Mapping SNOMED CT to ICD-10-CM

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ABSTRACT

A SNOMED CT-encoded problem list is required to satisfy the Certification Criteria for Stage 2 "Meaningful Use". ICD-10-CM has replaced ICD-9-CM as the reimbursement code set in 2015. Having a cross-map from SNOMED CT to ICD-10-CM would promote the use of SNOMED CT as the primary problem list terminology, while easing the transition to ICD-10-CM. There is no established principle and methodology on systematically and semantically linking SNOMED CT to ICD-10-CM.

This research project describes the development of mapping principle, mapping guidelines, mapping tools and mapping methodology for a rule-based crosswalk to support semi-automatic generation of ICD-10-CM codes from SNOMED CT-encoded data. A series of mapping guidelines were developed based on the clinical use case, SNOMED CT modeling convention, and ICD-10-CM classification guidelines. One of the important methodology in developing the map set is using triangulation in generating legacy maps. Using the SNOMED CT to ICD-9-CM map and General Equivalence Mappings sequentially, Indirect Map was generated from SNOMED CT to ICD-10-CM for 96.2% of the SNOMED CT concepts within the scope of the study. Another innovation in this crossmapping research is implementation of a principle to handle age specification. The age rule was one type of rule to handle cases in which one SNOMED CT concept can map to different ICD-10-CM codes depending on the age of the patient. The age rule quality assurance (QA) was a mechanism to capture the age specification that can be easily missed by manual mapping.

The results showed that the mapping guidelines ensured the mapping consistency, which potentially would reduce the mapping discrepancy between the two independent

parallel mapping efforts. It also made it possible that the map set can be used in a meaningful way when data is exchanged. On this triangulation method in generating legacy map, an Indirect Map generated from SNOMED CT to ICD-10-CM covered a very high percentage of SNOMED CT concepts. Overall, this Indirect Map had a moderate degree of agreement with the Direct SNOMED CT to ICD-10-CM map. However, the indirect synonymy maps have much higher precision and can be used for quality assurance (QA) of the three maps. The age rule QA identified 342 out of 7,277 concepts which potentially required age rules, among these 50.3% turned out to be true positives. Without this QA, a large proportion of age rules in the published Map would have been missed.

The outcomes of this research project include a set of mapping principle, mapping guidelines, mapping tools and mapping methodology for a rule-based crosswalk from SNOMED CT to ICD-10-CM. All these could be used as a prototype in other cross standard mappings. For example, in the US, ICD-10-PCS officially replaced ICD-9-CM from October 2015 onwards. A project was formulating earlier this year (2015) for the purpose of creating the map from SNOMED CT procedure to ICD-10-PCS. It is a pleasant finding that tooling, principles and guidelines established in SNOMED CT to ICD-10-CM mapping can be re-used, with modifications, for the PCS mapping process.

ACKNOWLEDGEMENTS

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CHAPTER 1 INTRODUCTION

1.1 Background

Through electronic health record (EHR) systems, digital technology enables a greater and more seamless flow of clinical information which transform the way care is delivered and compensated. With EHRs, information is available whenever and wherever it is needed.

Healthcare data are produced by people, through care process with multi-factors. These data include EMR data like clinical observation or lab results, billing data, cost data and patient satisfaction data. How the data are captured plays a role in data's quality. Healthcare data usually are produced and reside in multiple systems in different format. Such is the case with claims data versus clinical data. It is challenging and time consuming to link data from various sources into one central repository in a common format and ensure the data sets are talking to each other. Data aggregation is the key in terms of making this data accessible, computable and actionable. How the data are processed / analyzed determines if meaningful insights can be generated from the data. Healthcare data may be recorded in a structured or unstructured way. One of the purpose of EMR is to standardize the data capture process with data being entered in structured fields as designed. No different than any other data, healthcare data can have inconsistent or variable definitions. Same term can be used to represent different meaning and different terms can be used for same concept.

Accurate and comprehensive healthcare data are important for a variety of purposes. Using data to measure performance is an essential element in improving the quality of healthcare. These data may be used for local assessments or evaluations within a healthcare system, such as for specific outpatient conditions or inpatient hospital events. The data may also be used regionally or nationally for assessing performance within or across healthcare systems. Data help determine where opportunities for improvement exist and document the impact that system change interventions have made on the outcomes or processes of care for a clinical condition. With data analysis, healthcare management can work to reduce administrative costs. Electronic artificial intelligent clinical applications can help improving the way clinicians make decisions about their patients. Some such applications can be used by healthcare organizations to educate patients or remind patients to keep up with a healthy lifestyle, as well as keep track of where a patient stands in regard to their lifestyle choices, thus to improve patient wellness in general.

1.2 Significance of the Problem

One of the challenges in healthcare documentation is different systems have different ways of identifying the same concept. For example, Myocardial infarction can be recorded by health professional with the following names: infarction of heart, MI, mied, mies, myocardial infarct, cardiac infarction, heart attack, attack hearts, attacking hear, attacks heart, attacks hearts, coronary attack, attacks coronary, disorder infarction myocardial, infarctions myocardial, infarcts myocardial, syndrome myocardial infarction, myocardial necrosis.

Issus with lacking of shared Standards include

- Increases paperwork and data collection burdens at the point of care

Without standardized data or predefined value sets, data collection can be very time and labor consuming. The collected data could be fragmented and incomplete within and across organizations.

- Limit the ability to capture the detailed clinical information about the patient

  Clinical information include the diagnostic studies, past history, physical examination, discharge notes, nursing notes, and consultation notes. These data elements maybe documented at different places in an EMR in different ways. Lacking of unique and standard coding may results in important information loss.

- Little ability to make multiple uses or link data

  Clinical data can be used not only for patient care, but also in medical research, medical education and many other areas. Meaningful data re-use or secondary use can only be possible if the data can talk to each other and can be linked together via unified definition.

- Limit the function of computerized manipulation on data statistical analysis and information retrieval for use in improving clinical, financial and administrative performance

  Healthcare organizations produce massive amounts of data and much effort has been spend on collecting those data. But many organizations fail to translate it into actionable insights. Without data standardization, non-computable data cannot tell the story. Information is not retrieved from the data and knowledge is not generated from the information.

- Limits usefulness of data collected in generating patient-specific assessments or recommendations to facility clinicians in making clinical decisions.

1.3 Overview of Standard Terminology Systems

To obtain better understanding of the nature of coding systems, standard terminology systems and existing crossmappings were studied.

1.3.1 Standard Terminology Systems

The well established and wide adopted Standard Medical Terminologies / Ontology include:

- The Systematized Nomenclature of Medicine – Clinical Terms (SNOMED CT)
- Logical Observations, Identifiers, Names, and Codes (LOINC)
- International Classification of Diseases (ICD)
- Diagnosis-Related Groups (DRGs)
- Current Procedural Terminology (CPT)
- Drug Codes - RxNorm
- Medical Subject Headings (MeSH)
- Gene Ontology (GO)
- Unified Medical Language System (UMLS)

<u>The Systematized Nomenclature of Medicine – Clinical Terms (SNOMED CT)</u>

SNOMED CT mergerred from SNOMED Reference Terminology (SNOMED RT) and Clinical Terms Version 3 (CTV3). SNOMED RT was developed by the College of American Pathologists (CAP) and Clinical Terms Version 3 was developed by the National Health Service (NHS) of the United Kingdom. SNOMED CT is owned and distributed (via NLM) by The International Health Terminology Standards

Development Organization (IHTSDO). It is comprised of concepts, terms and relationships. It has 19 hierarchies with over 376,000 concepts covering almost all clinical aspects, including body structure, clinical finding, procedure, orderable, medication, biological product, substance, specimen, medical devices. It is designed with the objective of precisely representing clinical information across the scope of health care. SNOMED CT has been used as a comprehensive clinical terminology to code, retrieve and analyze clinical data. It is can be used as a coding system, controlled vocabulary, classification system or thesaurus. …. According to the Final rule of the Stage 2 "meaningful use" certification criteria of the Centers for Medicare & Medicaid Services incentive program, SNOMED CT is implemented to encode medical problems and procedures in the EHR.

<u>International Classifications of Disease and the U.S. Modifications – ICDs</u>

The International Classification of Disease (ICD) is a medical classification used by the World Health Organization (WHO) for epidemiology, health management and clinical purposes. In the U.S., a national extension of the core ICD called Clinical Modification (CM) is used to categorize diseases and procedures for various purposes including billing, reimbursement, public health reporting, outcome measurement, quality improvement and other functions. In 2015, ICD-9-CM, which had been in use for over 30 years, has been replaced by its successor, ICD-10-CM. General Structure of ICDs covers Epidemic diseases, constitutional or general diseases, local diseases arranged by site, development diseases and Injuries. ICD disease classification is released with a tabular list, and an alphabetic index. Tabular List contains classification of diseases and injuries with Etiology (cause of disease) and Anatomical (body) system as part of the code. 17 to 22 chapters are arranged with a monohierarchy of sections, categories, subcategories, subclassifications. Alphabetic Index to diseases has three major sections: Index to Diseases and Injuries (, which is arranged by main terms, subterms, carryover lines), table of Drugs and Chemicals and table to External Causes of Injury and Poisoning (E Codes in ICD-9-CM).

Logical Observation Identifiers, Names, and Codes - LOINC

The LOINC standard is maintained and distributed freely by the Regenstrief Institute (with support from the U.S. National Library of Medicine (NLM). LOINC has been endorsed by the American Clinical Laboratory Association and the College of American Pathologists. It is also a part of the NLM's Unified Medical Language System (UMLS), and it has been adopted by several Federal agencies including the Centers for Disease Control and Prevention (CDC), the Department of Defense (DoD), and the Department of Veterans Affairs. LOINC applies universal code names and identifiers to medical terminology related to electronic health records. The purpose is to assist in the electronic exchange and gathering of clinical results (such as laboratory tests, clinical observations, outcomes management and research). There are two types of LOINC codes. One is Laboratory LOINC, which covers clinical lab tests like microbiology tests, chemistry non challenge tests, challenge chemistry tests, allergy testing, drug toxicology tests. The other type of LOINC codes is Clinical LOINC, which are used to code clinical observations like radiology studies, OB ultrasound impression & measures, clinical report documents (discharge), Tumor registry, physical exams.

RxNorm

RxNorm is a normalized naming system for generic and branded drugs. It contains the names of prescriptions and many nonprescription formulations that exist in the US.

It was developed to allow computer systems to communicate drug-related information efficiently and unambiguously. The scope of RxNorm includes Clinical drugs, which are pharmaceutical products given to (or taken by) a patient with therapeutic or diagnostic intent, and Drug packs - packs that contain multiple drugs, or drugs designed to be administered in a specified sequence.

Current Procedural Terminology – CPT

It was developed by the American Medical Association (AMA). It is the most widely-used nomenclature in the US for billing and reimbursement on diagnostic and therapeutic procedures. CPT codes are arranged in three categories. Category I codes cover services (or procedures) common in contemporary medical practice. For example,

42825 Tonsillectomy, primary or secondary; younger than age 12

42826 Tonsillectomy, primary or secondary; age 12 or over

Category II codes have focus on performance measurement. Category III codes deal with emerging technology i.e. 0301T DEST/REDUC MALIG BRST TUMR W/US THRMORX GUIDANCE.

1.3.2 SNOMED CT vs ICD-10-CM

Even terminologies with significant domain overlap can differ substantially in granularity, structure and organizing principles, usually as a result of the different purposes that they are designed for. A case in point is SNOMED CT (Systematized Nomenclature of Medicine--Clinical Terms) and the ICD (International Classification of Disease) classifications, which are very different even though they are both primarily related to the domain of findings, diseases and disorders. SNOMED CT is considered as the most comprehensive, multilingual clinical terminology in the world. [6] Since its inception in 2007, the International Health Terminology Standards Development Organisation (IHTSDO, owner of SNOMED CT) has doubled its number of member countries from nine to eighteen. SNOMED CT is slowly gaining momentum as the international clinical terminology standard. On the other hand, ICD-10 is a medical classification.[7] The root of ICD can be traced back to the International List of Causes of Death created 150 years ago. [8] ICD is endorsed by the World Health Organization (WHO) to be the international standard diagnostic classification for epidemiology, health management and clinical purposes. The current version of ICD is ICD-10 which was first published in 1992. Apart from reporting national mortality and morbidity statistics to WHO, many countries use ICD-10 for reimbursement and healthcare resource allocation. To better suit their national needs, several countries have created national extensions to ICD-10, including ICD-10-AM (Australia), ICD-10-CA (Canada) and ICD-10-CM (U.S.).[9-11]

As a clinical terminology, SNOMED CT is inherently more suitable than other terminologies/classifications for clinical documentation in the EHR (electronic health record). However, SNOMED CT has better clinical coverage than ICDs. Looking at the number of codes in each of these code sets. SNOMED CT Clinical finding domain has over 100,000 codes. The number for ICD-9-Cm and ICD-10-CM are 14,000 and 68,000, respectively.

This is not to say that ‘SNOMED CT is superior to ICD, since they are designed for different purposes and each should each be used for the purpose for which it was designed. ICD’s focus is statistical – less common diseases get lumped together in “catch-all” categories e.g. J15.8 Pneumonia due to other specified bacteria, which could result in loss of information. While SNOMED CT is clinically-based – document whatever is needed for patient care. In another example, Metabolic acidosis, Respiratory acidosis, and Lactic acidosis are three different conditions with distinguished clinical meanings. In SNOMED CT, these three conditions are assigned with three codes.

- 59455009 Metabolic acidosis
- 12326000 Respiratory acidosis
- 91273001 Lactic acidosis

While in ICD-9-CM, all three conditions are coded with a same single code 276.2 Acidosis. Same happens in ICD-10-CM, with code E87.2 Acidosis. (Table 1)

	ICD-9-CM	ICD-10-CM	SNOMED CT
Metabolic acidosis	276.2 Acidosis	E87.2 Acidosis	59455009 Metabolic acidosis
Respiratory acidosis	276.2 Acidosis	E87.2 Acidosis	12326000 Respiratory acidosis
Lactic acidosis	276.2 Acidosis	E87.2 Acidosis	91273001 Lactic acidosis

Table 1. Coding difference in SNOMED CT, ICD-9-CM and ICD-10-CM on “acidosis”

Another major difference between SNOMED CT and ICD-10-CM is that the structure of SNOMED is multi-hierarchical while ICD-10-CM is mono- hierarchical. As shown in Figure 1, in ICD hierarchy, condition “lung cancer” can only be found in neoplasm table. Tracing from repository disease tree will reach this code. While in SNOMED CT, whose multihierarchy structure allows a concept to have multiple parent, condition “lung cancer” would be retrieved from either neoplasm branch or repository disease branch.

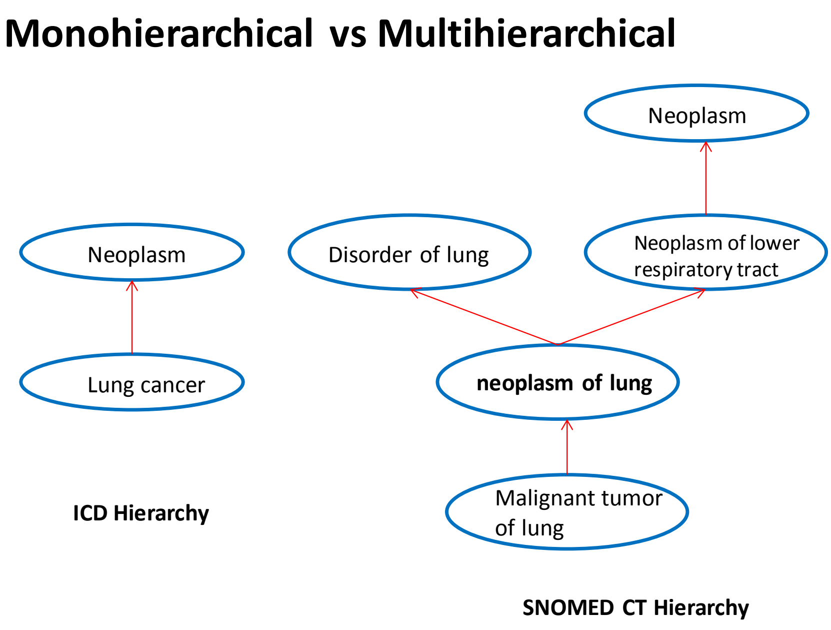

Figure 1: Monohierarchical vs Multihierarchical

With the overlapping in content while differences in structure, it is not difficult to understand that the similarity and difference in users and usage of these two coding systems. SNOMED CT is direct used by healthcare providers during the process of care. While ICD-10-CM will be used by coding professionals after the episode of care. It may be problematic for healthcare providers to use ICD directly since some terms are not “clinical user-friendly’ and presumed knowledge of coding rules and conventions are not familiar to healthcare providers.

1.3.3 Terminology mapping

Healthcare data standardization can realized via terminology mapping:

- Diagnosis terms / problem list can be mapped to clinical terminology (SNOMED CT) and standard reimbursement coding systems (ICD-9-CM, ICD-10-CM).

- Procedure terms for orderables and performables can be coded with clinical terminology (SNOMED CT), clinical classification (ICD-9-CM V3, ICD-10-PCS) and standard reimbursement coding system (CPT - Current Procedural Terminology).
- Pharmaceutical product given to, or taken by, a patient, with a therapeutic or diagnostic intent, and be mapped to RxNorm, a standardized nomenclature for clinical drugs.
- Allergy reactions are usually mapped to clinical terminology (SNOMED CT).
- Allergy reactant – medication reactants can mapped to RxNorm. Non-medication reactants can be mapped to SNOMED CT (substance hierarchy) or UMLS.
- Lab tests or observations made on specimens can be mapped to LOINC (Logical Observation Identifiers, Names, and Codes).
- Vaccines (administered) - HL7 Standard Code Set CVX

The implementation of electronic health records (EHRs) has increased dramatically, resulting in huge volumes of clinical data are accumulated. Historically, clinical terminology used to represent clinical data elements has varied among different systems and often from site to site even within the same system. Not having standard terminology creates difficulty in sharing data, performing computer-based decision support, or aggregated data analysis for research. Overtime multiple standards of terminology have been developed and adopted in healthcare at different time for different purpose. The need for mapping between controlled terminologies arises commonly to enable the re-use of data encoded in one terminology for another purpose that requires a different encoding system – the “code once, use multiple times” principle. [1-5] It also would facilitate the re-use of data encoded in one terminology for another purpose that requires a different encoding system.

Following are some cross-terminology map sets that are developed via SDO collaboration.

1): SNOMED CT to ICD-9-CM Rule Based Mapping

The purpose for this set of mapping is to support administrative reporting and reimbursement processes where the data is coded with SNOMED CT for clinical descriptive purposes.

This set of rule-based cross-reference from SNOMED CT to ICD-9-CM is from SNOMED CT to the ICD-9-CM diagnosis classification system is developed by SNOMED Terminology Solution, a division of the College of American Pathologists (CAP), on behalf of NLM. The map set consists of approximately 5,000 mappings with prioritized SNOMED CT terms.

Source SNOMED CT concepts are limited in three hierarchies: Clinical finding (finding), Event (event) and Situations with explicit context excluding procedure with explicit context. The target ICD-9-CM classification data employed in this mapping include Classification of diseases, E-codes for external causes of injury and poisoning and V-codes for patient health status and reasons for provision of health services.

2): ICD-9-CM Diagnostic Codes to SNOMED CT Map

The purpose for this set of cross walk is to support migration to SNOMED CT as the primary clinical terminology for patient problems (diseases and conditions) with the legacy ICD-9-CM data to SNOMED CT translation. The map set is developed and maintained by NLM.

The mapping is conducted at two mapping levels:

I. one-to-one maps - a single SNOMED CT concept can be used to represent the full meaning of an ICD-9-CM code

II. one-to-many maps - algorithmically developed maps which involved multiple SNOMED CT targets

ICD-9-CM source codes include commonly used ICD-9-CM codes in short-stay and outpatient hospitals respectively, for the year 2009, which were obtained from the Centers for Medicare & Medicaid Services (CMS), covering. Target SNOMED CT codes employed in this mapping limited to three hierarchies: Clinical finding, Situation with explicit context, and Events.

3): General Equivalence Mappings: ICD-9-CM to and from ICD-10-CM and ICD-10-PCS

The purpose for this cross mapping between different version of ICDs is to assist with converting large ICD-9-CM databases to ICD-10-CM. The GEMs can be used in converting coded data in payment systems. It can also be useful in updating ICD-9-CM-based code sets in quality measures and other use cases. The diagnosis mapping was developed by The National Center for Health Statistics (NCHS). The mapping for procedure codes was developed by the Centers for Medicare & Medicaid Services (CMS). In GEMs, mapping from ICD-9-CM to ICD-10-CM is called “forward mapping,” while mapping from ICD-10-CM to ICD-9-CM “backward mapping.” This design enabled GEMs to be used for bi-directional translation.

4): Regenstrief and the IHTSDO are working together to link LOINC and SNOMED CT

The purpose of this set of mapping is to build to support order entry and result reporting with links between the SNOMED CT and LOINC terminologies.

The full version of the cross-map would include the following:

- a map of LOINC terms to post-coordinated SNOMED CT expressions;
- a map of LOINC parts to SNOMED concepts;
- a map between LOINC terms and existing pre-coordinated SNOMED concepts;
- LOINC Answer sets mapped to SNOMED codes;
- Addition of new content in either terminology.

The released Technology Preview contains two main sets. One is the LOINC Term to SNOMED Expression Reference Set, which contains 9730 active LOINC terms associated with post-coordinated SNOMED CT expressions. The second set is the LOINC Part to SNOMED Reference Set, which consists of 2121 LOINC Parts (LP) mapped to one or more SNOMED concepts.

1.4 Goals and Objectives

It is crucial that healthcare documentation to be standardized through coding in health information management. Vocabulary, terminology, and classification systems are key in this function.

- A vocabulary is a collection of words or phrase with their meanings, that is, a dictionary of those terms.
- A terminology is a set of terms representing a system of concepts.
- A classification is a system that arranges or organizes like or related entities.

- Ontology, is a common vocabulary organized by meaning that allows for an understanding of structure of descriptive information, which helps to facilitate interoperability.

SNOMED CT is a comprehensive clinical terminology that is used to code, retrieve and analyze clinical data. ICD-10-CM is a medical classification used for epidemiology, health management and clinical purposes. The goal and objective of this project is to create crosswalk between these two coding systems.

1.5 Hypothesis

Standardized Medical Terminologies / Ontologies provide the functions that would allow access to complete & accurate clinical data, to collect data in electronic version, to capture detailed clinical data about patients. It would also allow different site, different healthcare providers to send and to receive medical data for patient care. With the logic embedded in medical ontology, decision support systems like practitioner alerts and reminder can be implemented in electronic patient record to improve patient safety. With data standardization, the computer can manipulate clinical data and find information relevant to individual patient as well as certain patient population to link to medical knowledge to provides an organized system of data collection and retrieval, resulting in the linkage of published research with clinical care, to improve the quality of care through outcome measurements. It provides data for use in monitoring public health and risks. Standard terminology system not only benefits clinical data analysis, but also is useful in medical research and epidemiogical studies. It enables the collection and reporting of basic health statistics to ensure a high-quality database for accurate clinical and statistical data. Standard medical disorder classifications are also used for healthcare claims, especially for use in designing payment systems and determining the correct payment for healthcare services. It helps to identify fraudulent or abusive practices. The consuming clinical applications include Electronic medical records, Physician order entry, Clinical decision support, Laboratory reporting, Case report forms for clinical research, Surgical procedure masters, Consumer health information services.

