, affected fetus, and severity. Review of attribute metadata associated with code siblings will allow us to consolidate the questions and answers displayed to users via consuming applications by combining the attributes that do not need to be individually differentiated. For example, some fractures have an attribute for displacement, with values of "displaced" or "nondisplaced." This attribute may be combined with the type of fracture, so that users would only need to pick the type of fracture, regardless of displacement, instead of answering two independent questions to describe the condition.

CONCLUSION

We have designed and implemented a set of services that facilitates the ICD-10-CM encoding of clinical encounters by clinical users without translation from ICD-9-CM. In our initial implementation, we are able to return data for 96% of the PPLS (after exclusion of procedures) and return up to 76% of all billable ICD10-CM codes. Initial feedback from clinical users indicates that the increased number of codes in ICD-10-CM is easier to manage using the PI-10 Services, because applications can display initial search results in short, easy-to-read lists from which clinicians can then select a code for further refinement. Future work will investigate the application of custom

rules to increase both the PPLS coverage ratio as well as the upper bound of returned ICD-10-CM codes and the enhancement of attribute metadata on ICD-10-CM codes.

CONTRIBUTORS

Each of the listed authors meets all four of the criteria for authorship per ICMJE's recommendations.

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COMPETING INTERESTS

None.

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