With the examination on Standard Medical Terminology systems (1.4.1), and the comparison between SNOMED CT and ICD-10-CM (1.4.2) and existing crossmapping between and among coding systems (1.4.3), the following hypothesis are formulated to serve the base of this project:

1: To study the relationship between health data standardization and Meaningful Use

Research Question 1 (RQ1): Is the health data standardization essential for Meaningful Use?

Null Hypothesis 1 (H01): Health data standardization is not essential for Meaningful Use

Alternative Hypothesis 1 (HA1): Health data standardization is essential for Meaningful Use

2: To study the suitability of creating the crosswalk between SNOMED CT and ICD-10-CM

Research Question 2 (RQ2): Is the coverage overlapping between SNOMED CT and ICD-10-CM make it suitable to create a crosswalk between these two coding systems?

Null Hypothesis 2 (H02): Coverage overlapping between SNOMED CT and ICD-10-CM does not make it not suitable to create a crosswalk between these two coding systems.

Alternative Hypothesis 2 (HA2): Coverage overlapping between SNOMED CT and ICD-10-CM make it suitable to create a crosswalk between these two coding systems.

3: To study the essential requirements in mapping to overcome the gap between SNOMED CT and ICD-10-CM due to coding and modeling invention difference in these two coding systems

Research Question 3 (RQ3): Does it requires specific mapping principle, mapping guidelines and mapping algorithm to overcome the gap between these two coding systems?

Null Hypothesis 3 (H03): It does not require specific mapping principle, mapping guidelines and mapping algorithm to overcome the gap between these two coding systems.

Alternative Hypothesis 3 (HA3): It requires specific mapping principle, mapping guidelines and mapping algorithm to overcome the gap between these two coding systems.

1.6 Significance of Study

This research is to develop SNOMED CT to ICD-10-CM mapping methodology. With this methodology, a set of maps would be created to promote the adoption of SNOMED CT internationally. Similarly, mapping from SNOMED CT to national extensions of ICD-10 would encourage the uptake of SNOMED CT nationally. All these mapping principle, mapping guidelines, mapping tools and mapping methodology could be used as a prototype in other cross standard mappings.

CHAPTER 2 LITERATURE REVIEW

To better understand the medical standards in relevance to Meaningful Use and to study the methodology of cross terminology mapping, an extensive literature review was conducted. The literature review consists the following four parts:

- Meaningful Use and medical standard terminology
- SNOMED CT use
- Cross terminology mapping
- SNOMED to ICD mapping

1: Meaningful use and medical standard terminology[12-17]

Literature search scrip

"meaningful use"[MeSH Terms] OR "meaningful"[All Fields] OR "meaningful use"[All Fields]) AND medical[All Fields] AND standard[All Fields] AND terminology[All Fields]

SNOMED CT (SCT) is recommended as standard for encoding diagnoses and problem lists in electronic health records (EHRs). Agrawal A. studied the "SCT Clinical Observations Recording and Encoding" published by the National Library of Medicine and the "Veterans Health Administration and Kaiser Permanente" problem lists ("PL") for its readiness to support meaningful use of EHRs. The study shows inconsistencies exists in some of the hierarchical relationships and the PL needs QA efforts to promote meaningful use of EHRs[12].

Zhou L reported a study on two standards (SNOMED CT and HL7 Family History Standard) used by Stage 2 of Meaningful Use[13]. Coverage to represent local terms used in ambulatory EHR system is satisfactory.

In the study "Quality requirements for EHR archetypes" [14], Kalra D reported that In terms of semantic interoperability, it is quite challenging to make any EHR data be communicated between heterogeneous systems and fully understood by computers as well as people on receipt.

Rossi Mori reported the sublanguage that healthcare provider used to store and transmit general medical knowledge and patient-related information requires adequate formalisms to obtain a standard representation of semantics of medical expressions for computable data process. ("Semantic standards for the representation of medical records. [17])

Even though one of the goals of the standards is to overcome the barrier between systems, it is also discovered that too much optionality and variability exists in how particular clinical entries may be represented with standardized generic models for the EHR and standard terminology systems[14].

2. literature review of SNOMED CT use[18-38]

Literatures were also reviewed to learn how SNOMED CT has been used in healthcare. Literature search scrip:

("review"[Publication Type] OR "review literature as topic"[MeSH Terms] OR "literature review"[All Fields]) AND ("systematized nomenclature of medicine"[MeSH Terms] OR ("systematized"[All Fields] AND "nomenclature"[All Fields] AND "medicine"[All Fields]) OR "systematized nomenclature of medicine"[All Fields] OR ("snomed"[All Fields] AND "ct"[All Fields]) OR "snomed ct"[All Fields])

As a multi-hierarchical medical terminology, SNOMED is constructed with codes, terms, and synonyms. It is used to index, store, retrieve, and aggregate clinical data across domains and healthcare sites. The concepts in SNOMED cover almost all aspects of the EHR[18].

While on the other hand, as a multilingual vocabulary to classify diseases, ICD ha its focus on epidemiological and clinical applications. It is originally created to assist with the statistical report on the incidence and prevalence of diseases across countries, populations, and specific subgroups[18].

Lee D did an extensive review on SNOMED CT use[19], as well. In this review, it is reported that it has been a data quality issue on using free text and local terms in EHR. It creates barrier in information interoperability, data mining, secondary use of data and computerized clinical decision support. Introducing SNOMED in EHR can potentially improve data quality and patient safety, via clinical data standardization. The review also reports that In EHR, the most common domains that use SNOMED include Problem list/diagnoses, nursing, drugs and pathology. SNOMED has been used in the following areas

- Planned standard for electronic health records;
- Design considerations;

- Used to classify or code in a study;
- Retrieve or analyze patient data;
- Developed decision support capabilities for detecting adverse drug events, managing wounds and obesity

Cornet R did a forty years overview on SNOMED[27]. It has been noticed that the awareness of SNOMED and its development has raised significantly. This change partially due to the benefits that SNOMED offers:

- Keep consistency of clinical data indexing, storing, retrieving and aggregating
- Structuring the medical record to standardize in data capture,
- Automated reasoning for decision support.

In the earlier years, most studies describe SNOMED usage in pathology information system for patient data encoding. In the recent years the usage has been expend to cover other systems as well.

In "eHealth Interoperability"[32], Hammond WE reported that unstandardized data and unambiguous component create problem for semantic interoperability. A master data set repository is proposed where all documentation of care would be mapped to a universal terminology or existing terminologies. Subsets or minimum data sets for defined business purposes would be derived from the master repository. It is very interesting that this report raised the issue that sue to the absence of such a master repository, the healthcare community has been using multiple controlled terminologies, which creates another layer barrier on data Semantic Interoperability cross systems. Cross terminology mapping seems currently a more feasible solution to this problem.

This issue also mention in a study conducted by Simpson CR in the research to investigate if SNOMED can improve data quality in allergic disorders[33]. Several medical coding systems have emerged resulting in variation on using these coding systems exists per user populations. The study reported the advantage of using SNOMED:

- Post-coordinated concepts used in clinical practice
- Capability of allowing detailed coding without compromising fluidity.
- Being useful for decision support: real-time patient summaries, patient safety and efficacy alerts, and individualized treatment recommendations were implemented with SNOMED model via clinical concepts including allergies, presenting symptoms, diagnoses and test results.

The study also reported the disadvantage of using SCT: being a comprehensive terminology and having complex modeling, it requires in depth knowledge for user to conduct secondary analysis;

Cimino JJ endorsed that as being a comprehensive, high-quality terminology, SNOMED-CT has had significant impact on coding of clinical data, and on health information systems and healthcare in general[34].

3. Cross terminology mapping[39-43]

Literatures were also reviewed to learn cross terminology mapping, with the following literature search scrip:

cross[All Fields] AND standard[All Fields] AND terminology[All Fields] AND mapping[All Fields]

Kim TY in her "Automating lexical cross-mapping"[39] paper stated that cross terminology mapping is essential to ensure the interoperability of healthcare data, given the fact huge volumes of clinical data accumulated as a result if increasing implementation of electronic health records (EHRs). The study investigated various cross-mapping solutions and found that automation of term mappings can promote data integration, exchange and secondary use of clinical data. It is especially true when mapping large terminology systems. A machine-aided mapping process is researched to create a candidate set of equivalencies for experts' validation and editing. UMLS CUIs were utilized to identify synonymous relationships of individual concepts across terminologies. Via this method, candidate target codes can be achieved in crossmappings of selected terminologies. MRMAP were queried against on validated mappings to increase the accuracy of candidate maps.

Goossen W's paper on "Cross-Mapping Between Three Terminologies With the International Standard Nursing Reference Terminology Model"[41] was also reviewed. This study tested the degree to which three terminologies could be cross-mapped to each other. The research compared terms from different terminology system to determine the semantic equivalence and distance. Because cross terminology mapping can be very time consuming, a reference terminology, SNOMED CT, is suggested to be used to assist in improving mapping efficiency.

Similar report[43] was published byWang X. I tis found that manually indexing large-scale terminology databases could be laborious and often impractical. Solutions on using reference terminologies have been proposed, but coordination of terms from the databases of interest to these reference terminologies is also laborious. The researcher described a method of connecting different databases using terminology networks constructed with automated mapping methods. The two biomedical terminology databases are SNOMED-CT and HDG, with two reference databases (UMLS and OMIM) as intermediators. The following methods were used in the study:

- Creating networks to link disparate databases
- Automated Mapping
- Evaluation of terminology pathways

Both quantitative evaluation and qualitative evaluation on mapped concepts were performed. Results revealed that it is feasible to use automated networks of terminologies to achieve terminology integration in support of database intermediation. Automated terminology pathways enables linkages between biomedical databases when manual mapping is not practical.

4: SNOMED to ICD mapping[44-60]

At last, articles on SNOMED to ICD mappig were studied with the following searching scripts: ("systematized nomenclature of medicine"[MeSH Terms] OR ("systematized"[All Fields] AND "nomenclature"[All Fields] AND "medicine"[All Fields]) OR "systematized nomenclature of medicine"[All Fields] OR "snomed"[All Fields]) AND icd[All Fields] AND mapping[All Fields]

Difficulties are expected in cross mapping concepts in ICPC-2, ICD-10, SNOMED-CT and UMLS. Jamoulle M's article[44] shows the variability of the various international classifications and nomenclatures. The researcher emphasized the need for structured guidelines and the need for classification expertise in sophisticated terminological resources.

Steindel SJ studied the difference between SNOMED and ICD-10 via a comparison between a subset of the SNOMED CT (Clinical Observations Recording and Encoding) Problem List and the ICD-10-CM codes[49]. The comparison was done with quality of the match being defined as “Exact,” “Inexact,” “Model” (one SNOMED CT term to many ICD-10-CM/PCS terms), “Not Elsewhere Classified,” “Not Otherwise Specified,” “Synonym,” and “Not Found” to classify the CORE Problem List terms. The results of this study suggest that ICD-10-CM/PCS meets the intended design goal of increased clinical precision.

A study on “disease distribution with SNOMED CT and ICD-10” [53, 54,55] by Nyström M and Vikström A analyzed the distribution of 2,5 million diagnostic codes from primary healthcare in the Stockholm region. The patient encounters, originally coded with ICD-10 (mono-hierarchical), were mapped to SNOMED CT concepts (polyhierarchical) through a mapping table. The results of this study showed hidden information about health problems and diagnoses, and illustrated the advantage of a poly-hierarchy.

Stenzhorn H reported methods developed in mapping Clinical Documentation to SNOMED CT[56]. The study reported that common coding issues like mapping variation among users, mapping errors and mapping incompleteness, plus the problem with almost exponential growth of clinical data. The researcher presented a new methodology with natural language processing to map free natural language texts from the clinical domain to SNOMED CT. A manual analysis of clinical texts was analyzed and the issues found in them were evaluated. A proposal to solve those issues within a practically implemented system was also presented.

Brown SH reported a study on "Using SNOMED CT® as a Reference Terminology to Cross Map Two Highly Pre-coordinated Classification Systems"[58]. The hypothesis was that SNOMED CT, a granular formal reference terminology, could be used to assist in the creation of a valid crosswalk between two administrative classifications: the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) and the U.S. Veterans Benefits Administration (VBA) disability code set. An ICD-9-CM terminology server was created as a baseline. Textual descriptions of the VBA disability codes were mapped to ICD-9-CM. Then the ICD-9-CM and the VBA Disability codes were mapped to SNOMED CT. An expert coder's reviewed the mappings. The researcher reported that the method using the SNOMED CT crosswalk provided significantly better coverage than the ICD-9-CM direct mapping alone. It is concluded that SNOMED CT can be a useful adjunct to direct mapping between administrative classifications.

Vikström A reported a mapping process and mapping rule development in "Mapping the categories of the Swedish primary healthcare version of ICD-10 to SNOMED CT concepts"[59]. In this study, the research evaluated intercoder reliability and the assessed degree of concordance when primary healthcare version of ICD-10 is matched to SNOMED CT. The proposed mapping rules includes "Concept oriented perspective in mapping", and "Not to use 'limited' concepts in SNOMED CT".

Upon literature review, the following conclusions can be draws:

- health data standardized is essential for Meaningful Use.
- SNOMED CT, as a comprehensive medical terminology, has been used to index, store, retrieve, and aggregate clinical data across domains and healthcare sites

- the need for mapping between controlled terminologies has been identified and acknowledged

CHAPTER 3 MAPPING METHODOLOGY

A collaborative project between IHTSDO and WHO was started to create a map between SNOMED CT and ICD-10. The aim of the map was to support semi-automated generation of ICD-10 classification data from a clinical record encoded in SNOMED CT. [61] The expected benefits of the map include:

- Re-use of clinical data for additional statistical purposes
- Rapid submission and response to national reporting requirements
- Saving time and improving efficiency for the coding professional
- Improved accuracy and reproducibility of code mapping
- Promulgation of widespread comparable epidemiologic and statistical data
- Cost saving for IHTSDO member countries which maintain ICD-10 derivative product maps

One of the stated goals of the map was to facilitate the development of maps to national extensions of ICD-10. A preview release of the SNOMED CT to ICD-10 Crossmap was published in September 2011. [62]

A separate project led by the U.S. National Library of Medicine (NLM) was started to create a map between SNOMED CT and ICD-10-CM. Year 2015 and prior, the U.S. was using ICD-9-CM for reimbursement purpose. A transition to ICD-10-CM occurred on October 2015. It is anticipated that the public availability of a map from SNOMED CT to ICD-10-CM would promote the use of SNOMED CT as the primary clinical terminology in the EHR (Electronic Health Record) by enabling the secondary generation of ICD-10-CM codes for administrative purposes.

3.1 Rule based map

The creation of a map from SNOMED CT to ICD-10 or ICD-10-CM is to create a bridge between two very different artifacts: a clinical terminology and a classification.[63, 64] It is not always possible to find a one-to-one correspondence between a SNOMED CT concept and an ICD code.[65] In some cases, more than one ICD code is required to fully encode the meaning of a SNOMED CT concept. For example, the SNOMED CT concept *301011002 Escherichia coli urinary tract infection* requires two ICD-10 codes for proper encoding: *N39.0 Urinary tract infection, site not specified* and *B96.2 Escherichia coli as the cause of diseases classified elsewhere*. In addition, there are cases in which alternative ICD codes exist for the same SNOMED CT concept, and which one to use depends on the patient's demographic characteristics (e.g. age, gender) and existing co-morbidities. For example, *73430006 Sleep apnea* can map to either *P28.3 Primary sleep apnea of newborn* or *G47.3 Sleep apnea*, depending on the patient's age. To allow the map to reflect the coding guidelines in ICD-10, a rule-based map structure was used. Alternative ICD map targets are represented as "map rules", and related map rules are grouped into "map groups". At run-time, the map rules are evaluated in a prescribed order, taking into consideration patient contextual information and comorbidities. Each map group will resolve to at most one ICD-10 code in the final result. The same rule-based approach was adopted in the ICD-10-CM map, using the same type of rules (age and gender rules) to handle patient context, and the same method to handle exclusion notes.[61]

Map group	Rule order	Map rule	Target code	ICD description
1	1	IF AGE >= 29 DAYS	L08.82	Omphalitis not of newborn
1	2	DEFAULT	P38.9	Omphalitis (of newborn) without hemorrhage
2	1	IFA 403841009 | staphylococcal omphalitis of newborn (disorder)	B95.8	Unspecified staphylococcus as the cause of diseases classified elsewhere
2	2	IFA 403843007 | streptococcal omphalitis of newborn (disorder)	B95.5	Unspecified streptococcus as the cause of diseases classified elsewhere
2	3	DEFAULT	NULL	NULL

Table 2. ICD-10-CM Map for the SNOMED CT concept "Omphalitis"

Table 2 illustrates the rule-based map using the ICD-10-CM map for the SNOMED CT concept *239095007 Omphalitis* as an example. It consists of two map groups and five map rules. In map group 1, the first rule is evaluated based on the patient's age. If the patient is not a neonate (defined as from birth to 28 days), the map target is *L08.82 Omphalitis not of newborn*. Otherwise, the default code is *P38.9 Omphalitis (of newborn) without hemorrhage*. If the infective agent is specified, as in two of the descendants of the source SNOMED CT concept *(403841009 staphylococcal omphalitis of newborn* and *403843007 streptococcal omphalitis of newborn)*, an additional ICD-10-CM code is needed. This triggers the creation of map group 2, in which the first two map rules point to the appropriate additional codes. If neither map rule 1 or 2 is satisfied, the second ICD-10-CM code is not needed. This is represented by the NULL map target in map rule 3.

Due to the additional level of specificity in ICD-10-CM, some modifications in the methodology are needed. In ICD-10-CM, most injury-related diagnostic codes require episode of care information (e.g. initial encounter, subsequent encounter or sequela) for proper coding. Most SNOMED CT concepts do not specify episode of care. Without this information, no valid target codes can be assigned. This is resolved by adding placeholder codes (replacing the 7th character of the ICD-10-CM code by "?"), which allow us to identify the target code cluster.

3.2 Mapping principles:

3.2.1 Map group

Map group is an integer assigned to each set of map records which multi-targets are required to fully represent a SNOME CT concept in ICD-10-CM. Each Map Group collates and orders the rules which are sequentially evaluated to yield at most a single target code. The first Map Group designates the set of records used to specify the first (primary) target code. The second Map Group identifies the set of records for the second target code. These are repeated as required to specify a complete set of mapping target codes.

3.2.2 Map advice

Map advice is human-readable textual statement that is used in the map set to inform the clinician user or the classification expert during an interactive mapping session. The purpose of the map advice is to remind the user to look for additional information in patient's record to arrive a valid ICD-10-CM targets. These additional patent information might be related to alcohol assumption, or external cause, or co-mobility which are usually not modelled in SNOMED CT concept with pre-coordination. For example, The map advice “EPISODE OF CARE INFORMATION NEEDED” is added to alert users that additional information will be needed to arrive at a valid ICD-10-CM code. Another difference between ICD-10-CM and ICD-10 is the specification of laterality (e.g. fracture of right hip), which is only used in ICD-10-CM. In most SNOMED CT concepts, laterality is not specified. In those cases, a valid ICD-10-CM code for “unspecified laterality” can still be used as a default map target. A special map advice “CONSIDER LATERALITY SPECIFICATION” is added to alert the user that further specification of laterality is possible in ICD-10-CM. For similar reasons, two new map advices “CONSIDER TRIMESTER SPECIFICATION” and “CONSIDER WHICH FETUS IS AFFECTED BY THE MATERNAL CONDITION” are added for the possibility of further specifying the trimester of pregnancy, or a particular fetus in multiple pregnancy. Some other map advices may serve the purpose of a clarification on how and why a map target is chosen. For example, map advice “MAPPED WITH NCHS GUIDANCE” indicates the map set is created with special NCHS guidance or ICD-10-CM coding convention..

The following a complete list of map advices that are available to use in mapping process.

- DESCENDANTS NOT EXHAUSTIVELY MAPPED
- EPISODE OF CARE INFORMATION NEEDED
- CONSIDER ADDITIONAL CODE TO IDENTIFY SPECIFIC CONDITION OR DISEASE
- CONSIDER LATERALITY SPECIFICATION
- CONSIDER TRIMESTER SPECIFICATION

- CONSIDER WHICH FETUS IS AFFECTED BY THE MATERNAL CONDITION
- POSSIBLE REQUIREMENT FOR AN EXTERNAL CAUSE CODE
- POSSIBLE REQUIREMENT FOR CAUSATIVE DISEASE CODE
- THIS IS A MANIFESTATION CODE FOR USE IN A SECONDARY POSITION
- THIS IS AN EXTERNAL CAUSE CODE FOR USE IN A SECONDARY POSITION
- THIS IS AN INFECTIOUS AGENT CODE FOR USE IN A SECONDARY POSITION
- ADDITIONAL CODES MAY BE REQUIRED TO IDENTIFY PLACE OF OCCURRENCE AND ACTIVITY
- USE AS PRIMARY CODE ONLY IF SITE OF BURN UNSPECIFIED, OTHERWISE USE AS A SUPPLEMENTARY CODE WITH CATEGORIES T20-T25 (Burns)
- USE AS PRIMARY CODE ONLY IF SITE OF CORROSION UNSPECIFIED, OTHERWISE USE AS A SUPPLEMENTARY CODE WITH CATEGORIES T20-T25 (Burns)
- MAPPED WITH NCHS GUIDANCE
- MAPPED WITH IHTSDO GUIDANCE
- NCHS ADVISES TO ASSUME CLOSED FRACTURE
- MAP IS CONTEXT DEPENDENT FOR GENDER
- MAP SOURCE CONCEPT CANNOT BE CLASSIFIED WITH AVAILABLE DATA
- SOURCE SNOMED CONCEPT IS INCOMPLETELY MODELED

- CONSIDER STAGE OF GLAUCOMA SPECIFICATION
- CONSIDER TOPHUS SPECIFICATION

3.2.3 Independent Dural Mapping Approach

As a built-in mechanism for quality assurance, this projects employed dual independent mapping to reduce the variability in manual mapping. Every concept was mapped concurrently by two map specialists, who were terminology experts with knowledge in both terminology systems, and had received special training for the mapping projects. Only maps that were identical were accepted as final. Any discordance was reviewed by a third specialist, and escalated to wider discussion if necessary. The only exception to the dual mapping process was when an existing, reliable source of maps (which is called “legacy maps”) was available. In those cases, the legacy map is compared to a manually-created map. Only when the two maps were different was it necessary for mapping by a second map specialist. Because of this, having an existing source of legacy map would save time by avoiding a second mapping in some cases. In the ICD-10 map, two sources of legacy maps are used: an existing map owned by the U.K, and synonymy maps identified through the UMLS (Unified Medical Language System). [2, 3] In the ICD-10-CM map, three legacy map sources are used: ICD-10-CM simple maps included in some of the Convergent Medical Terminology contents donated by Kaiser Permanente, [66] synonymy maps from the UMLS, and algorithmically generated ICD-10-CM maps based on the available ICD-10 maps from the ICD-10 map project.

3.3 Mapping tools

Three kinds of tools were developed for the mapping projects:

3.3.1 ICD index viewer

The search for a target code in either ICD-10 or ICD-10-CM began with the index. For ICD-10, there was already an electronic version of the index developed by the WHO with adequate searching functionality. However, there was no readily available ICD-10-CM index viewer suitable for the mapping project. an ICD-10-CM index viewer is custom-built, primarily modeled on the ICD-10 index viewer, with some enhancements for more efficient searching (Figure 2). Direct level-specific search in the first three levels of the index was added, so that the user could reach the code *I50.9 congestive heart failure* in one search. Other enhancements included: wild card search words, tooltip hints showing the full index hierarchy, spell check and universal search of the whole index.

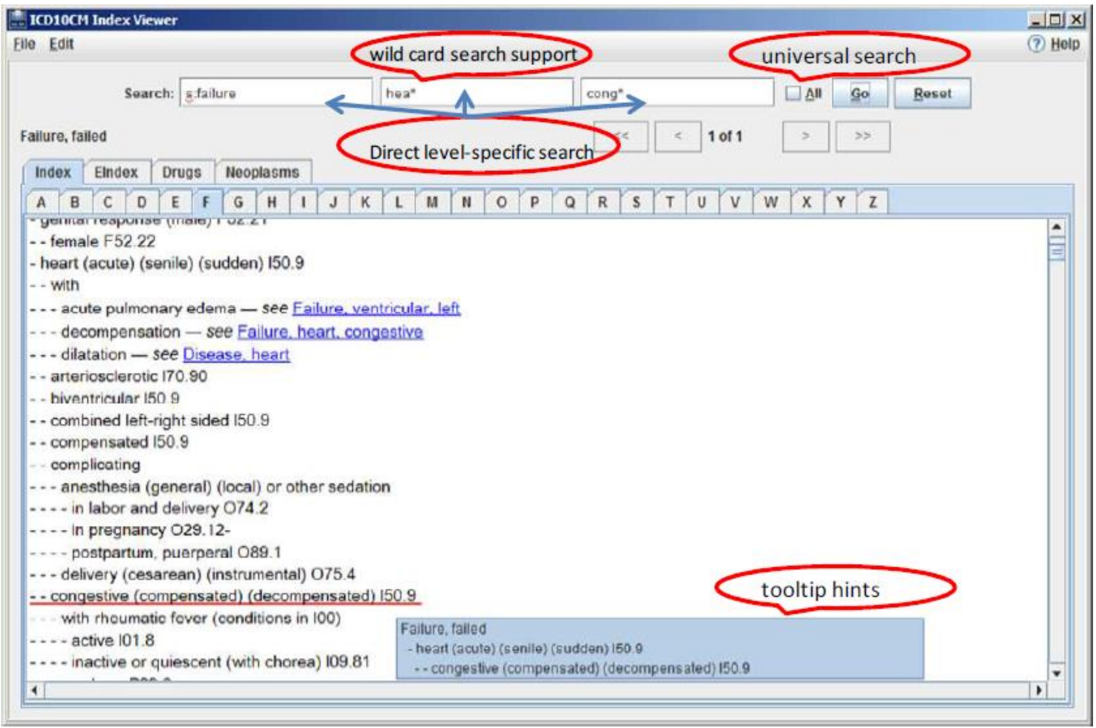

Figure 2. Screenshot of the ICD-10-CM index viewer

3.3.2 Mapping tool

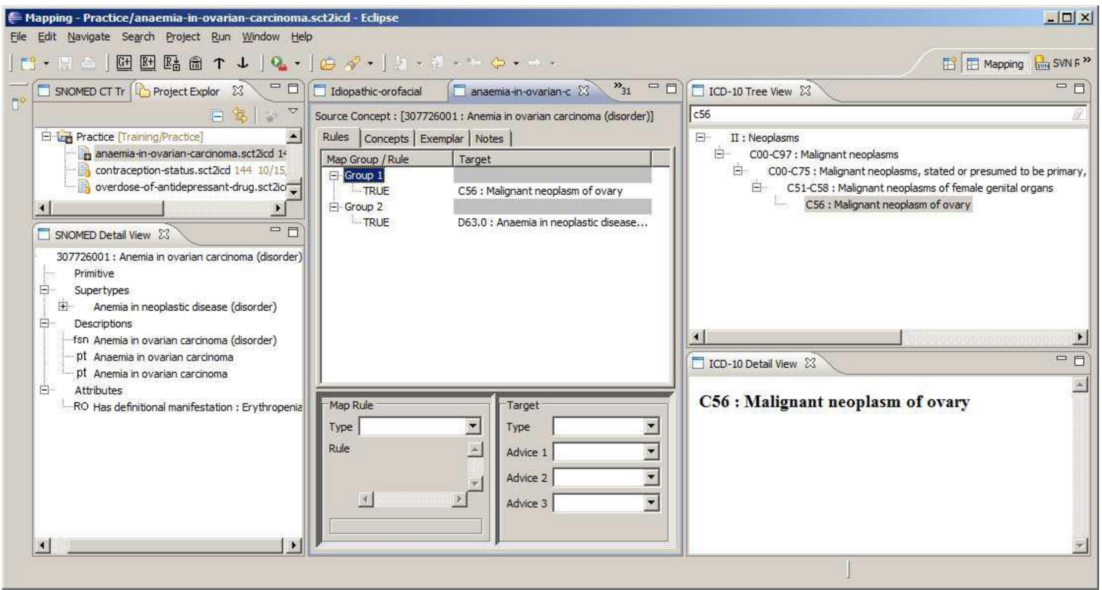

Figure 3. Screenshot of mapping tool (mapping view)

The same tool was used in the ICD-10-CM map project, with some minor modifications. Since the tool required loading of ICD-10 data in the ClaML

(Classification Markup Language) format, the ICD-10-CM data had to be converted to the same format before loading into the tool. The map advices for the two maps were different and so the pick list for map advice field had to be modified.

3.3.2.1 Default View

The tool will open up to the default view which is the "Mapping" perspective.

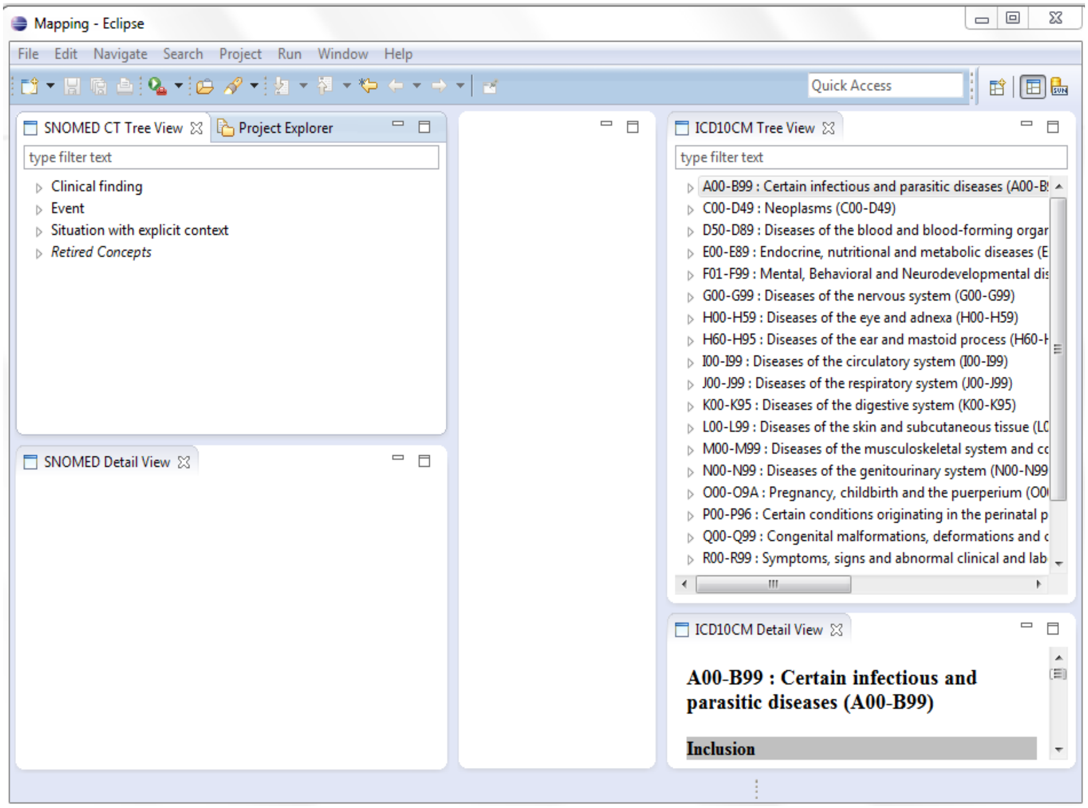

Figure 4. Screenshot of mapping tool (Default View)

There are six main panels on this view.

- SNOMED CT Tree View
- SNOMED CT Detail View
- ICD-10-CM Tree View
- ICD-10-CM Detail View

- Project Explorer
- Blank Central Mapping Panel

3.3.2.2 SNOMED CT Tree View

The first panel is located to the top left of the screen and is the "SNOMED CT Tree View".

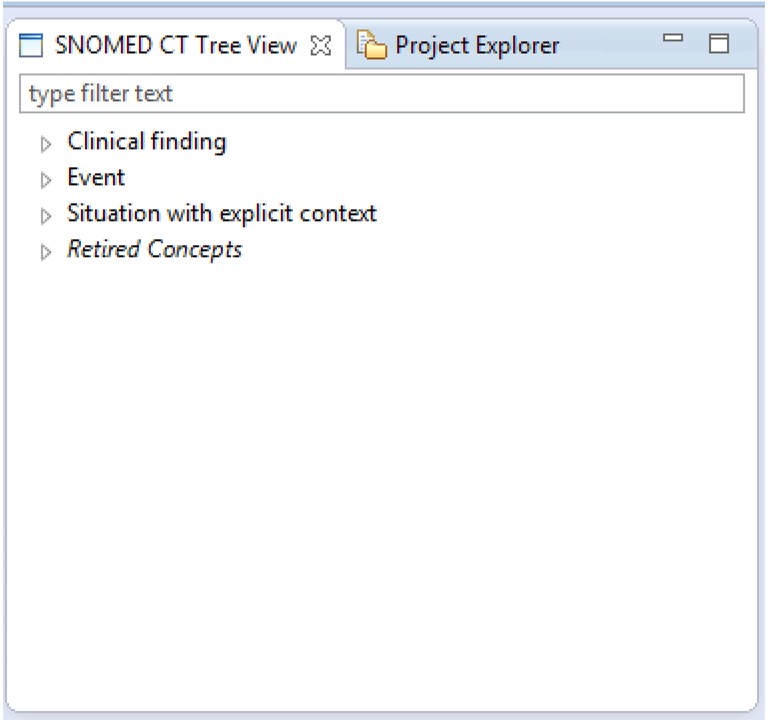

Figure 5. SNOMED CT Tree View

This browser view of the SNOMED CT taxonomies has been restricted to the hierarchies within scope of the classifications for this project. These are:

404684003 | Clinical finding (finding)

272379006 | Event (event)

243796009 | Situation with explicit context (situation)

Click on the sign would lead the mapper to walk down the taxonomy to locate a particular concept:

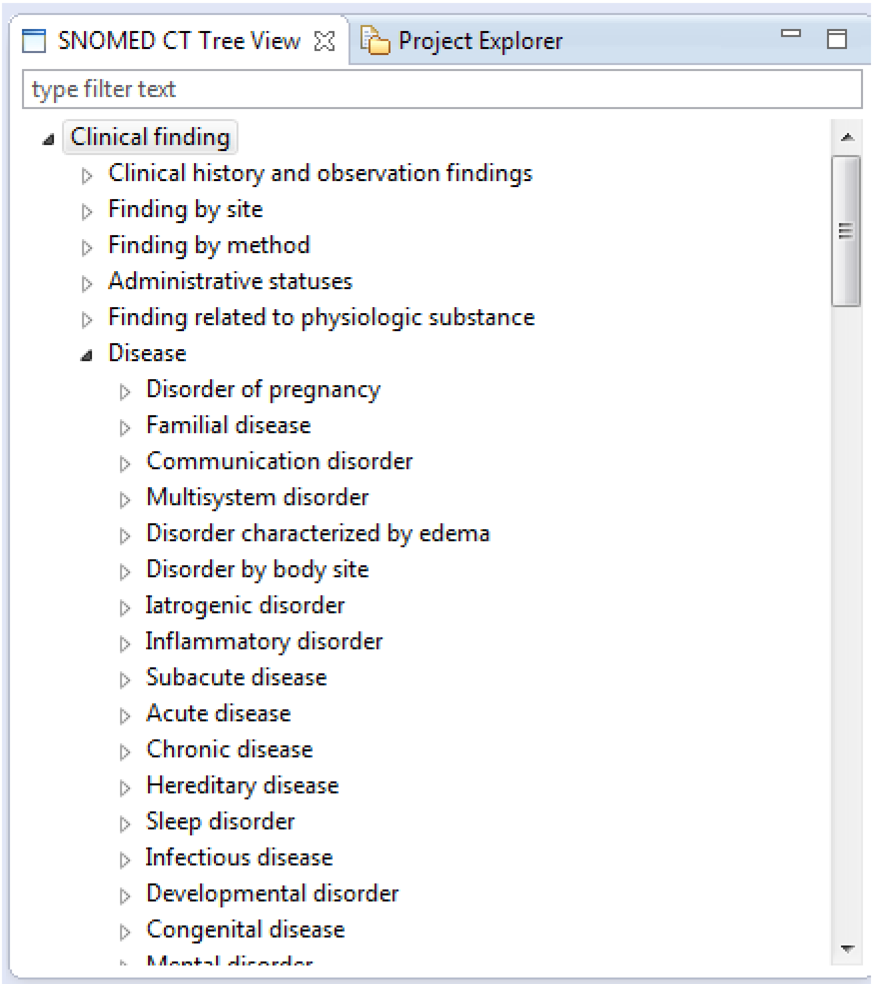

Figure 6. SNOMED CT Tree View - branch

OR type a description into the "type filter text" box. Here "Carpal tunnel syndrome" is used as example.

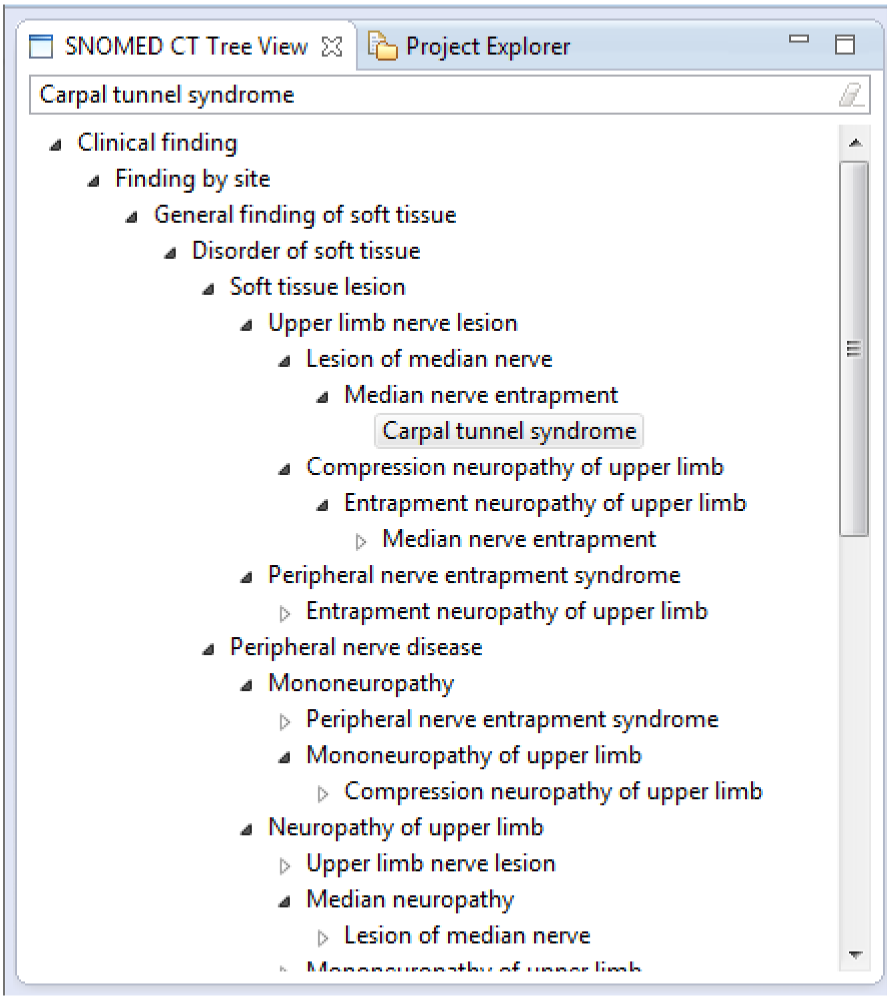

Figure 7. SNOMED CT Tree View – taxonomy search

3.3.2.3 SNOMED CT Detail View

The panel at the bottom right of the screen is the "SNOMED Detail View": This is populated with the detail of the concept which has been highlighted in the "SNOMED CT Tree View":

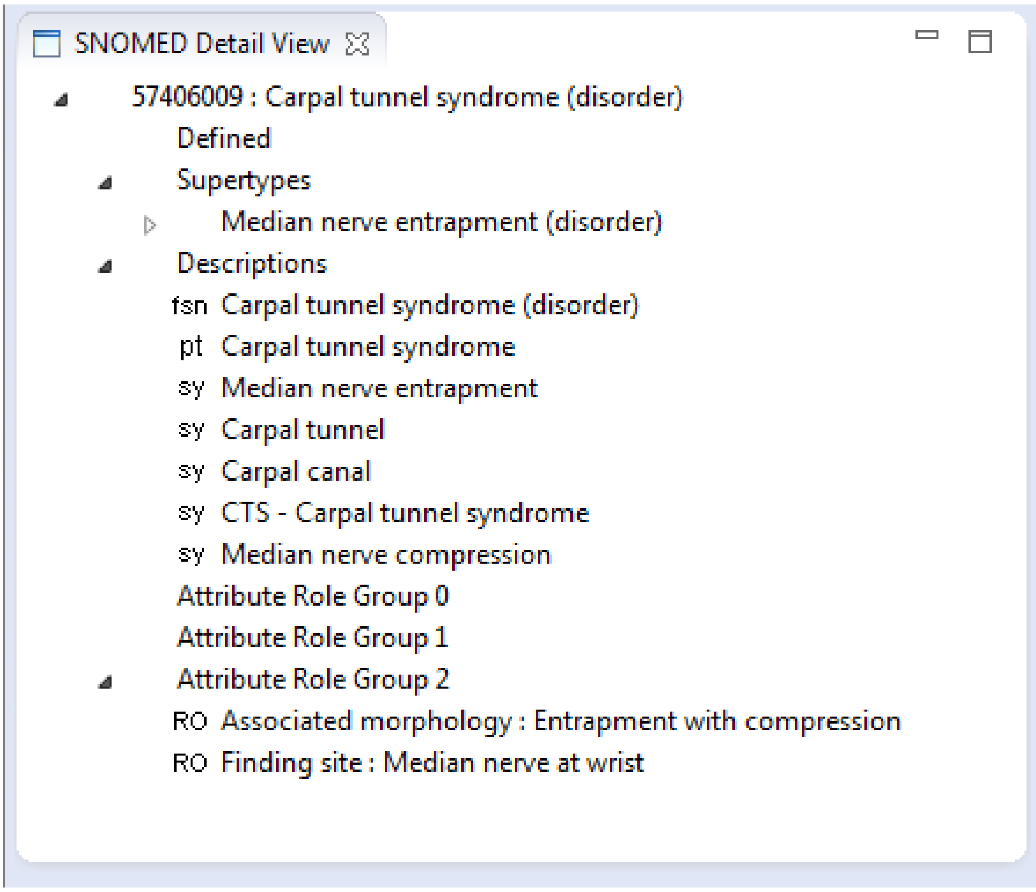

Figure 8. SNOMED Detail View

This view details the ConceptID, states whether the concept is defined or primitive and then details the "Supertypes" (parents) of the selected concept. sign can be clicked on to further expand, showing the IS-A relationships. The user can navigate up and down the taxonomy.

Also detailed is the Fully Specified Name (fsn), Preferred Term (pt), any synonyms (sy) and attribute relationships (ro).

3.3.2.4 ICD-10-CM Tree View

The panel on the top right of the screen is the "ICD10CM Tree View":

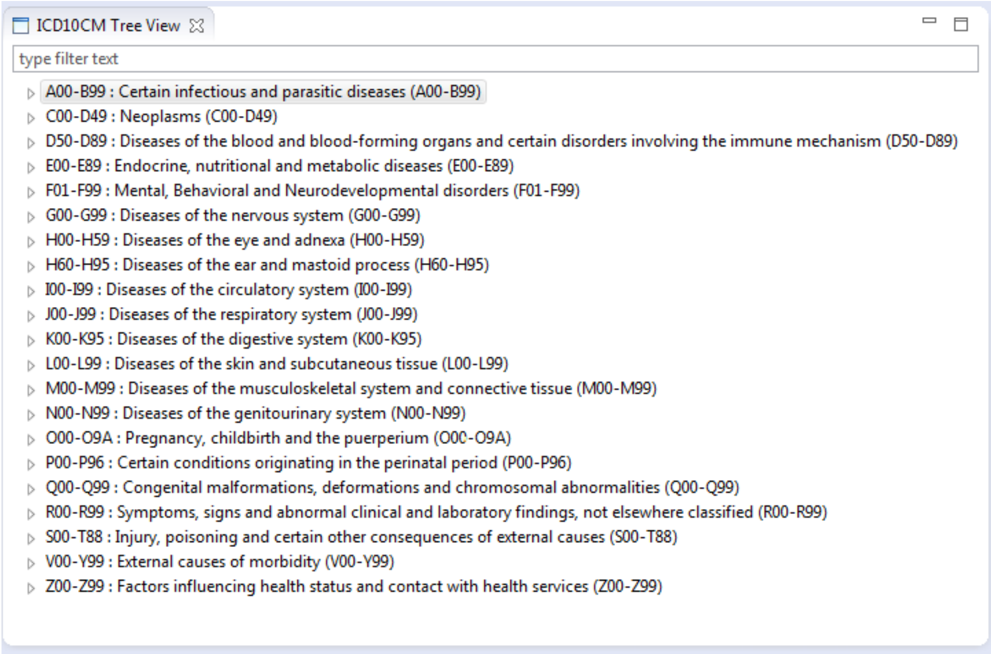

Figure 9. ICD10CM Tree View

This high level view lists the 21 chapters found in ICD-10-CM, Tabular List. Clicking on the signs allows the user to navigate down to category and subcategory level.

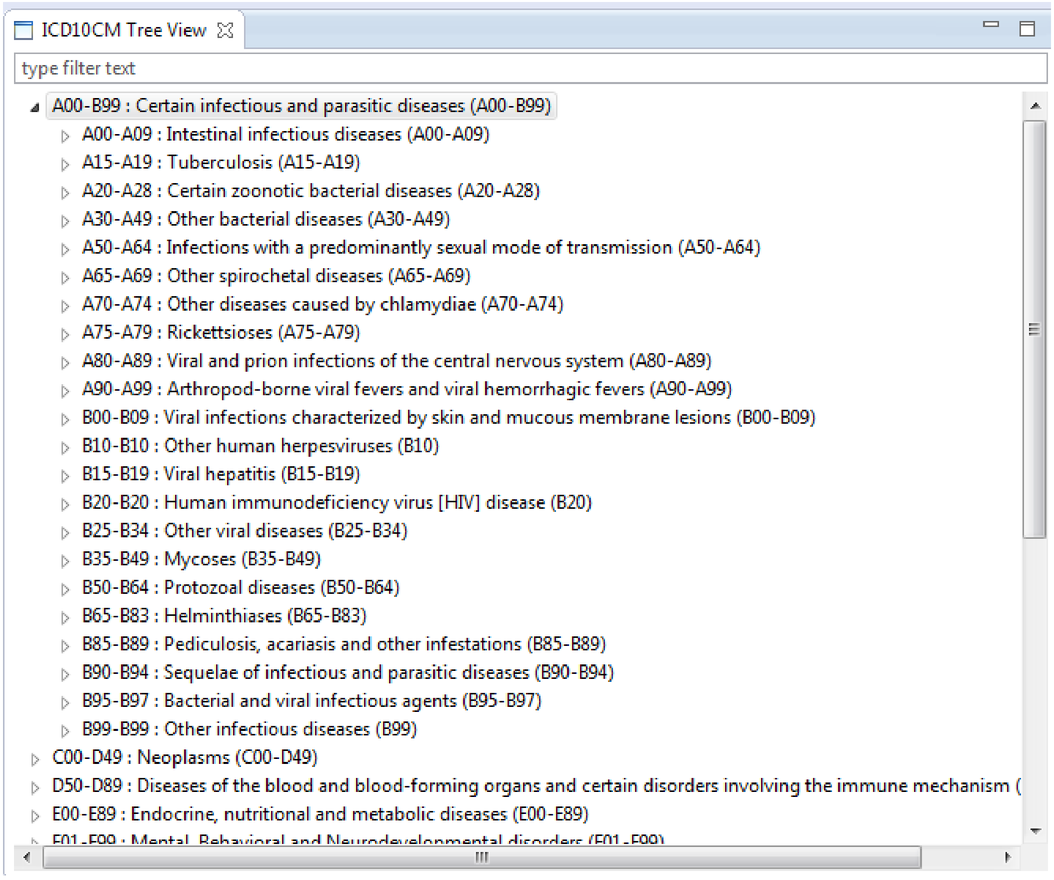

Figure 10. ICD10CM Tree View - Subcategory

OR type a search into the "type filter text" box. Example: type "Myocardial" into the box then highlight the code and I21 : ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction

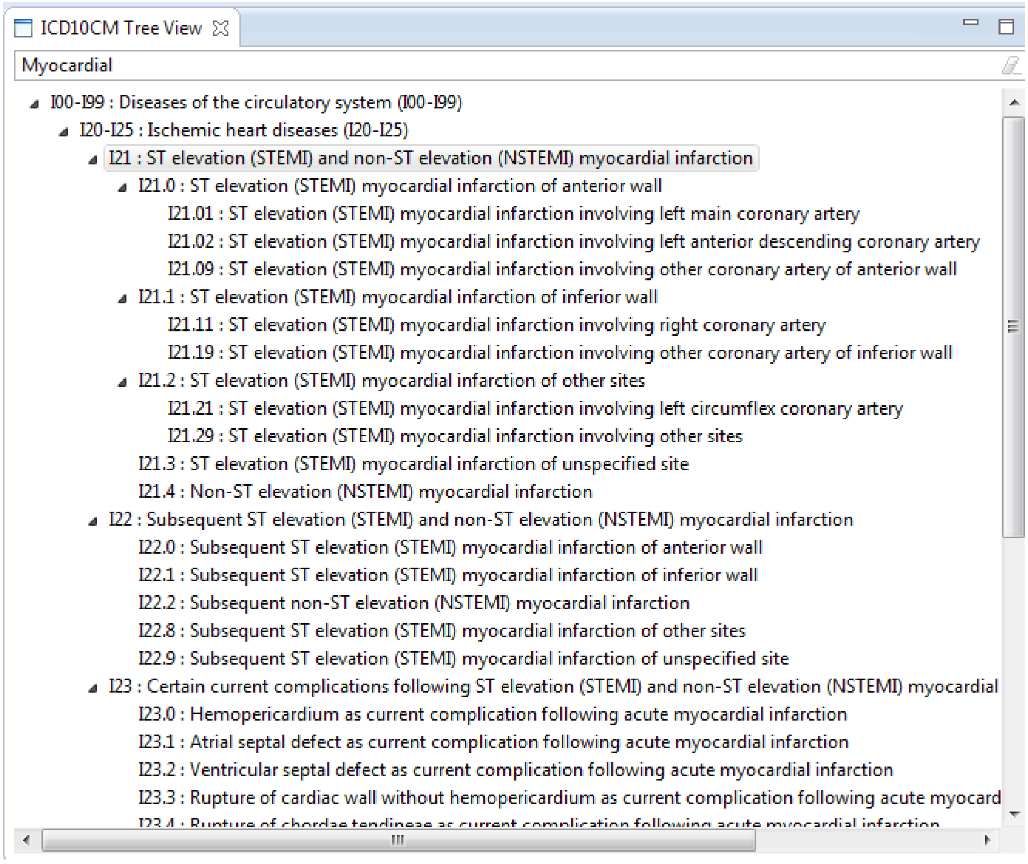

Figure 11. ICD10CM Tree View – taxonomy search

Additionally the search can be by ICD-10-CM three or four character code. Type **I21** into the search box and press “enter” , the display is shown in figure 12:

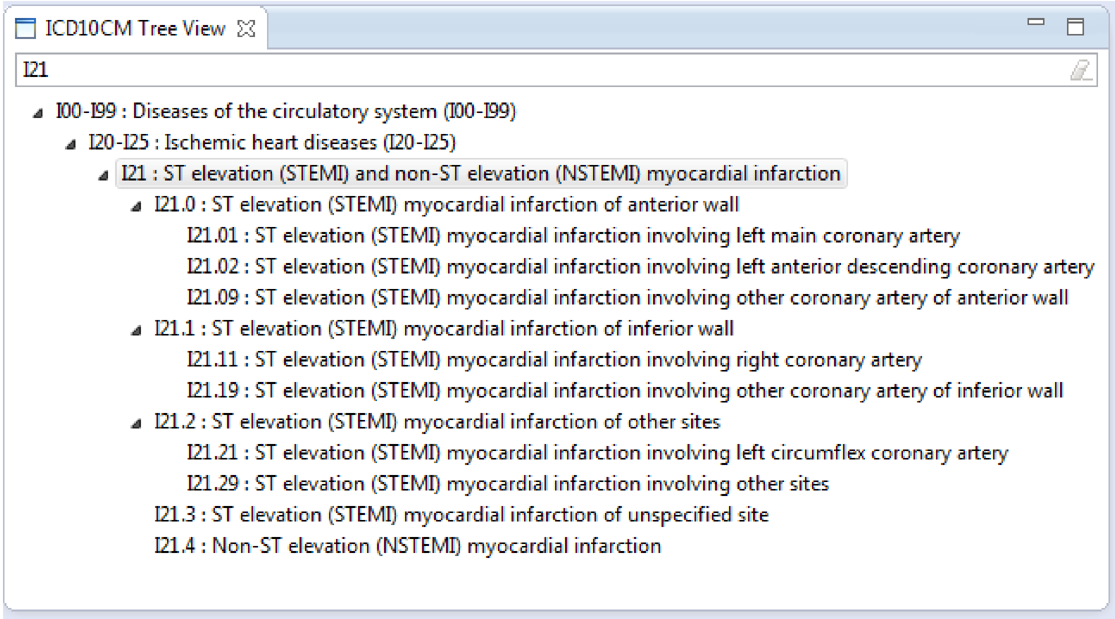

Figure 12. ICD10CM Tree View – code search

3.3.2.5 ICD-10-CM Detail View

The panel on the bottom right of the screen is the "ICD10CM Detail View":

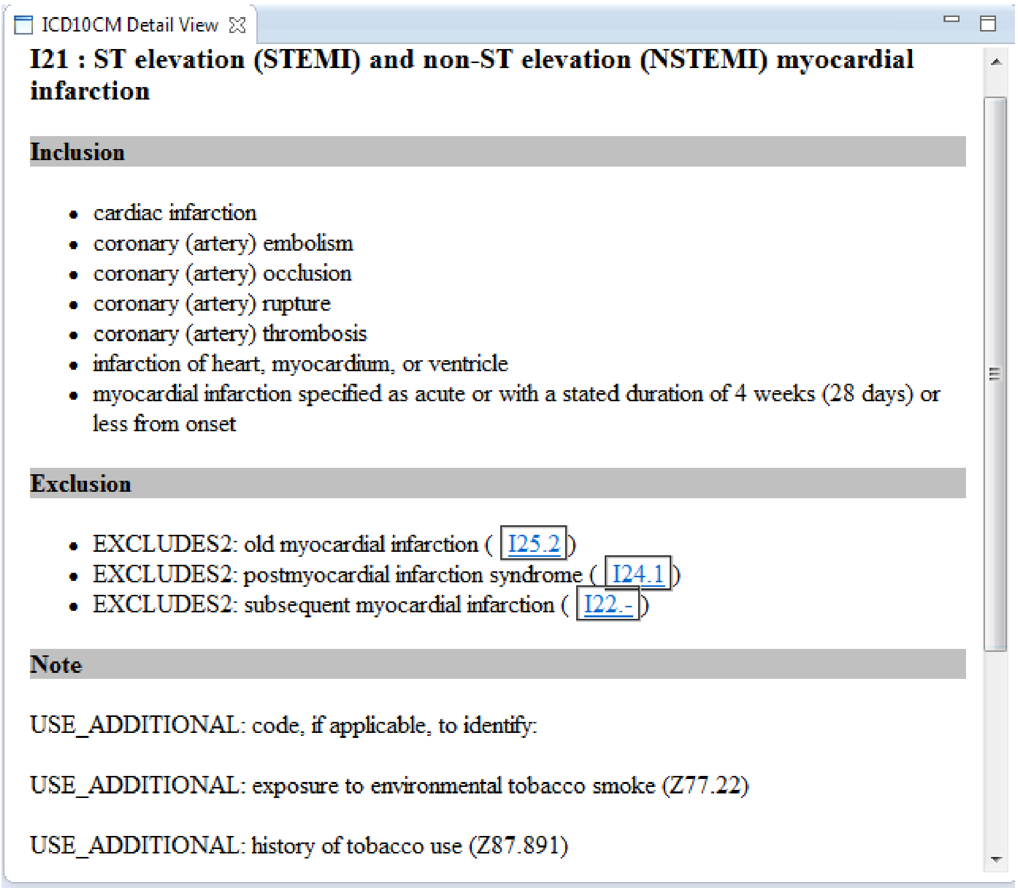

Figure 13. ICD10CM Detail View

This lists any notes, inclusions and exclusions which can be found in ICD-10-CM Tabular List. As in category **I21: ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction** in the "ICD10CM Tree View" the panel displays the inclusion and exclusions specific to the whole of category **I21.** Each of the codes represented in blue can be reached via hyperlink. Click on **I25.2** displays the view change in the "ICD10CM Tree View" panel to highlight **I25.2 Old myocardial infarction**:

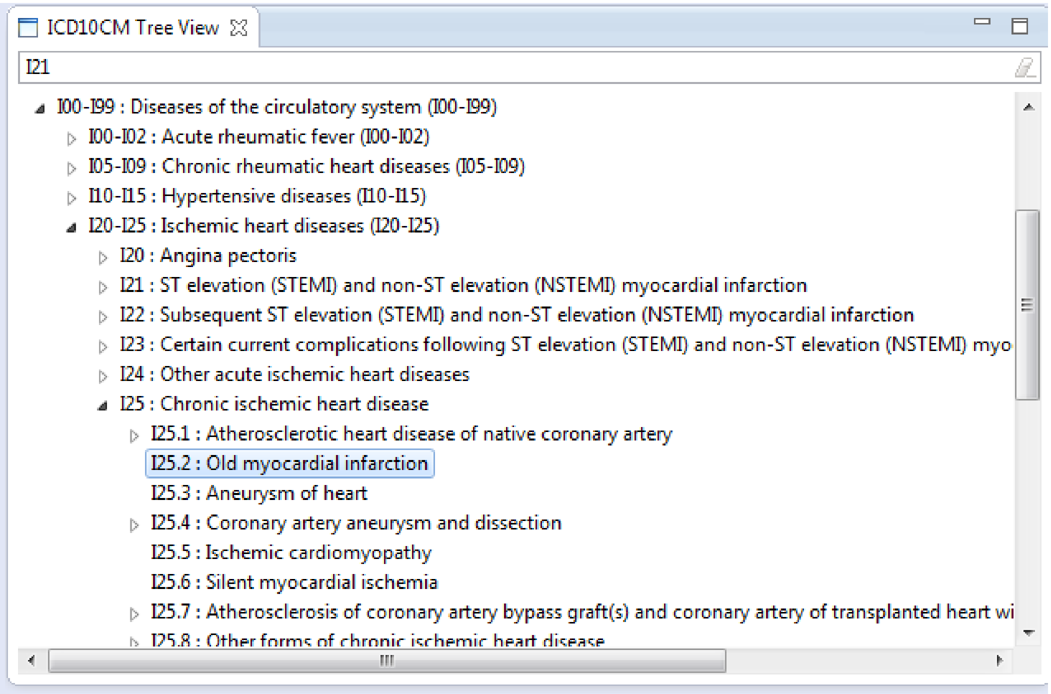

Figure 14. ICD10CM Detail View – code search

Clicking on subcategory, chapter and block levels will show the different detail available at each level.

For example, the block of I00-I99 displayed in tree view and detail view:

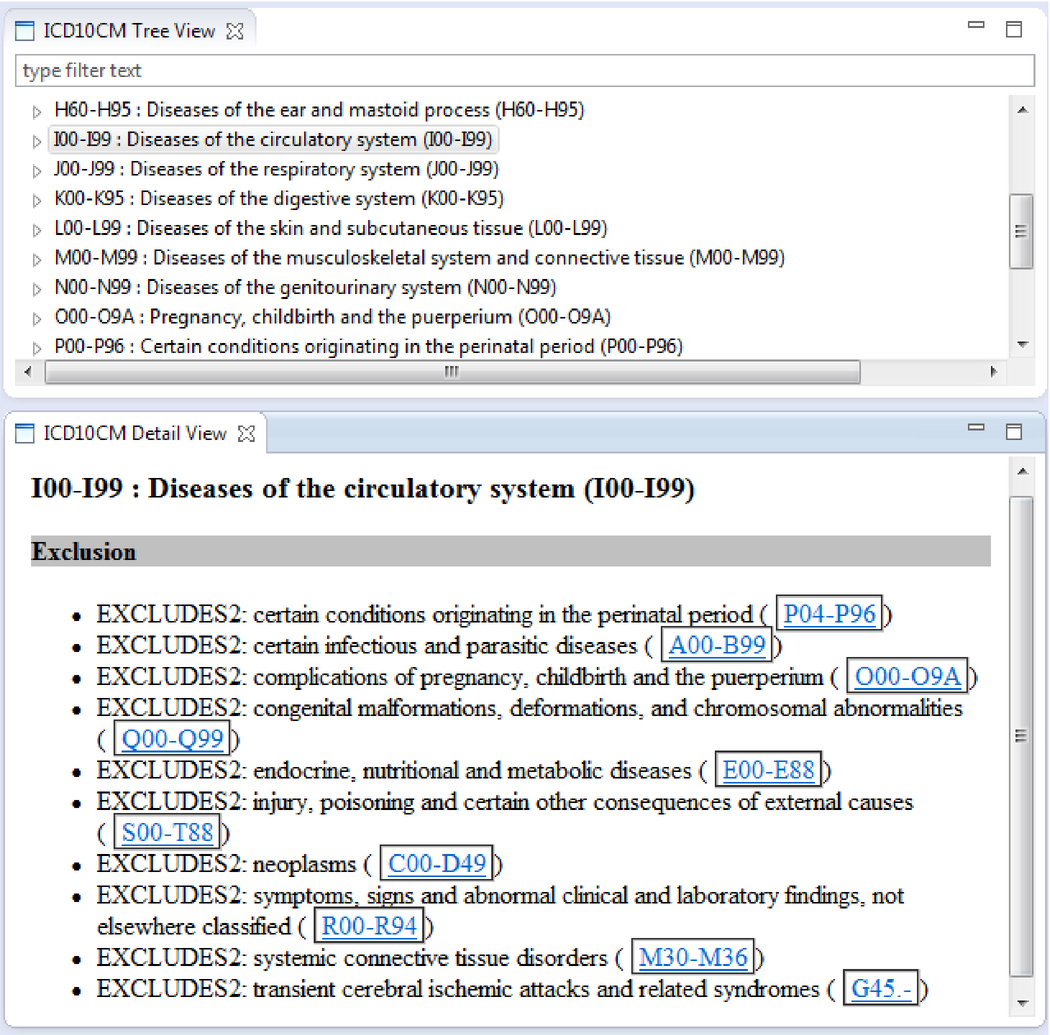

Figure 15. ICD10CM Tree View – Detail View

3.3.2.6 Project Explorer

The panel "Project Explorer" which is located to the right of the "SNOMED CT Tree View" panel contains all the imported mapping batches.

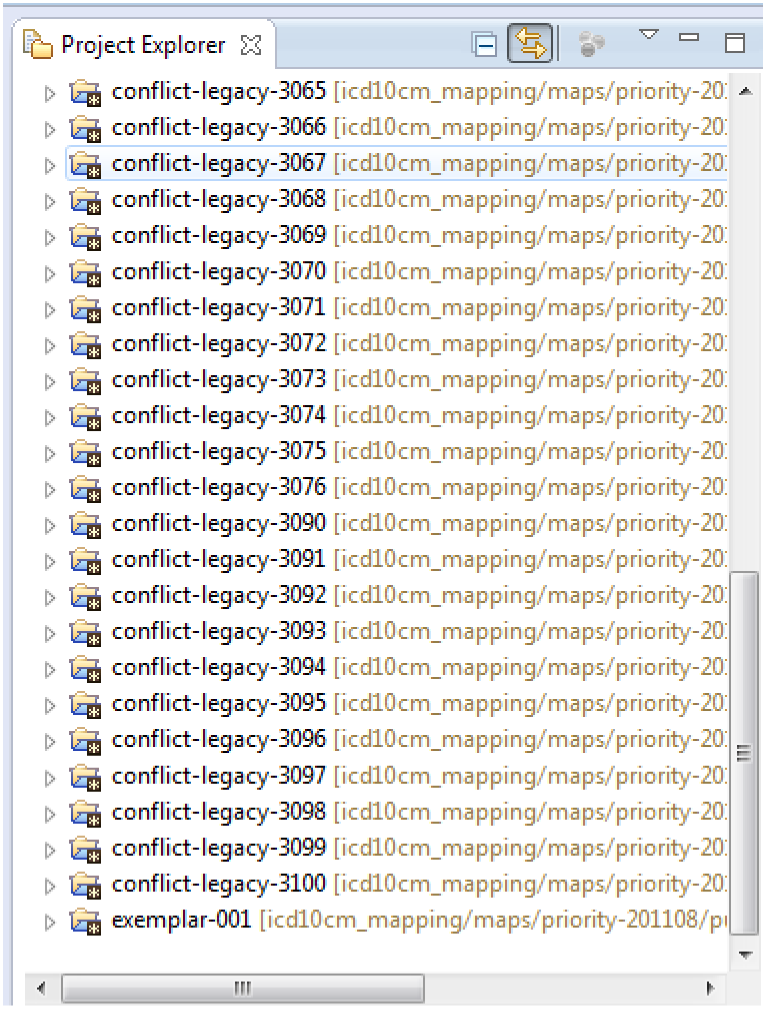

Figure 16. Project Explorer

This is the repository for the map specialist workflow ("to do" lists). The batches of concepts for mapping will be located here. Clicking on the ▷ sign will expand the content:

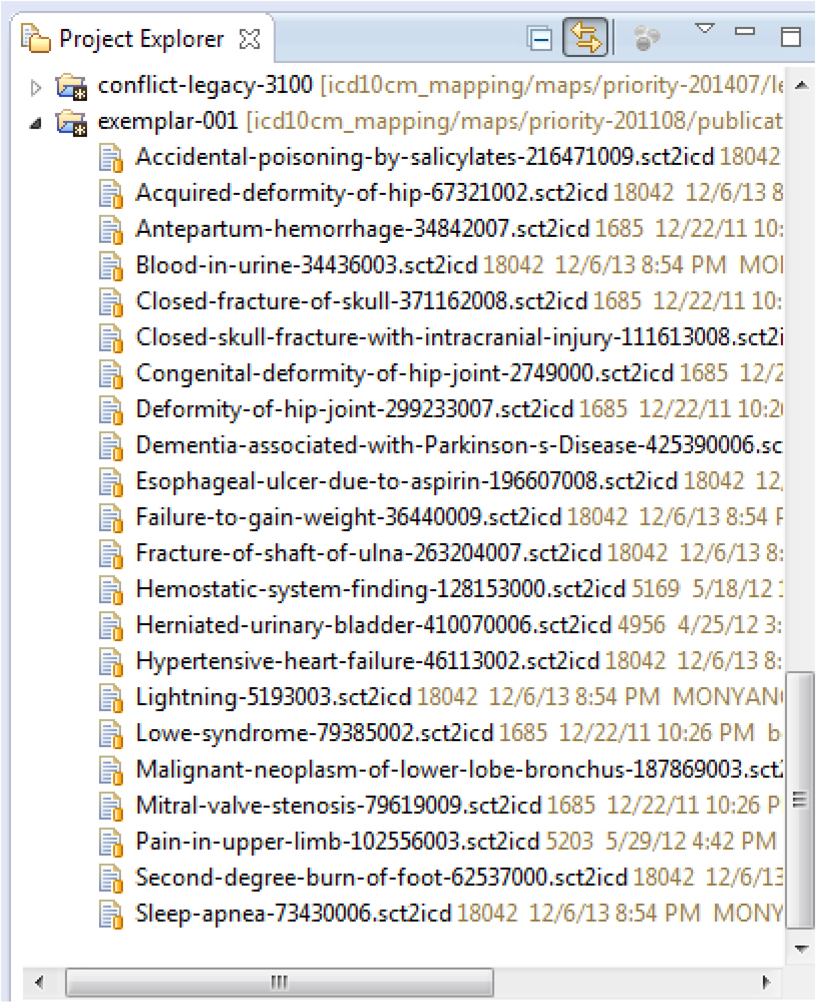

Figure 17. Project Explorer - content

The final panel is the mapping work area where the construction of the MAP, including associated rules and advice, takes place. When the tool is first opened this panel is blank. The selection of a concept from the "Project explorer" panel will activate the area.

For example: “Antepartum hemorrhage” double clicking will open the mapping options in mapping panel.

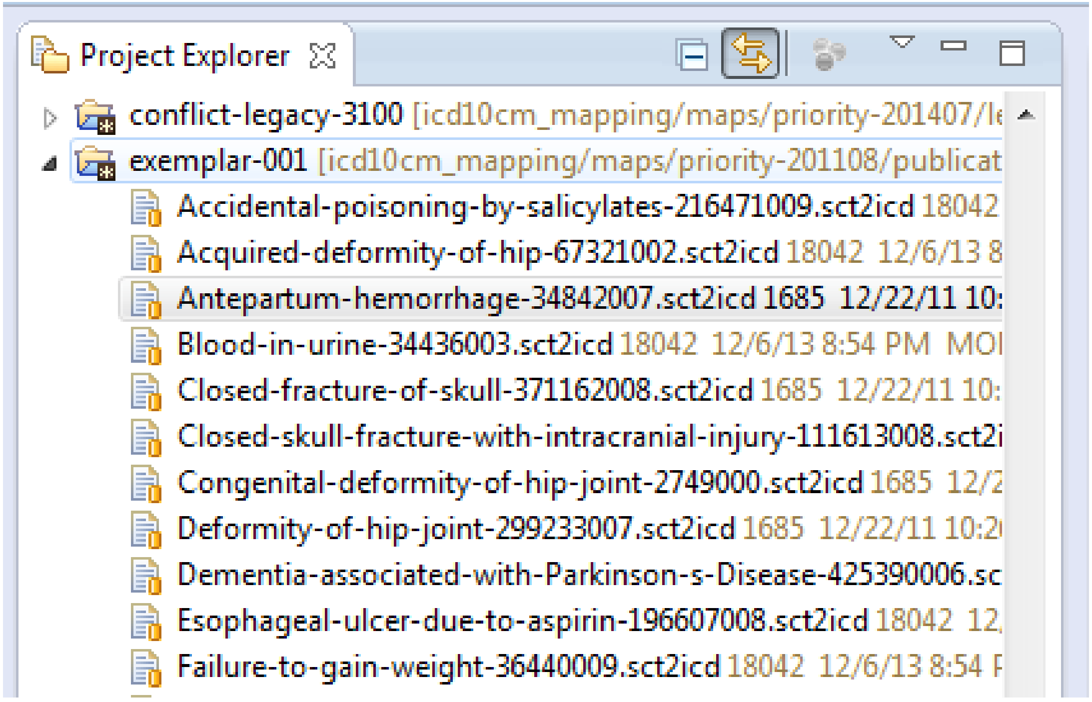

Figure 18. Project Explorer - Antepartum hemorrhage

3.3.2.7 Mapping Panel

The central panel is now activated, as follows:

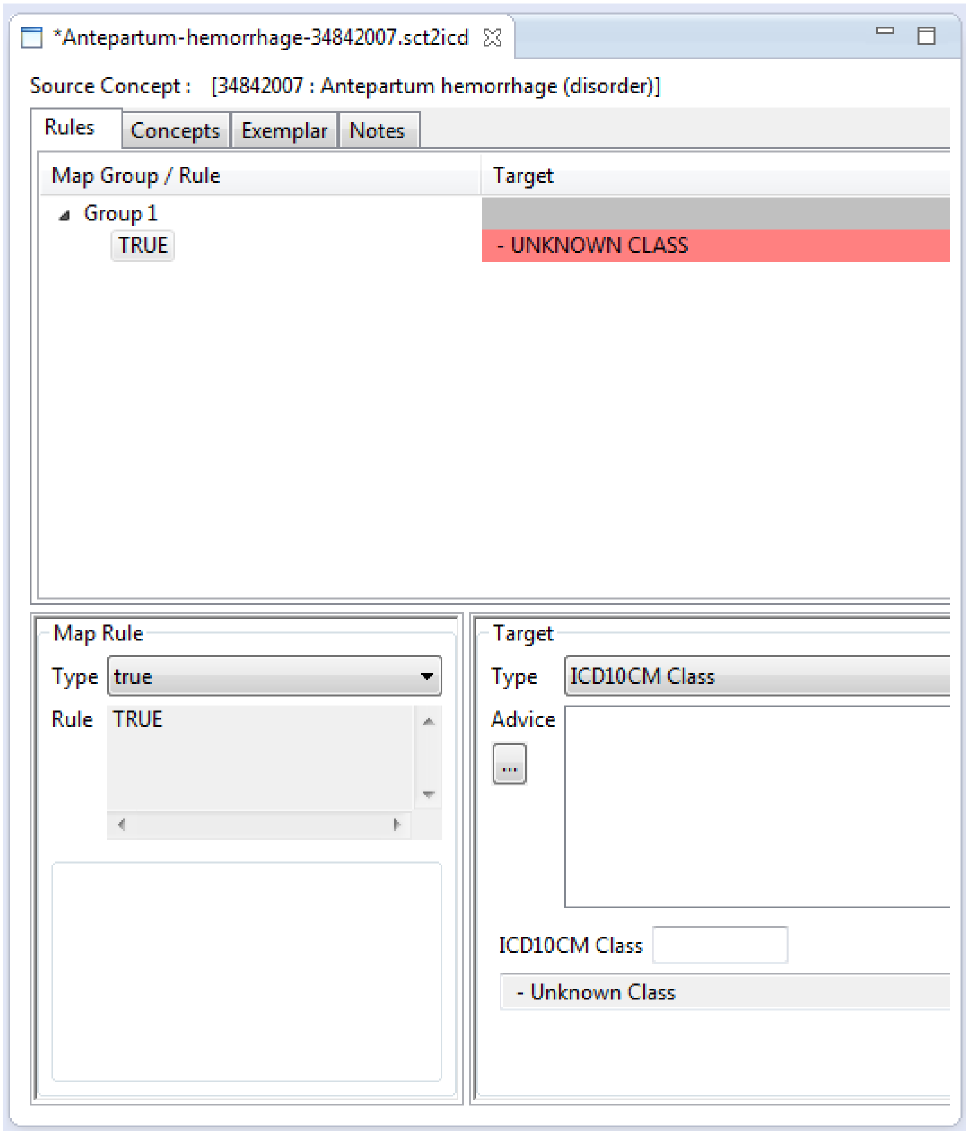

Figure 19. Mapping Pane

The tab heading shows the concept that has been selected for mapping. At the top of this panel the ConceptID and Fully Specified Name (FSN) of the source concept is displayed (a) along with 4 tabs titled "Rules", "Concepts", "Exemplar" and "Notes".

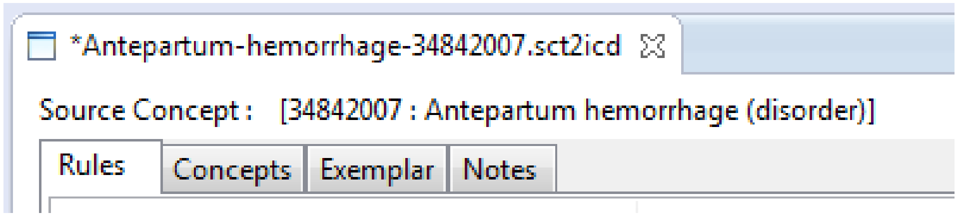

Figure 20. Mapping Panel - tab heading

3.3.2.7.1 Mapping Panel – Rule Tab

The “Rules“ tab is populated with “Group 1”:

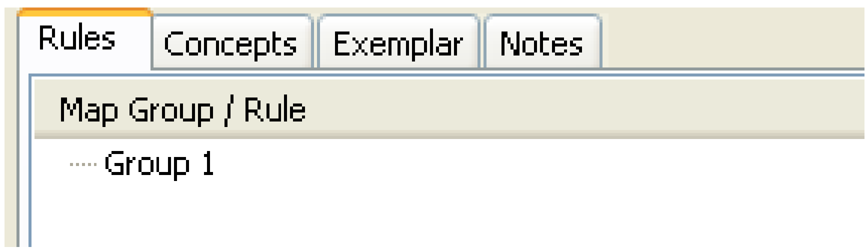

Figure 21. Mapping Panel – Rule Tab – map group

The following icons on the top toolbar are used in conjunction with this tab:

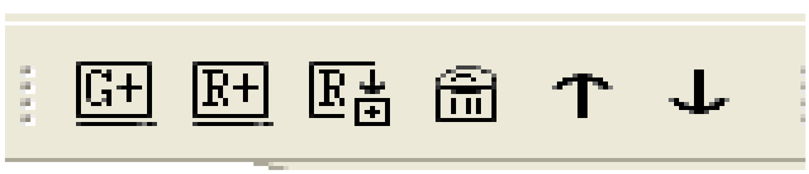

Figure 22. Mapping Panel – Rule Tab – toolbar

These enable the addition of new groups , new rules to groups and nested rules . Rules and groups can be deleted by clicking on the trash can symbol and the order of groups and rules can be changed by the use of the up and down arrows .

3.3.2.7.2 Mapping Panel – Concept Tab

The "Concept" tab is populated with any subtypes (children) of the source concept.

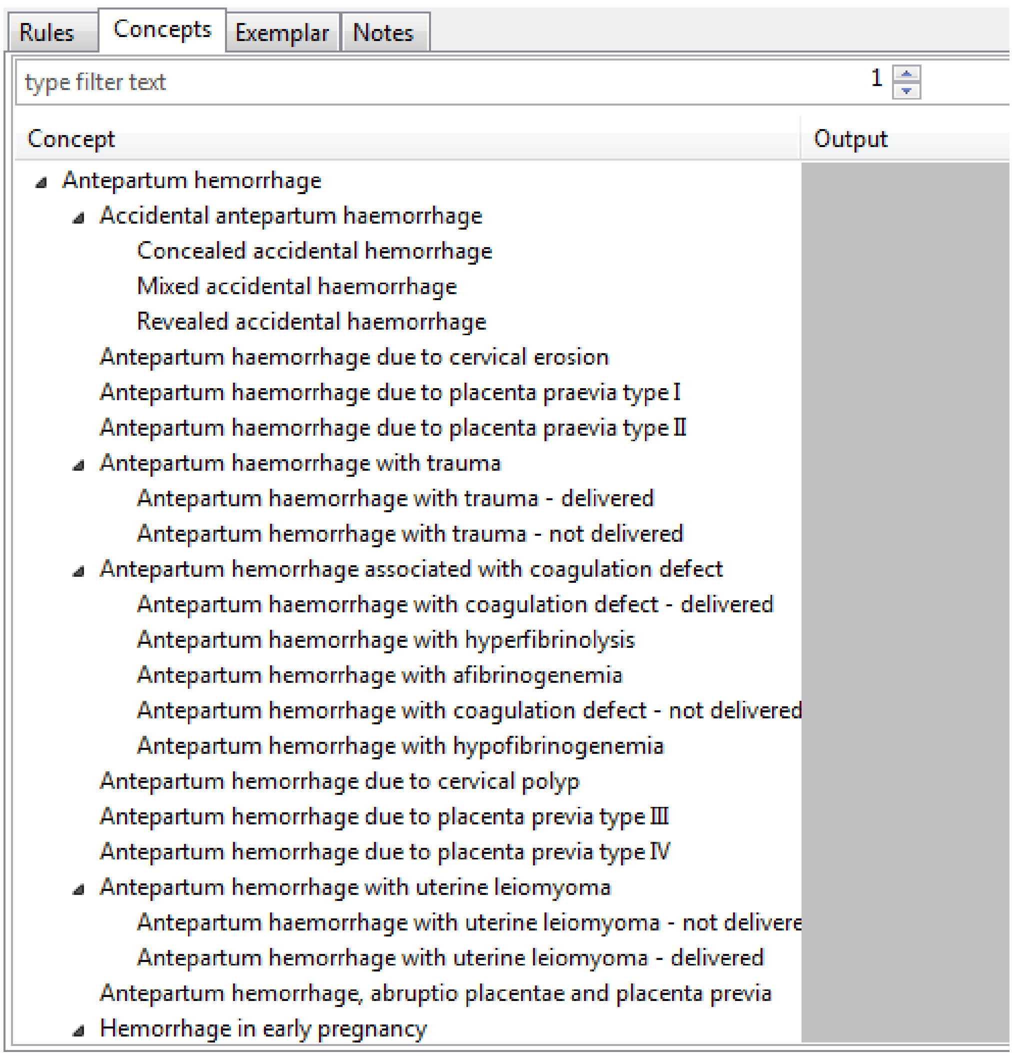

Figure 23. Mapping Panel – Concept Tab

The "type filter text" box informs that the user is working on group 1. The output field relates to target ICD-10-CM codes. These are empty because no target code has been specified so far.

3.3.2.7.3 Mapping Panel – Exemplar Tab

The "Exemplar" tab will contain a summary view of the MAP and contains all the necessary fields as specified in the technical specifications document; Map Group (G) Map Priority (O), Map Category (C), Rule, advice and target code:

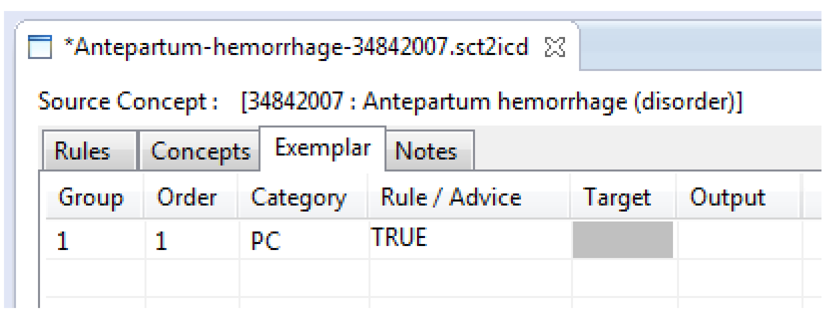

Figure 24. Mapping Panel – Exemplar Tab

3.3.2.7.4 Mapping Panel – Notes Tab

The final tab "Notes" is a free text area where the map specialist can record potential map targets and rationales for selection, with options of "Flag to Map Lead", "Flag for Editorial" and "Flag for Consensus":

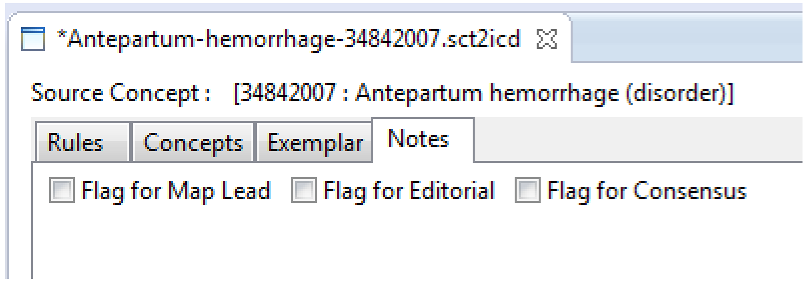

Figure 25. Mapping Panel – Notes Tab

At the bottom of the central work area panel are 2 boxes – "Map Rule" and "Target"

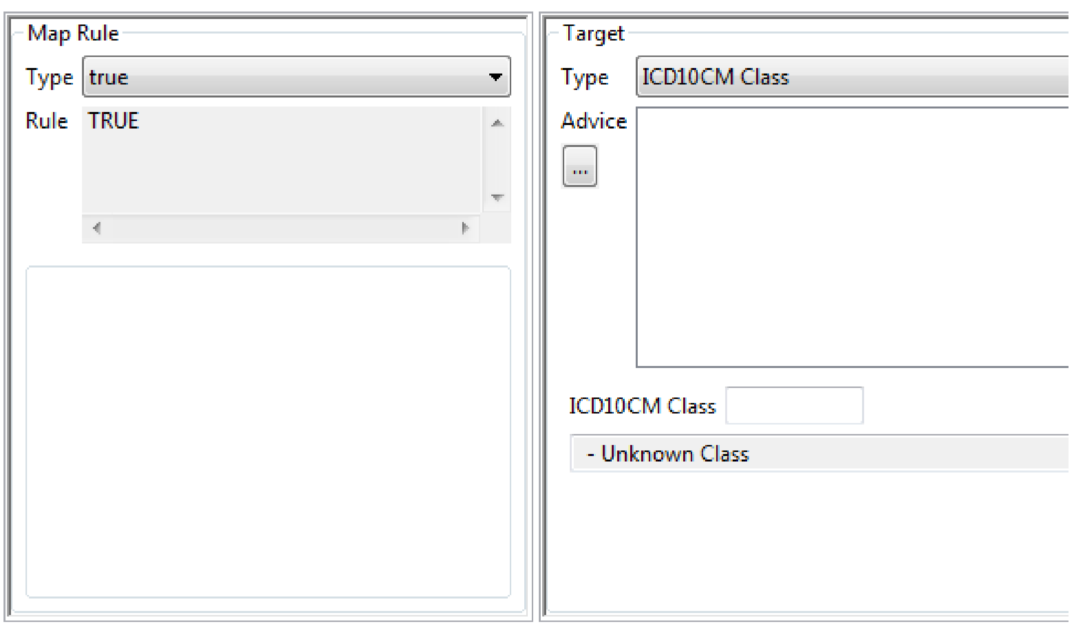

Figure 26. Mapping Panel – "Map Rule and "Target"

3.3.2.7.5 Map Rule

This is where the map specialist will construct rules. Click on the down arrow allows the user to see the types of rules which can be built:

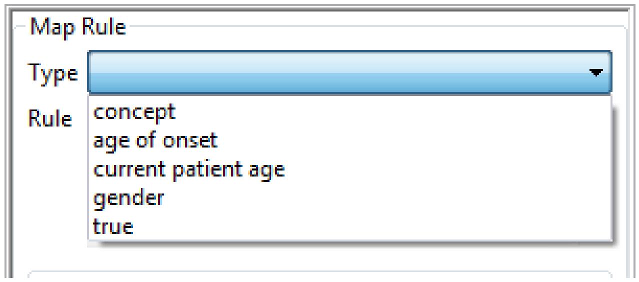

Figure 27. Mapping Panel – “Map Rule”

This panel view changes in response to the type of rule that is being constructed. When constructing a concept rule the panel view looks like this:

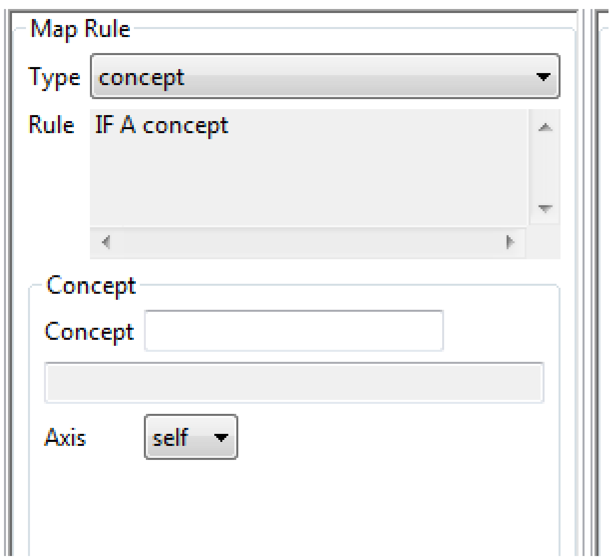

Figure 28. Mapping Panel – “Concept Rule”

When constructing a “concept” rule the user is able to select a relevant concept in the “SNOMED CT Tree View” panel and holding a left mouse click can drag and drop the concept into the “Concept” field in the “Map Rule” box.

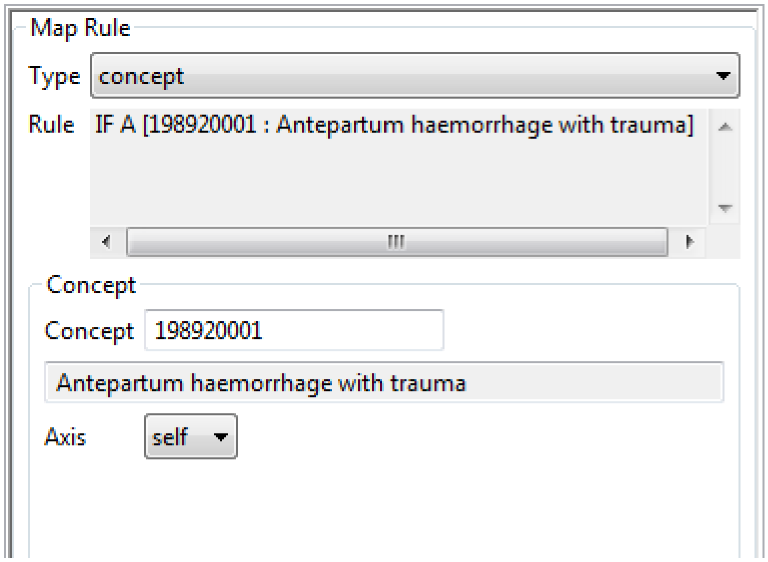

Figure 29. Mapping Panel – "Concept Rule" – Concept

When constructing an "Age" rule the panel view is as follows

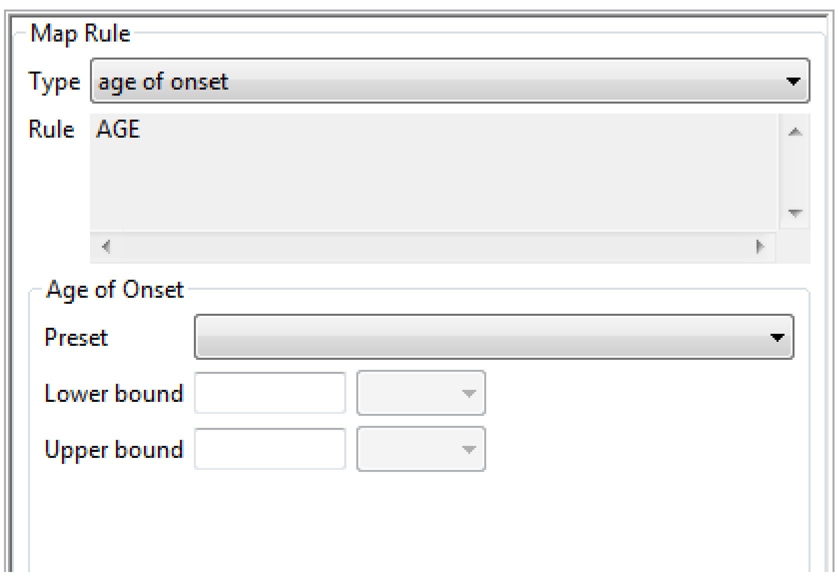

Figure 30. Mapping Panel – "Age Rule"

A set of age range is prepopulated in the tool for handy use. They are available by clicking on the down arrow:

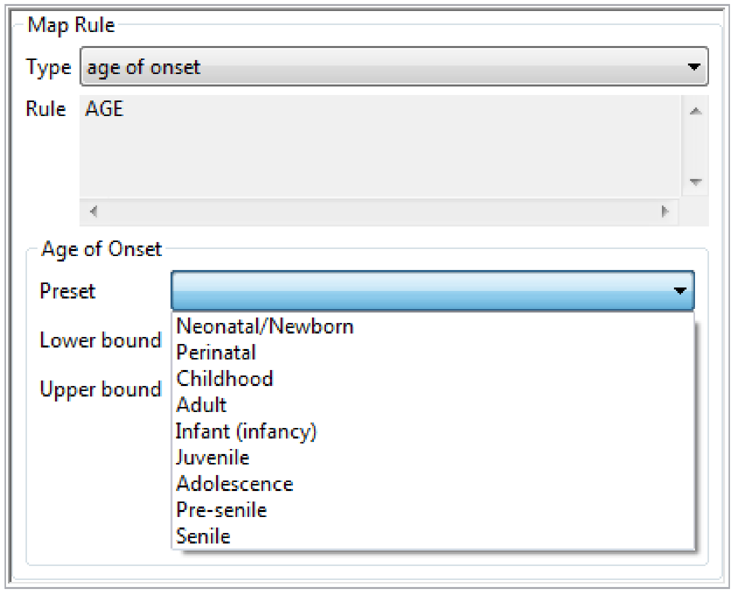

Figure 31. Mapping Panel – “Age Rule” - Preset

The definition on the preset age range is:

- "Neonatal": birth to 28 days of life (age < 29 days)
- "Perinatal": 22 weeks of gestation to 7 days of life (age < 8 days)
- "Childhood": less than 18 years of age (age < 18.0 years)
- "Adult": 18 years of age and older (18.0 years =< age)
- "Infant (infancy)": birth to less than 1 year of age (age < 1.0 year)
- "Juvenile": 1 year of age to less than 18 years of age (1.0 years =< age < 18.0 years)

- "Adolescence": 12 years of age to less than 18 years of age (12.0 years =< age < 18.0 years)
- "Pre-senile": less than 65 years of age (age < 65.0 years)
- "Senile": 65 years of age and older (65.0 years =< age)

When a preset is selected, the lower bound and the upper bound will be auto loaded. For example, preset as “Adolescence” in the following:

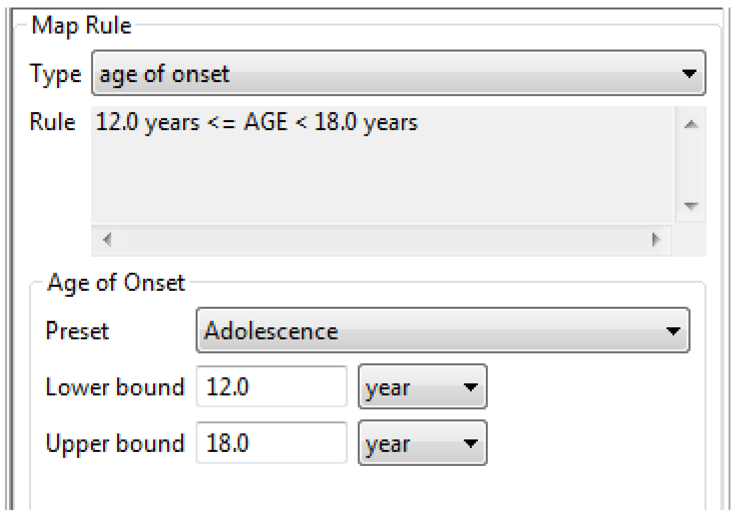

Figure 32. Mapping Panel – “Age Rule” - Adolescence

When constructing a "Gender" rule the panel view is:

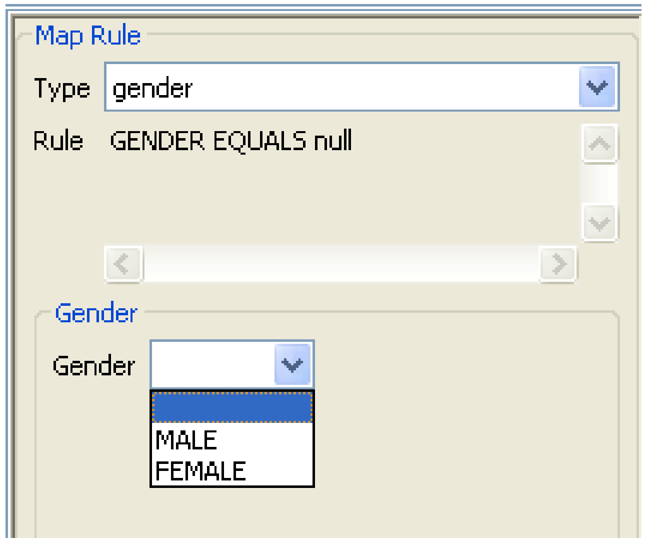

Figure 33. Mapping Panel – "Gender Rule"

And finally, selection of a "TRUE" rule generates the following panel view:

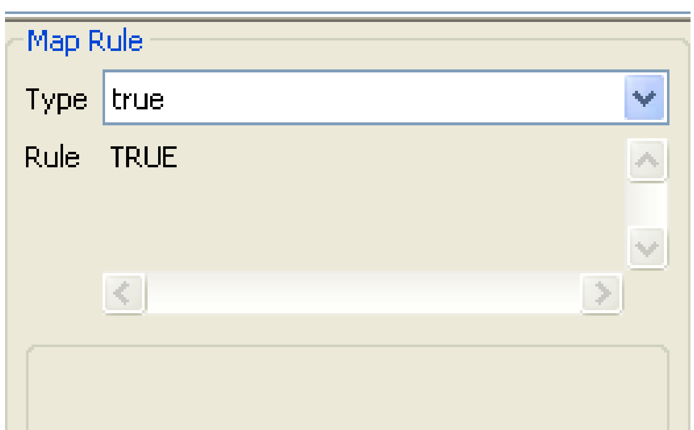

Figure 34. Mapping Panel – "Ture Rule"

When a new rule is created in a map group by clicking on , "True" rule is set to be default. However, it can be changed to any other type of rules.

3.3.2.7.6 Target

This specifies either the target ICD-10-CM code or allows assignment of a number of map categories as specified in the SNOMED CT to ICD-10 Technical Specification document draft v1.12. Click on the drop down box and scroll shows the different types:

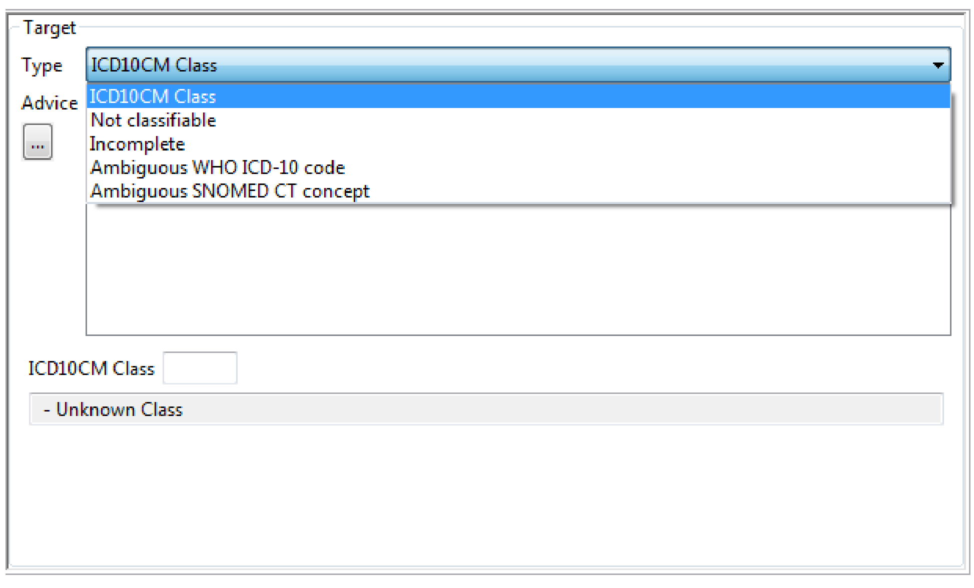

Figure 35. Mapping Panel – Target

See the SNOMED CT to ICD-10-CM Technical Specification Document on "Map Category" section on page 10 for definitions of the following:

- ICD10CM Class
- Not Classifiable
- Incomplete
- Ambiguous WHO ICD-10 Code (This should be Ambiguous NCHS ICD-10-CM Code)
- Ambiguous SNOMED CT concept

By choosing "ICD10CM Class" the user is able to select an ICD-10-CM target code and description from the ICD-10-CM Tree View by holding a left mouse click and then dragging and dropping the code and description to the "ICD10CM Class" field in the Target box:

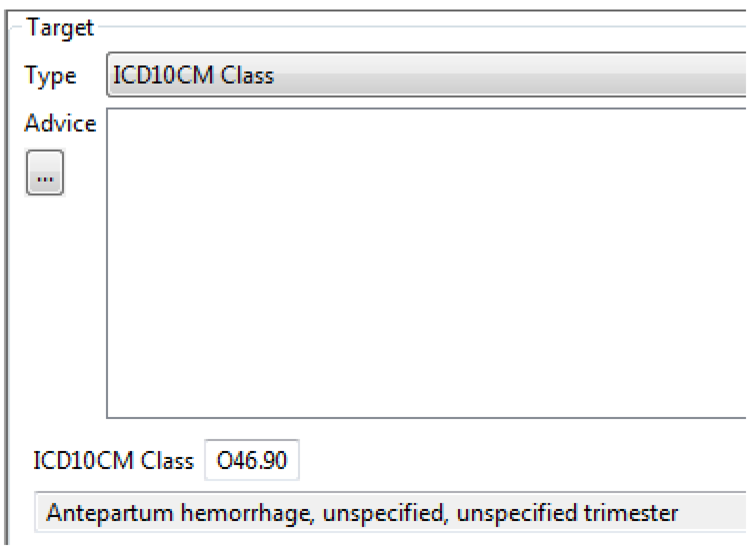

Figure 36. Mapping Panel – Target - Map Category

There are certain pieces of advice which are particular to ICD-10-CM and which may need to be brought to the attention of the user of the MAP. These have been collated and included in the tooling as standard pieces of advice which can be selected and assigned to a map record in the "Target" box. Click on the ... sign beneath "Advice" displays the list:

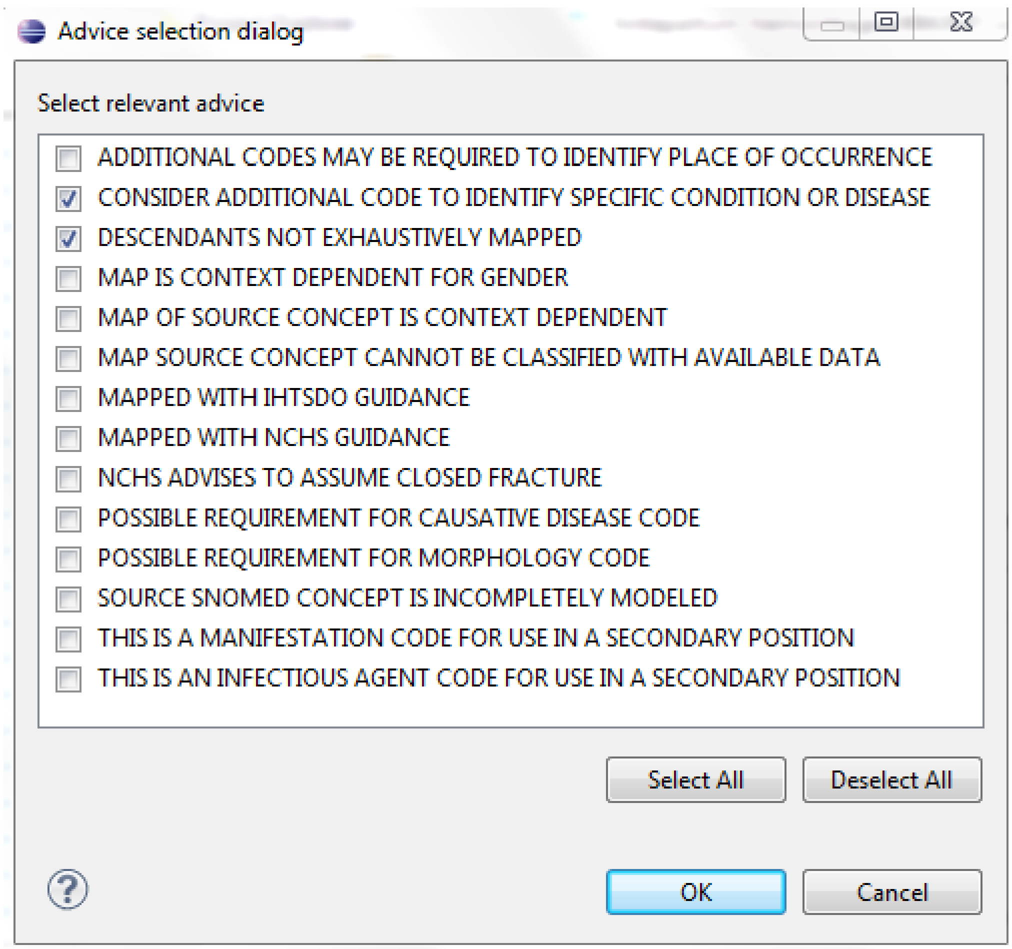

Figure 37. Mapping Panel – Target - Map Advice

Click on the checkbox to select the appropriate map advice(s) and click on the "OK" button. The selected map advices will be inserted in the MAP

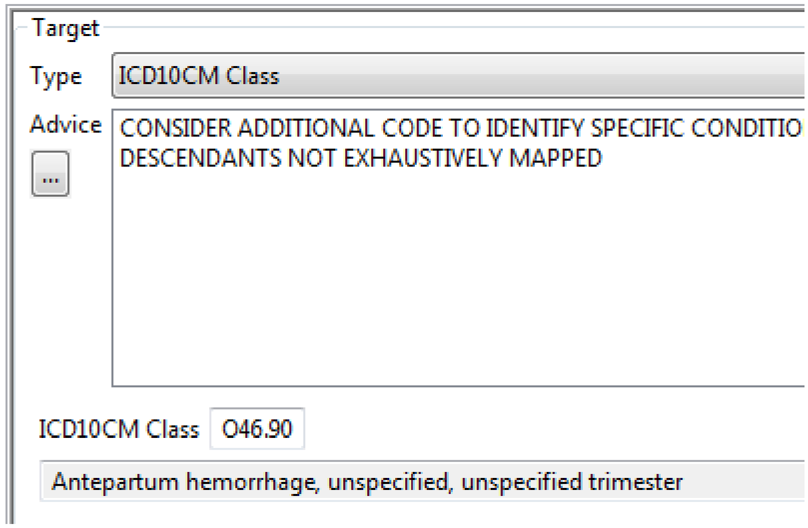

Figure 38. Mapping Panel – Target + Map Advice

A list of map advices that will be inserted to the map with automated algorithm at post mapping QA process. They may not be list in the map advice panel in this mapping tool, but they can be displayed with existing maps.

4 Map repository and workflow management tools

For the ICD-10 project, a map repository was created to store the mapping data. The mapping tool communicated with the repository through secure Internet connection. In the repository, concepts to be mapped were algorithmically divided into batches (each containing up to 25 concepts). The batching program would try to keep concepts that were close to each other in the SNOMED CT hierarchy in the same batch as far as possible. Batches were assigned to map specialists for mapping. For the ICD-10-CM project, a similar repository was installed on an NLM server. Initially, the handling of workflow and batch assignment was done manually, which led to some data issues (e.g. typos in folder names). To circumvent this problem, a set of web-based tools are developed to automate the process. Automated scripts on the repository kept track of the status of the batches, ran comparison between candidate maps, and generated work statistics reports. These tools will improve workflow management in the next phase of the ICD-10 map project.

CHAPTER 4 MAPPING GUIDLINES

Often times, there are multiple ways to map a single source SNOMED CT concept. Different approach would lead to different targets. When correctness can not be absolute defined, mapping consistency takes higher priority. A set of mapping guidelines were developed over time to keep the mapping convention consistent as much as possible. Doing so would potentially reduce the mapping discrepancy between the two independent parallel mapping efforts so the map conflict rate can be lowered. More important, mapping consistency would make it possible that the map set can be used in a meaningful way when data is exchanged.

Following reported are selected the mapping guidelines.

4.1: Mapping should be to a single billable, leaf-level node

A billable ICD-10-CM code, sometimes referred as “valid codes”, is defined as a code that has been coded to its highest level of specificity. The general rule is only billable codes is used as map target, because it is the most specific and it is the only codes that are accepted by most of the health insurance plans.

Example of billable ICD-10-CM codes with corresponding non-billable codes:

Billable		**Non-Billable**	
Q65	Congenital deformities of hip	Q65.9	Congenital deformity of hip, unspecified
M21.85	Other specified acquired deformities of thigh	M21.859	Other specified acquired deformities of unspecified thigh

Table 3: Billable vs non-billable codes

4.2: A SNOMED CT concept should always be mapped to the most specific appropriate match but not to a code that is more specific than the source concept.

SNOMED CID	SNOMED FSN	ICD10	ICD10 Description
49727002	cough (finding)	R05	Cough
25064002	headache (finding)	R51	Headache
68566005	urinary tract infectious disease (disorder)	N39.0	Urinary tract infection, site not specified
161891005	backache (finding)	M54.9	Dorsalgia, unspecified

Table 4. ICD-10 assignment where there is one to one equivalence

a) Follow the ICD-10 CM coding guidelines;

    i. Inclusion and exclusion criteria

    ii. "Code first" or "code also" rules.

b) Look first to the Alpha Index for the desired term. The Tabular List will have more details about inclusion and exclusion criteria and "code first" rules. "Code first" rules will lead to grouping ICD10 codes.

c) Exceptions to the "ISA" mapping rule in ICD10 may be needed if the SNOMED CT concept:

i. Is found as an inclusion under a term that is not strictly an IsA mapping in the ICD10 tabular view

Example:

SNOMED CT concept 128053003 deep venous thrombosis (disorder)

Correct ICD10 mapping = I82.409 Acute embolism and thrombosis of unspecified deep veins of unspecified lower extremity

Even though "Acute embolism" does not work well for an IsA mapping – but "DVT NOS" is listed as an inclusion in the I82.40 parent ICD10 term

ii. IF directed to the code from the Alpha Index (even if the SNOMED CT concept is not in the display name or an inclusion in the Tabular View

Example:

SNOMED CT concept 95695004 Degeneration of retina (disorder)

Correct ICD10 mapping = H35.9 Unspecified retinal disorder

Alpha Index has the following trial to support this map:

Degeneration

- retina H35.9

4.3: Drug allergy vs Allergic reaction:

Drug allergies are a group of symptoms caused by an allergic reaction to a drug. Adverse reactions to drugs are common. Many drugs or substance can cause adverse reaction. Reactions range from irritating or mild side effects such as nausea and vomiting to life-threatening anaphylaxis. Allergy to a medication like cloxacillin can mean two things:

- The patient has the propensity to some allergic reaction on exposure to cloxacillin

  or

- The patient suffers from an allergic reaction after exposure to cloxacillin.

In this SNOMED CT to ICD-10-CM mapping project, the conclusion is to take the first meaning, i.e., the propensity and not the reaction. So in this case, the correct map is Z88.1 Allergy status to other antibiotic agents status. In essence, we are interpreting this concept as '(History of) allergy to cloxacillin'. Another example: 294516001 Azlocillin allergy (disorder) should be mapped to Z88.0 : Allergy status to penicillin

If a SNOMED CT concept clearly indicate an adverse reaction, such as 'penicillin-induced anaphylaxis', it should be mapped to the adverse reaction codes in ICD-10-CM.

In general, descendants of SNOMED CT concepts 416098002 Drug allergy (disorder) should be mapped to Z88 : Allergy status to drugs, medicaments and biological substances. Descendants of 419076005 Allergic reaction (disorder) should be mapped to T codes (Adverse effect of XXXX).

4.4: Gender rule format:

Gender is usually referred to the state of being male or female (typically used with reference to social and cultural differences rather than biological ones). Even though there are other state like “undifferentiated”, for the purpose of clinical relevance, in this SNOMED CT to ICD-10-CM mapping, gender only has two values: male or female. As part of the patient’s characteristics, gender is taken into consideration when a map is created. When SNOMED CT concept is gender specific, map to a gender specific ICD-10-CM code:

6738008 Female infertility (disorder) → N97.9 Female infertility, unspecified

2904007 Male infertility (disorder) → N46.9 Male infertility, unspecified

When SNOMED CT concept is gender unspecific, while gender specification is coded in ICD-10-CM. gender rule is to be created as part of the map. The general rule of creating gender rule is described as following:

1): When no default ICD-10-CM code is available, set default as “NC” (not classifiable), with gender rule targeting to gender specific code. For example, SNOMED CT concept 237145004 Unexplained infertility (finding) does not specify gender. In ICD-10-CM, only gender specific codes for this condition exist, while code for gender unspecified does not. This concept will be mapped as following:

237145004 Unexplained infertility (finding)

IFA 248152002 | Female (finding) | → N97.9 Female infertility, unspecified

IFA 248153007 | Male (finding) | → N46.9 Male infertility, unspecified

OTHERWISE TRUE → Not Classifiable

2): If both gender unspecific code and gender specific codes exist, default the map target to gender unspecific codes with gender rule targeting to gender specific codes: For example:

204821009 Congenital malformation of genital organs (disorder)

IFA 248152002 | Female (finding) | → Q52.9 : Congenital malformation of female genitalia, unspecified

IFA 248153007 | Male (finding) | → Q55.9 : Congenital malformation of male genital organ, unspecified

OTHERWISE TRUE → Q89.9 : Congenital malformation, unspecified

3): For some clinical conditions, ICD-10-CM assume the gender being male (if Not Otherwise Specified) and default to a male gender specific code. In case like this, ICD-10-CM alpha index guidance is followed. For example, Fournier's gangrene is a horrendous infection of the genitalia that causes severe pain in the genital area and progresses from erythema to necrosis of tissue. It usually occurred in the penis and scrotum or perineum. So, in ICD-10-CM default this condition being an inflammatory disorders of male genital organs, not elsewhere classified.

398318005 Fournier's gangrene (disorder)

IFA 248152002 | Female (finding) | → N76.89 : Other specified inflammation of vagina and vulva

OTHERWISE TRUE → N49.3 : Fournier gangrene

Another example: sexual dysfunction due to failure of genital response is usually defined as erectile dysfunction, which falls in male sexual disorder category. Even though it could be a female condition as well, the common cases would default to male gender, unless otherwise specified.

268723003 Failure of genital response (finding)

IFA 248152002 | Female (finding) | → F52.22 : Female sexual arousal disorder

OTHERWISE TRUE → F52.21 : Male erectile disorder

4): Sometimes, ICD-10-CM provide gender specification in alpha index. However, the codes used for these specification do not provide gender information as expected. In cases like these, gender rules are aborted. For example, gonorrhea is a contagious disease transmitted most often through sexual contact with an infected person. It could occurred in either gender. In ICD-10-CM, the default code is A54.9 : Gonococcal infection, unspecified. For pelvic gonococcal infection, default code is A54.24 : Gonococcal female pelvic inflammatory disease. Alpha index provides further specification on female pelvic inflammatory disease. However, the suggested target code is the same as without gender specification (as shown in figure 39. Thus, the gender rule is not created in the map.

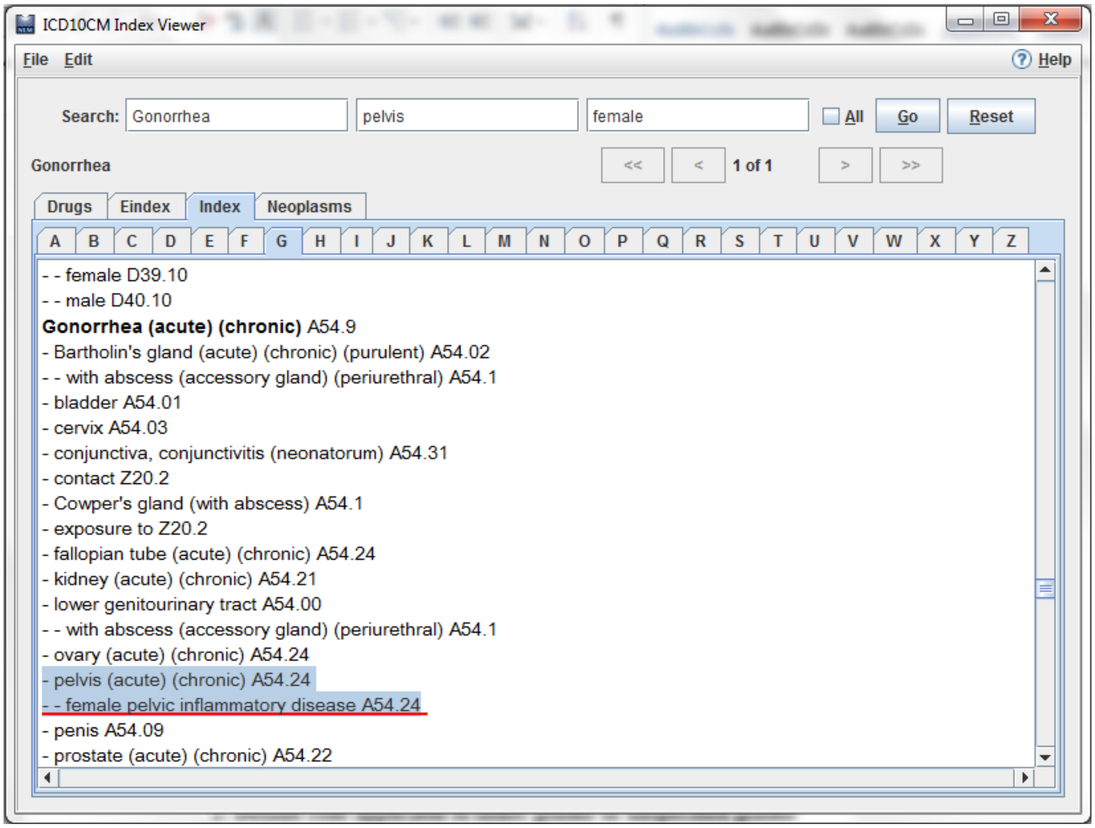

Figure 39: Gonococcal female pelvic inflammatory disease

4.5: Guideline on mapping concepts related to substance poisoning / medication adverse effect:

ICD-10-CM TABLE of DRUGS and CHEMICALS contains a classification of drugs and other chemical substances to identify poisoning states and external causes of adverse effects. Each of the listed substances in the table is assigned a code according to the poisoning classification. These codes are used when there is a statement of poisoning, overdose, wrong substance given or taken, or intoxication. The codes are arranged as:

- Poisoning, Accidental (unintentional)
- Poisoning, Intentional self-harm

- Poisoning, Assault
- Poisoning, Undetermined
- Adverse effect
- Underdosing

In SNOMED CT, the adverse reaction to drug is a descendant of adverse reaction to substance. Poisoning by drug AND/OR medicinal substance is modeled under "poisoning", and "drug-related disorder". The following mapping convention is followed:

1). If the SNOMED-CT concept refers to "poisoning" or "overdose", then use the "Poisoning" target code. In the absence of any additional information about the "intent" in the concept or the SNOMED Detail View, map to "accidental (unintentional)", rather than "undetermined".

2). If the SNOMED-CT has the name of medication, use the "Adverse effect" target code. If the intention is not stated for therapeutic drugs, then map to "Adverse effect" target code.

3). If the SNOMED-CT states "Drug-induced", then it is considered a therapeutic medication, then map to "Adverse effect" target code.

4). If the SNOMED-CT contains the name of a substance (e.g., talc or foreign body) which is not normally a therapeutic drug, and without directional key words, it should be mapped to "Poisoning" with "accidental (unintentional)" intention.

5). If an SNOMED-CT does not have directional words, but we know it is a poison (e.g, pelagic paralysis, overdose), it should be mapped to “Poisoning”.

6). For Post-immunization problems, map to T50.A, B or Z target codes, and should use code for “Adverse effect”, unless stated as an “overdose”.

7). To determine if the “drug” in the SNOMED-CT concept is a therapeutic medication vs. a non-therapeutic substance of abuse, look at the descendants to see whether the concept includes non-therapeutic substances, if so, map to “Poisoning”; if it is a therapeutic substance, then map to “Adverse effect”.

4.6: Guideline on handling “USE_ADDITIONAL” notes

1) If the information the “USE_ADDITIONAL” note refers to is NOT included in the SNOMED CT concept, there is no need to create additional map group. Such additional map group would be necessary if it is indicated in the name of the source concept. For example:

   18504008 toxic shock syndrome (disorder)

   The ICD-10-CM target is A48.3 : Toxic shock syndrome. With the note under A48.3, “USE_ADDITIONAL: code to identify the organism (B95, B96), organism is evaluated. In the SNOMED CT concept, there is no infective agent information carried. So, additional code is not added to the map.

240450004 staphylococcal toxic shock syndrome (disorder)

The same ICD-10-CM code A48.3 : Toxic shock syndrome is mapped as target. While, in evaluating the infective agent, staphylococcus is found. So the second code B95.8 : Unspecified staphylococcus as the cause of diseases classified elsewhere is added to the map.

2) The information in the “USE_ADDITIONAL” note is related to the SNOMED CT concept. In case there is a ICD-10-CM code for unspecified condition, secondary map target is added. For example:

82523003 congestive rheumatic heart failure (disorder)

This SNOMED CT concept is mapped to I09.81 Rheumatic heart failure. This ICD-10-CM has note “Use additional code to identify type of heart failure (I50.-)”. In evaluating the heart failure information in the source concept, the second code I50.9 : Heart failure, unspecified is added to in map group 2. This I50.9 code represent the Congestive heart disease as an inclusion.

While, in other times, there is no ICD-10-CM code for unspecified condition. In case like this, the “user_additional” note is omitted. For example:

42708900XX diabetes mellitus due to cystic fibrosis with foot ulcer (disorder)

This SNOMED CT concept is mapped to E84.9 : Cystic fibrosis, unspecified, and Map group 2: E08.621 Diabetes mellitus due to underlying condition with foot ulcer. This ICD-10-CM E08.621 has note “Use additional code to identify site of ulcer (L97.4-, L97.5-)”. In evaluating the site of ulcer information in the source concept, it is stated in the name. However, there is no proper ICD-10-CM code to represent “foot ulcer”. So, the third code is not used.

CHAPTER 5 LEGACY MAP GENERATION VIA TRIANGULATION

To save time and effort, an algorithm is derived to generate a candidate ICD-10-CM map to use as legacy maps in the ICD-10-CM project.

5.1 Maps Between SNOMED CT, ICD-9-CM and ICD-10-CM

SNOMED CT is a clinical terminology designed to capture information required in patient care. It is more suitable for use in the EHR, compared to the ICD classification which is better suited for statistical and administrative purposes.[70] However, it will be a big efficiency booster if clinical data encoded in SNOMED CT can be used to generate ICD codes.[70,71] Accompanying the international release of SNOMED CT, there is a simple version of SNOMED CT to ICD-9-CM map that is updated with every release of SNOMED CT and ICD-9-CM. The National Library of Medicine (NLM) is undertaking a project to create a cross-map from SNOMED CT to ICD-10-CM.[67,68] A preview of that map has been released in June 2012 with a coverage of 15, 000 SNOMED CT concepts.[72] This mapping effort is ongoing, with new releases planned that will increase coverage and provide updates to the new versions of SNOMED CT and ICD-10-CM.

The National Center for Health Statistics (NCHS) has developed maps between the different versions of ICD to help the transition to ICD-10-CM.[73] These are known as "General Equivalence Mappings" (GEMs). The mapping for procedure codes was developed by the Centers for Medicare & Medicaid Services (CMS). In GEMs, mapping from ICD-9-CM to ICD-10-CM is called "forward mapping," while mapping from ICD-10-CM to ICD-9-CM "backward mapping." This design enabled GEMs to be used for bi-directional translation. The GEMs are not a substitute for learning how to use ICD-10-CM and does not remove the need to upgrade systems from ICD-9-CM to ICD-10-CM. The GEMs are a tool to assist with converting large ICD-9-CM databases to ICD-10-CM. The GEMs can be used in converting coded data in payment systems. It can also be useful in updating ICD-9-CM-based code sets in quality measures and other use cases.[73,74,75]

5.2 Triangulation Between Maps

The existence of maps between three coding systems (i.e. A, B and C) provides an opportunity to use the maps for triangulation (mutual validation). When one wishes to move from, say A to C, there are two possible routes: A→C and A→B→C. Whether one gets the same result via the two routes will be an interesting and important question. In our study, there are two routes to get from SNOMED CT to ICD-10-CM, first by the NLM created map (referred to as the *Direct Map*), and second, by using the SNOMED CT to ICD-9-CM map and then the forward GEM map in tandem (referred to as the *Indirect Map*). Following is a description of our method of creating and evaluation of the maps, the results, and a discussion of some possible uses of this methodology.

5.3 Generation of the Direct and Indirect Map

Direct Map**:** In February 2012, NLM released a preview version of the map that provided mapping from 7,277 SNOMED CT concepts to ICD-10-CM codes. In June 2012, an updated version with mapping from approximately 15, 000 SNOMED CT concepts was published. The mapping effort continued with an expansion of the scope of SNOMED CT coverage. In this study, the latest version of the finalized maps extracted from the editing environment in February 2013 is used.

Indirect Map**:** SNOMED CT concepts in the Direct Map were first mapped to ICD9-CM using the SNOMED CT to ICD-9-CM map published by IHTSDO. The IHTSDO map was accessed via NLM's Unified Medical Language System (UMLS) 2012AB release. Most of the maps were one-to-one maps, although some were one-to-many maps, with one SNOMED CT concept mapping to a combination (usually two) of ICD-9-CM codes. The ICD-9-CM codes were then translated to ICD-10-CM through GEM forward maps ("ICD9_ICD10")[27], which included both one-to-one and one-to-many maps. (Figure 40)

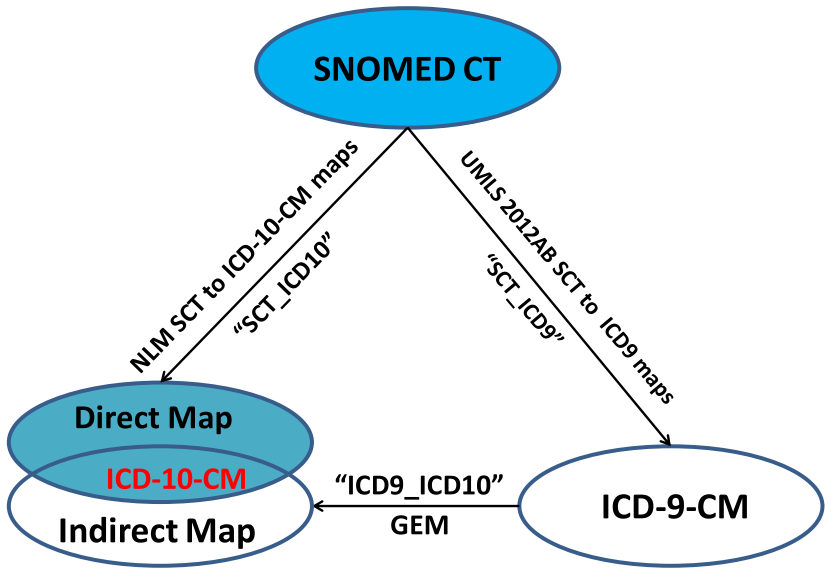

Figure 40: Crossmapping Generation

5.4 Comparison of Direct and Indirect Map

For each SNOMED CT concept, the map targets in the Direct and Indirect Map were compared. Additional information (such as map rules and map advices) from the rule-based Direct Map were ignored, and so was the order of map targets where there were more than one. In cases where the ICD-10-CM target in the Direct Map used a placeholder as the 7th digit (e.g. M84.30X? *Stress fracture, unspecified site, episode of care unspecified*), only up to the 6^{th} digit were compared. The following categories were used to measure the concurrence between the Direct and Indirect Map.

- Exact agreed: Maps where target codes were identical in both Direct and Indirect Map.
- Partial agreed: Maps where only some, but not all, target codes were the same. Note that this category was applicable only to SNOMED CT concepts with more than one map targets.
- Not agreed: Maps where target codes from the two maps did not overlap at all.

Recall and precision of the Indirect Map were also calculated using the Direct Map as the reference standard. To simplify the calculation, when there were more than one target codes for a SNOMED CT concept, each SNOMED CT-ICD-10-CM code pair was treated as a separate map record.

For the single-target maps (i.e. only one ICD-10-CM target existed for a SNOMED CT concept) in the Indirect Map, a subset called the "synonymy maps." was further defined. These were the cases that evidenced that, a. the SNOMED CT concept was mapped to a synonymous (not a broader or narrower) ICD-9-CM code, AND b. the ICD-9-CM code was mapped to a synonymous ICD-10-CM code. It was anticipated that these synonymy maps would have a higher degree of agreement with the Direct Map. For identification of synonymy between a SNOMED CT concept and an ICD-9-CM code, two approaches were tried. First, the SNOMED CT to ICD-9-CM map explicitly flagged maps in which the SNOMED CT concept and ICD-9-CM target were considered identical or synonymous, or that the SNOMED CT term was listed as an inclusion within the ICD-9-CM code. These maps had MapAdvice value of '1' in the original data file, and in the UMLS MRMAP table, they had REL= 'RQ.' Second, synonymy was also identified by the UMLS concept structure. When a SNOMED CT concept and an ICD-9-CM code were encompassed by the same UMLS concept, they were considered synonymous.[61] The two approaches gave quite different results and so both were tried to determine which one was better. To identify synonymy between ICD-9-CM and ICD-10-CM codes, the "Identical match" label was used in the GEM maps, or UMLS-asserted synonymy. Since the two methods gave very similar results, it was accepted either one as evidence of synonymy between a pair of ICD-9-CM and ICD-10-CM codes in our study.

5.5 Manual Review of Disagreed Maps

To gain insight into the limitations and pitfalls of our method, manual review of a sample of cases of disagreement between the Direct and Indirect Map was conduceted. Emphasis was put on the disagreed synonymous maps, as they were expected to have a high degree of agreement.

5.6 Legacy map results

5.6.1 Characteristics of Direct Map and Indirect Map:

Cross terminology mapping cannot always be achieved with one-to-one match. Sometimes multiple targets are required to fully represent the meaning of the source SNOMED concept or to follow ICD-10-CM mapping guidance like "Code_First" or "Use additional code."

Table 1 shows the distribution and cardinality of the Direct and Indirect Map. In the Direct Map, the maximum number of targets for a SNOMED CT concept was four, but the majority of them had a single map target (90.4%). A total of 201 concepts did not have a map target. These unmappable concepts usually fell into one of three categories:

- Normal findings *(e.g.* 168749009 *Mammography normal (finding)*, 281900007 *No abnormality detected (finding), 169741004 Breast fed (finding))*

- Concepts that were used as grouper concepts for abnormal findings (e.g. 449736004 *Finding of periwound skin (finding)*, 449747006 *Wound edge finding (finding)*)

- Additional context information, such as gender, was required for proper classification (e.g. 8619003 *Infertile (finding)* is mapped to either N97.9 *Female infertility, unspecified* or N46.9 *Male infertility, unspecified*, but is unmappable when gender is not specified). In the full SNOMED CT to ICD-10-CM map, these concepts were accompanied with age[3] or gender rules that would resolve to valid target codes with additional input of contextual information.

In the Indirect Map, the number of target codes for a SNOMED CT concept could be as high as 165, but the majority (90%) had less than 5 target codes. Single-target maps constituted about two-thirds of all maps. There were 922 concepts without a target code. Among these, 457 concepts did not have an ICD-9-CM map, and 465 concepts had an ICD-

9-CM map (but did not have a GEM map). Therefore, no ICD-10-CM map target could be identified.

	Direct Map		Indirect Map	
# of ICD10 targets	SCT Concepts	%	SCT Concepts	%
0	201	0.8%	922	3.8%
1	21,992	90.4%	15,908	65.4%
2	2,021	8.3%	3,890	16.0%
3	110	0.5%	1,350	5.5%
4	16	0.1%	1,084	4.5%
>=5	---	---	1,186	4.9%
Total	24,340	100.0%	24,340	100.0%

Table 5: Distribution of Direct Map and Indirect Map by Map Target Number

5.6.2 Concurrence Between Direct Map and Indirect Map

For all the maps with at least one map target, the Direct and Indirect Map concurred completely on 44.2% of all the mapped concepts, as shown in Table 6. The overwhelming majority (98.4%) of the exact agreed maps were single-target maps (Table 5). The following are some examples of single-target maps in exact agreement.

- Direct Map:

  140004 Chronic pharyngitis (disorder) → J31.2 Chronic pharyngitis

  Indirect Map:

140004 Chronic pharyngitis (disorder) → 472.1 Chronic pharyngitis (through SNOMED CT to ICD-9-CM map) → J31.2 Chronic pharyngitis (through GEM map)

- Direct Map:

  1388004 Metabolic alkalosis (disorder) → E87.3 Alkalosis

  Indirect Map:

  1388004 Metabolic alkalosis (disorder) → 276.3 Alkalosis (through SNOMED CT to ICD-9-CM map) → E87.3 Alkalosis (through GEM map)

Concurrence Level	SCT Concepts	%
Exact agreed	10,358	44.20%
Partial agreed	4,908	21.00%
Not agreed	8,152	34.80%
Total	23,418	100.00%

Table 6: Concurrence Between Direct and Indirect Map

# of target codes	SCT Concepts	%
1	10,195	98.40%
2	159	1.50%
4	4	0.04%
Total	10,358	100.00%

Table 7: Distribution of Exact Agreed Map

CHAPTER 6 AGE SPECIFICATION

6.1 Rule-based mapping

In the creation of the SNOMED CT to ICD-10-CM cross-map (hereafter referred to as the "Map"), it is not always possible to find a one-to-one correspondence between a SNOMED CT concept and an ICD-10-CM code. One SNOMED CT concept may require multiple ICD-10-CM codes to fully represent its meaning. Sometimes, the same SNOMED CT concept can be mapped to several alternative ICD-10-CM codes, depending on patient context and co-morbidities. So the Map needs to be a rule-based map to provide the flexibility and logic required in its usage. One factor that often affects the choice of ICD-10-CM codes is patient age. The age rule is one type of rule to handle cases in which one SNOMED CT concept can map to different ICD-10-CM codes depending on the age of the patient. For example, the SNOMED CT concept "Urinary tract infection" is mapped generally to N39.0: *Urinary tract infection, site not specified*. But if the problem occurs in newborn, the proper code should be P39.3: *Neonatal urinary tract infection*. The rule-based Map can be embedded in the problem list of the EHR to support real-time, interactive generation of ICD-10-CM codes based on SNOMED CT encoded clinical problems. This is known as the I-MAGIC (Interactive Map-Assisted Generation of ICD-10-CM codes) use case. A typical scenario will be as follows. At the end of a clinic encounter, the clinician enters the patient's problems in the problem list, and the entries are automatically encoded in SNOMED CT in the background. Based on the SNOMED CT-encoded problems and additional patient context information (gender and age) from the EHR, the Map-enabled application will output a list of candidate ICD-10-CM codes. When necessary, the clinician will be prompted for additional input to decide between alternative target codes or to refine the default codes. Figure 41 is a flow-chart showing how the age rule will help to determine the appropriate target code.

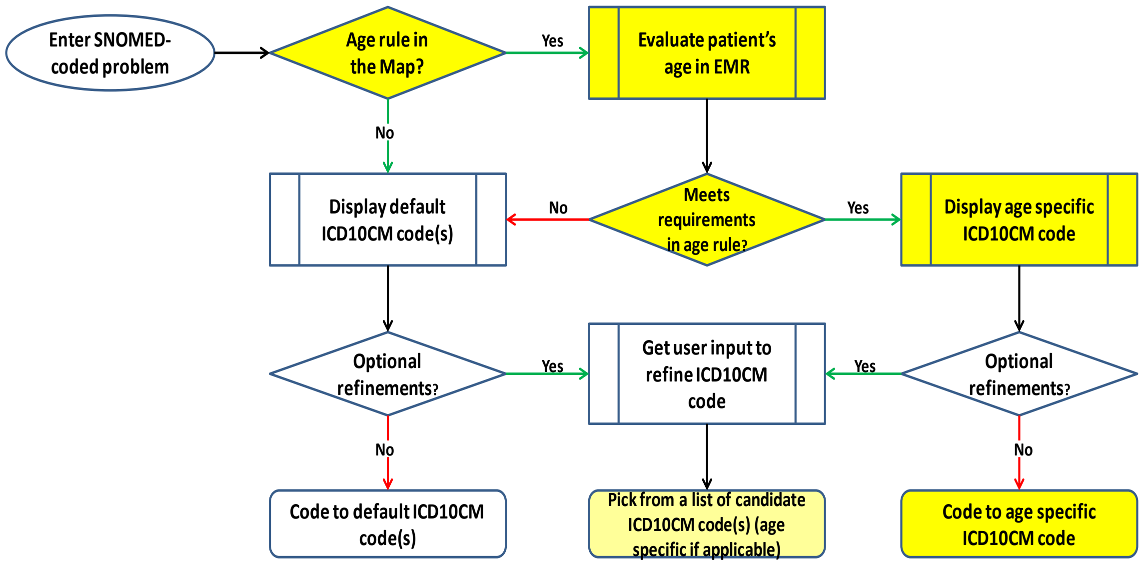

Figure 41: The use of age rule to determine the appropriate target ICD-10-CM code (highlighted boxes are specifically related to the age rule).

6.2 Age rule creation

In the creation of the Map, map specialists follow the standard procedure of coding, as recommended in the ICD-10-CM documentation. Firstly, the ICD-10-CM alpha index is searched using lookup terms. The identified codes are then confirmed by checking the tabular list of ICD-10-CM. The indication for an age rule usually comes from the alpha index. An age specific entry is found under the main entry as an indented entry (Figure 5). This is usually accompanied by a corresponding entry in the exclusion notes of the tabular list (Figure 42). For "Urinary tract infection", one of the exclusion note for code N39.0: *Urinary tract infection, site not specified* is "Excluses1: *neonatal urinary tract infection P39.3*". However, there are cases in which the age specification is only listed in the alpha index, without a corresponding exclusion note in tabular list.

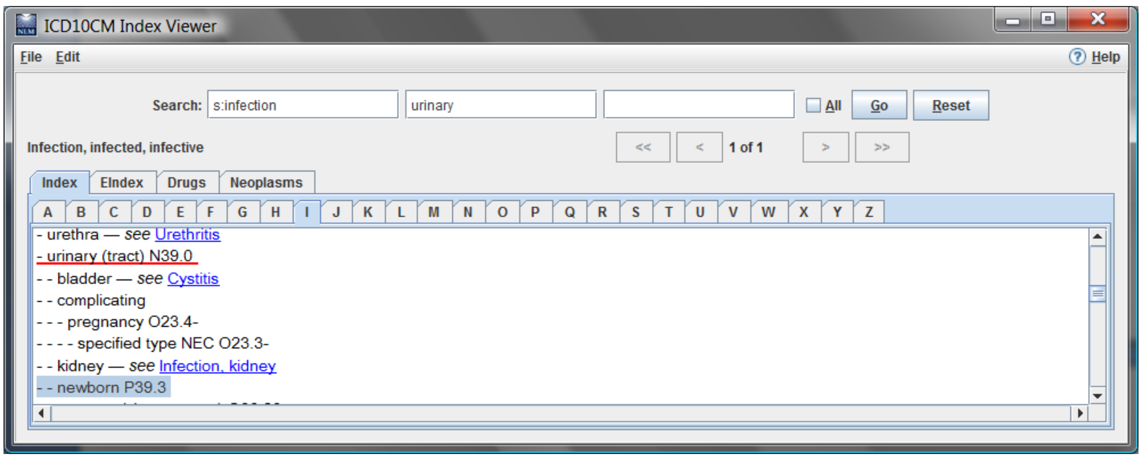

Figure 42: Screen shot of the ICD-10-CM Index Viewer, a custom-built browser for this mapping project, showing age specification listed in alpha index

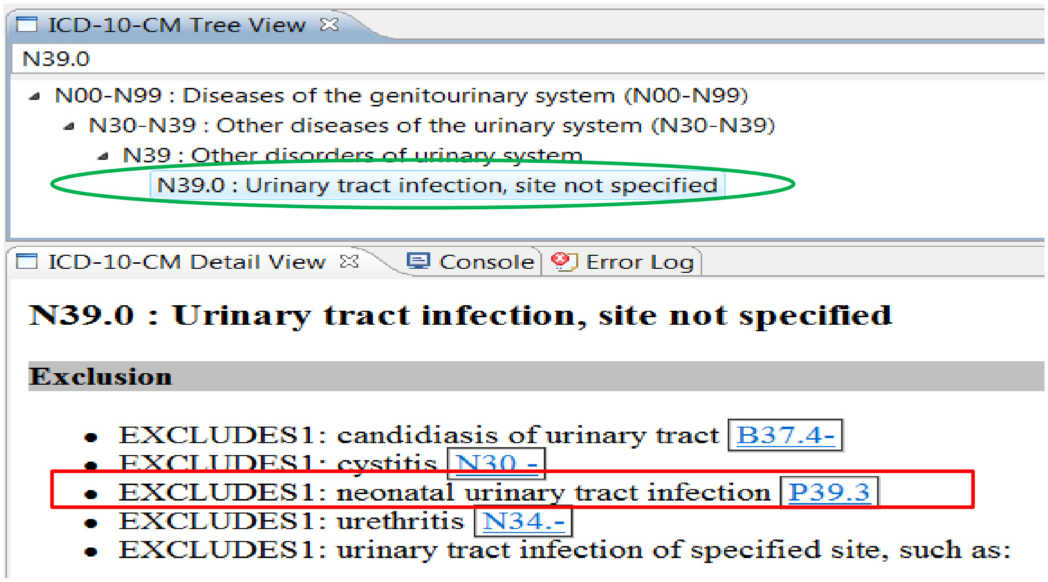

Figure 43: Screen shot of the ICD-10-CM tabular list in a custom-built mapping tool for this mapping project, showing exclusion note corresponding to age specification listed in alpha index in Figure 42

The age specification usually refers to a phase of life (e.g. neonate, adulthood). To convert it to a machine-processable age rule, the age ranges for these phases of life needed to be defined. The following list of reference age ranges was established and confirmed with ICD-10-CM experts (Table 8).

Age rule category	Definition	Age range
Perinatal	22 weeks of gestation to 7 days of life	age < 8.0 days
Neonatal	Birth to 28 days of life	age < 29.0 days
Infant (infancy)	Birth to less than 1 year of age	age < 1.0 year
Juvenile	1 year of age to less than 18 years of age	1.0 years =< age < 18.0 years
Adolescence	1 year of age to less than 18 years of age	12.0 years =< age < 18.0 years
Childhood	Less than 18 years of age	age < 18.0 years
Adult	18 years of age and older	18.0 years =< age
Pre-senile	less than 65 years of age	age < 65.0 years
Senile	65 years of age and older	65.0 years =< age

Table 8: Age ranges for age rule

According to the above definition, the age rule of the map for concept "Urinary tract infection" is represented as in Table 9.

Rules	Logic	Target ICD code	Target code description
Age Rule	IF AGE < 29.0 days	P39.3	Neonatal urinary tract infection
Default	ELSE	N39.0	Urinary tract infection, site not specified

Table 9: Representation of the age rule in the map for "Urinary tract infection"

Sometimes a SNOMED CT concept is already specific to a particular age group e.g. "Neonatal cerebral ischemia". In this case, the map to the ICD-10-CM code P91.0: *Neonatal cerebral ischemia* is final and no age rule is necessary. On the other hand, if the source SNOMED CT concept is "Cerebral ischemia", it will need a newborn age rule leading to the target code P91.0, while the default target is I67.8: *Other specified cerebrovascular diseases.*

Soon after the beginning of the mapping work, it was noticed that manually picking up concepts that required age rules was not carried out in a consistent manner by the map specialists. This manual process could be difficult because sometimes the age specification may be buried in a long list of indented entries in the alpha index. Besides, the proportion of concepts that required an age rule was relatively small. So age rules could be easily omitted when the maps were being created. For this reason, mapping project technical supporting team developed an algorithmic way of identifying concepts that might potentially require age rules to supplement the manual process. In this dissertation, this process was described and evaluate its performance.

6.3 Age rule methods

The following steps (the “age rule QA”) are used to add missing age rules to mapped concepts:

1. Identify all ICD-10-CM codes that can be refined by age-related modifiers.

   The whole ICD-10-CM alpha index was searched for age-related modifiers at all levels, based on a list of age-specifying keywords including neonate, newborn, perinatal, childhood, infant, juvenile, adolescence, senile etc. For example,

   Uremia, uremic N19

   - **newborn** P96.0

   In this case, “newborn” is the age-related modifier, and the code in the level immediate above it (N19) is the code being refined. So N19 will be added to the list of ICD-10-CM codes that can be refined by age-related modifiers. Sometimes, the modifier contains additional information which is not age-related. For example,

   Speech

   - defect, disorder, disturbance, impediment R47.9

   - - psychogenic, in **childhood and adolescence** F98.8

   F98.8 can only be satisfied when the speech defect is also “psychogenic”. Even though “childhood” and “adolescence” are age-specifying keywords, it was decided not to include the code being refined (R47.9) in the list.

2. Flag all mapped concepts that use any of the ICD-10-CM codes identified in 1. As target codes, but do not already have age rules in their maps

3. Manually review all flagged concepts and add age rules if appropriate
4. If, after review, an age rule is considered unnecessary in a flagged concept, it is labeled as "reviewed for age rule" so that the same concept will not show up again in future runs of the age rule QA.

To evaluate the performance of the age rule QA, it was run on all mapped concepts that were to be published in the preview release of the Map in February 2012. The distribution of the resulting age rules was analyzed for the different age ranges. The reasons why some flagged concepts ended up not requiring an age rule (false positives) were also examed.

6.4 Results

The age rule QA was run on 7,277 mapped concepts, and identified 342 concepts to be potentially requiring an age rule. After manual review, age rules were added to 172 concepts (true positive = 50.3%). The other 170 concepts did not need an age rule (false positive = 49.7%).

6.4.1 Concepts requiring age rule (true positives)

The breakdown of the true positive concepts by the specified age range is shown in table 10. The three most common categories were: 123 concepts (71.5%) mapped to newborn codes, 18 concepts (10.5%) to infant codes, and 16 Concepts (9.3%) to childhood codes.

Age rule category	Age rule counts	Percentage over all age rules	Percentage over all concepts flagged for age rule
Newborn	123	71.5%	36.0%
Infancy	18	10.5%	5.3%
Childhood	16	9.3%	4.7%
Juvenile	6	3.5%	1.8%
Senile	6	3.5%	1.8%
Adult	2	1.2%	0.6%
Adolescent	1	0.6%	0.3%
Total	**172**	**100.0%**	**50.3%**

Table 10: Counts and percentage of map records with age context per age specification category

Some examples of these age rules are shown in table 11.

Age rule category	**SNOMED CT concept**	**Default ICD-10-CM code**	**Age-specific ICD-10-CM code**
Newborn	Hypertrophy of breast	N62 : Hypertrophy of breast	P83.4 : Breast engorgement of newborn
	Infection of skin	L08.9 : Local infection of the skin and subcutaneous tissue, unspecified	P39.4 : Neonatal skin infection
Infancy	Intoxication with Clostridium botulinum toxin	A05.1 : Botulism food poisoning	A48.51 : Infant botulism
	Rumination	R11.10 : Vomiting, unspecified	F98.21 : Rumination disorder of infancy
Childhood	Pica	F50.8 : Other eating disorders (inclusion: Pica in adults)	F98.3 : Pica of infancy and childhood
	Gender identity disorder	F64.9 : Gender identity disorder, unspecified	F64.2 : Gender identity disorder of childhood
Juvenile	Dermatitis herpetiformis	L13.0 : Dermatitis herpetiformis	L12.2 : Chronic bullous disease of childhood (inclusion: Juvenile dermatitis herpetiformis)
	Rheumatoid arthritis	M06.9 : Rheumatoid arthritis, unspecified	M08.00 : Unspecified juvenile rheumatoid arthritis of unspecified site
Senile	Fatigue	R53.83 : Other fatigue (Inclusion: Fatigue NOS)	R54 : Age-related physical debility (Inclusion: Senile debility)
	Degenerative brain disorder	G31.9 : Degenerative disease of nervous system, unspecified	G31.1 : Senile degeneration of brain, not elsewhere classified
Adult	Failure to gain weight	R62.51 : Failure to thrive (child) (inclusion: Failure to gain weight)	R62.7 : Adult failure to thrive
	Stuttering	F80.81 : Childhood onset fluency disorder (inclusion: Stuttering NOS)	F98.5 : Adult onset fluency disorder
Adolescent	Conduct disorder	F91.9 : Conduct disorder, unspecified	F91.2 : Conduct disorder, adolescent-onset type

Table 11: Examples of age rule for each category

6.4.2 Concepts not requiring age rule (false positives)

Upon manual review, 170 (49.7%) of the flagged concepts turned out to be false positives, due to the following reasons (Table 12):

1: The source SNOMED CT concept contained modifiers that do not match the age-specific ICD code. For example, SNOMED concept "Senile dementia" was mapped to the ICD-10-CM code F03: *Unspecified dementia (inclusion note: Senile dementia NOS).* F03 was included in the list of target codes that potentially required an age rule because it had a subentry in the alpha index with the age related modifier *infantile, infantilis* under the main term ***Dementia,*** pointing to the alternative code F84.3: *Other* ***childhood*** *disintegrative disorder*. The alternative ICD-10-CM code clearly did not apply to the source SNOMED CT concept, so this age rule was not appropriate.

2: Multiple locations in the alpha index: An ICD-10-CM code could occur at multiple locations in the index, and the age-related specification was found in some locations but not others. The age rule QA included all ICD-10-CM codes with any age-specific modification anywhere in the index. So some map records might be falsely identified as requiring an age rule.

For example, "Cyclical vomiting – psychogenic" was mapped to F50.8 based on the following index trail. There was no age specification for this condition since there was no age specific subentry at this index position

Cyclical vomiting *— see also Vomiting, cyclical G43.A09*

- psychogenic F50.8

However, the code F50.8 *Other eating disorders* also occurred under the entry for eating disorder, because it covered "*Pica in adults*" according to the inclusion note in ICD-10-CM tabular list. In this other index location, there was an age-specific modifier

Disorder (of) *— see also Disease*

- eating (adult) (psychogenic) F50.9

- - pica F50.8

- - - childhood F98.3

With this index entry, F50.8 was included in our QA algorithm. However, this age specific code of F98.3 "***Pica*** *of infancy and childhood*" did not apply to the SNOMED CT concept of psychogenic cyclical vomiting. So an age rule was not added to the map.

3: Questionable entries in the ICD-10-CM index: There were some cases in which we did not agree that the age-specific code should be used as an alternative to the main term. Here are a couple of examples. If the index trail for "Heart disease" was followed, it would lead us to I51.9: *Heart disease, unspecified*. However, the indented subentry of "senile" seemed to suggest that heart disease in the elderly should be coded to Myocarditis.

Alpha index entry for this example:

Disease, diseased *— see also Syndrome*

- heart (organic) I51.9

- - senile — see Myocarditis

Another example was concept “Anemia”, which was mapped to D64.9: *Anemia, unspecified.* An age specific subentry was listed under main term “***Anemia***” for childhood type:

Anemia *D64.9*

- childhood D58.9

However, the age specific code in this subentry was D58.9: *Hereditary hemolytic anemia, unspecified*. Anemia occurring in childhood could be due to many causes, and restricting it to “Hereditary hemolytic anemia” seemed questionable. So an age rule was not created for this map record.

4: Age specific code was the same as default code:

SNOMED concept “Paralysis” was mapped to code G83.9: *Paralytic syndrome, unspecified*. There was a subentry for senile paralysis in alpha index:

Paralysis, paralytic *G83.9*

- senile G83.9

The age rule QA flagged the concept “Paralysis” as candidate. But the age specific target code was no different from the default target. So an age rule was unnecessary for this map.

False positive category	Concept flagged for age rule	Default target code	Index subentry triggering age rule QA	Age specific target	Result
Conflict with SNOMED CT modifier	**Senile** dementia	F03 : Unspecified dementia (inclusion: Senile dementia NOS)	Dementia F03 - **infantile,** infantilis F84.3	F84.3 : Other **childhood** disintegrative disorder (Inclusion: Dementia infantilis)	Age rules were not created
Multiple positions in alpha index	Cyclical **vomiting** – psychogenic	F50.8 : Other eating disorders (index entry: Cyclical vomiting - psychogenic **F50.8**)	Disorder (of) - eating - - pica **F50.8** - - - **childhood** F98.3	F98.3 : **Pica** of infancy and childhood	
Questionable index entry	Heart disease	I51.9 : Heart disease, unspecified	Disease, diseased - heart (organic) I51.9 - - **senile** — see Myocarditis	I51.4 : **Myocarditis,** unspecified	
Identical target as default	Paralysis	**G83.9:** Paralytic syndrome, unspecified	Paralysis, paralytic **G83.9** - **senile G83.9**	**G83.9:** Paralytic syndrome, unspecified (**same as default code**)	

Table 12: Examples for reasons that concepts identified by the age rule QA but ended up not requiring an age rule in the Map (false positives)

The breakdown of the false positive cases is shown in table 13. False positives due to conflicting SNOMED modifiers and ICD codes with multiple index positions together accounted for two third of all cases. The third most common reason was questionable index entries.

False positive category	Candidate concept counts	Percentage over all the false positives	Percentage over all concepts flagged for age rule
Conflict with SNOMED CT modifier	63	37.1%	18.4%
Multiple positions in alpha index	51	30.0%	14.9%
Questionable index entry	45	26.5%	13.2%
Identical target as default	11	6.5%	3.2%
Total	**170**	**100.0%**	**49.7%**

Table 13: Distribution of the concepts identified by the age rule QA but ended up not requiring age rule in the Map (false positives)

Among the SNOMED CT concepts that were not picked up by the age rule QA, only 20 concepts contained age rules in their original maps. This means that a large proportion (172/(172+20) = 90.0%) of concepts would have been missing age rules without the age rule QA. Overall, for the 7,277 concepts included in the preview publication, a total 192 concepts (2.6%) contained age rules. However, due to a small glitch when the Map data was generated, the age rule was missing for 18 concepts in the released data. This has been subsequently corrected in the final release of the Map.

CHAPTER 7 DISCUSSION

Mapping method development

It will be an additional incentive to use SNOMED CT as the primary terminology in the EHR if the coded data can be re-used for purposes other than clinical care. The output of ICD codes is an important function of many EHRs. Providing a map from SNOMED CT to the ICD-10 will help to promote the adoption of SNOMED CT internationally. Similarly, mapping from SNOMED CT to national extensions of ICD-10 will encourage the uptake of SNOMED CT nationally. Since the national extensions are structurally and semantically based on the international core, it is logical to employ the same method to map them. As demonstrated in the two mapping projects, there was heavy re-use of methods, tools and data between the ICD-10 and ICD-10-CM map projects. In addition, there was also sharing of documentation, training materials and mapping expertise.

Mapping is a labor-intensive process. Even for trained mappers, it took on average 10 minutes to map a SNOMED CT concept to ICD-10 or ICD-10-CM. In addition, it is decided to employ dual independent mapping which is necessary as a built-in quality assurance mechanism to ensure that the maps are consistent and reproducible. This significantly increased the mapping effort required. It was very important to find ways to cut down the mapping workload. It is found that when with a reliable preexisting (or legacy) map, the average number of maps required for a concept was 1.3 (instead of 2) maps, not an insignificant saving. To maximize the number of legacy maps for the ICD-10-CM map project, an algorithmic way is developed to generate candidate ICD-10-CM maps from the ICD-10 map. The ICD-10 map was not completely done when the ICD-10-CM project began, so the mapping team were not able to benefit from the full set of the ICD-10 Phase 1 map.

It was encouraging to find that the using ICD-10 map, a candidate ICD-10-CM map in 74% of mappable concepts were able to be generated, and that 77% of the generated maps actually agreed with the final map. The rate of agreement would be even higher with inclusion of those cases in which the agreement was not recognized because of the order of the map groups. The bulk of the generated maps originated from codes that were valid in both ICD-10 and ICD-10-CM. Not surprisingly, these were also the cases that had the highest rate of agreement with the published maps.

The direction of the Map is from SNOMED CT (source) to ICD-10-CM (target). All pre-coordinated SNOMED CT concepts that are appropriate for use in a problem list are within scope. Initially, a smaller subset of frequently used SNOMED CT concepts will be mapped. Not all ICD-10-CM codes will appear as targets. It is expected that frequently occurring ICD-10-CM codes will be covered in the initial phase. This can only be verified when real-life usage statistics of ICD-10-CM codes are available. Because of the difference in granularity of the two terminologies, some ICD-10-CM codes will not have SNOMED CT correspondents (e.g. concepts with laterality or episode of care information). Full representation of these ICD-10-CM codes will require post-coordination, which is not included in this Map.

The Map is intended to be used in a semi-automatic manner. The Map will suggest candidate ICD-10-CM codes based on SNOMED CT codes and, if applicable, additional information obtained from the electronic patient record or direct user input. Review of the candidate ICD-10-CM codes by either the healthcare provider or professional coder is recommended. The Map contains map rules and advice that can be used to highlight specific coding principles, or point to additional information required for coding. For the simple cases with one-to-one mappings, it is likely that a high proportion of the candidate ICD-10-CM codes will be adopted by the reviewer.

The order of the ICD-10-CM codes indicates the priority of the targets. When a single SNOMED CT concept generates a combination of ICD-10-CM codes, the order of the ICD-10-CM codes complies with ICD-10-CM coding guidelines. For example, in a 'manifestation-etiology" code combination, the etiology code will be in Map group 1 and the manifestation code Map group 2. For injury or poisoning cases, the clinical condition code will be in Map group 1 and the external cause/poisoning code Map group 2. However, when a patient has multiple SNOMED CT-coded problems for a single encounter, each mapping to a different ICD-10-CM code, the Map does not include information to determine the order in which the ICD-10-CM codes should be submitted e.g. as primary or secondary diagnosis.

The mappings are created to accurately reflect the meaning of the SNOMED CT concept. The level of reimbursement is not considered.

The ICD-10-CM maps can also be used to prime the ICD-10 map project. Generating ICD-10 candidate maps from ICD-10-CM should be even easier to do. Whether the findings in this study can be generalized to other national ICD-10 extensions (e.g. ICD-10-CA, ICD-10-AM) remains to be seen. Theoretically, these extensions bear similar relations to ICD-10, and it is possible that candidate maps to the extensions can be generated from the ICD-10 maps in a similar algorithmic way. If that is the case, it will be interesting to see whether the generated maps will agree with the actual maps to the same extent as in ICD-10-CM.

Triangulation

With the exhaustion of ICD-10 map that could be used, there was a need to develop additional method to generate candidate ICD-10-CM map. In Triangulation method, it showed that in almost all of the SNOMED CT concepts (96.2%) studied, it was able to arrive at least one ICD-10-CM target code based on the indirect route through ICD-9-CM. Among them, 44.2% of the Indirect Map exactly agreed with the Direct Map. This is a pleasant surprise because with the vast differences in granularity, content representation, organizing principles and coding guidelines among the three coding systems, one would not normally expect a high agreement rate in an algorithmically-generated sequential map. One potential limitation of the indirect route is that SNOMED CT (more granular) is first mapped to ICD-9-CM (less granular) which often results in loss of information[70]. Further loss of information may occur when ICD-9-CM is mapped to ICD-10-CM through the GEM map. This is similar to the game of “telephone” in which information is sequentially transmitted through a chain of communicators, with loss of fidelity in each step. But the results of our study suggest that this was not as big a problem as what was initially thought.

Theoretically, the synonymy maps should not suffer from this sequential loss of information. If a SNOMED CT concept (A) is mapped to a synonymous ICD-9-CM term (B), and subsequently to a synonymous ICD-10-CM term (C), C should be a good map for

A as they are synomymous (A=B and B=C; therefore, A=C). Indeed, it was found that the synonymy maps had much higher precision. The synonymy maps identified by the map advice label of the SNOMED CT to ICD-9-CM map did not have the same precision as those identified by UMLS synonymy because they were not truly synonymous maps, as the inclusion terms of an ICD-9-CM term were often narrower in meaning than the main term. With over 98% precision, the UMLS synonymy maps can be very useful as a quality assurance tool to identify true errors in the three maps, because the number of maps to be manually reviewed will be small but the percentage of true positives will be high. In our study, a high proportion of the reviewed cases do reveal true mapping errors.

Another potential use of the Indirect Map is to be candidate maps for the ongoing SNOMED CT to ICD-10-CM mapping project. As described in our earlier paper, the SNOMED CT to ICD-10-CM map is created using dual independent mapping as a built-in quality assurance process.[68] Every SNOMED CT concept is mapped at least twice, and only maps that are corroborated by two sources will be accepted as final. Normally, the two sources will be manually-created maps by different map specialists. However, when there is an independent reliable source of mapping, it would be used as the "legacy map" to be compared with one manually-created map. Only when the manually-created map is different from the legacy map will the concept need to be mapped by another map specialist. Therefore, having a high quality legacy map will save mapping time by avoiding a second round of mapping. For this purpose, the single-target Indirect Map in our study are probably the best candidates to use because they have reasonable recall and precision (46% and 63% respectively).

Also, the following limitations was acknowledged in our study. Only SNOMED CT concepts in the SNOMED CT to ICD-10-CM map were included in this study, which represented about one quarter of all SNOMED CT concepts that were considered to be within scope for mapping to ICD-10-CM. While the exhaustive review of the disagreed synonymy maps identified by UMLS synonymy was performed, the review on other types of disagreed maps was limited. The Direct Map was used as the gold standard in the calculation of recall and precision of the Indirect Map, but there could be errors in the Direct Map, as discovered in the process of manual review.

Age specification: Many differences between SNOMED CT and ICD-10-CM stem from the fact that SNOMED CT is a clinical terminology, while ICD-10-CM is a medical classification. One main use of the ICD group of classifications internationally is to generate epidemiological and population health statistics. Patient age is often an important consideration in such use cases, because the same disease occurring in different age groups may have different healthcare and resource allocation implications. Therefore, it is often the case that the same disease condition is assigned with different ICD codes for different age groups. To map from SNOMED CT to ICD-10-CM is to bridge the gap between a clinical terminology and a classification. One of the challenges is to properly reflect these coding guidelines and conventions in ICD-10-CM. It is designed the Map to be a rule-base map to fulfill this requirement. Even though only a small percentage (about 3%) of the concepts ended up requiring age rules, without these age rules, the Map will be incomplete and less useful.

In our mapping project, trained map specialists who are knowledgeable in both SNOMED CT and ICD-10-CM are responsible for creating the maps. All map specialists follow a standard mapping protocol, which involves the following steps: understanding the meaning of a SNOMED CT concept by checking the SNOMED CT hierarchy and defining relationships, locating the target code by searching main term and relevant modifiers in the ICD-10-CM alpha index, confirming the target code with the code description and inclusion notes in the tabular list, and adding map rules and map advices indicated by exclusion notes or additional notes, where appropriate. This is a complicated and mostly manual process. The learning curve is steep. Age rules are particularly challenging because the age-related modifiers may be buried deep in a long list of indentations under the main term and can be easily overlooked. The exclusions in the tabular list will be an additional reminder but they are not always there. To cater for individual variations in mapping, the project already has a built-in quality assurance mechanism. Every concept has to be mapped by two map specialists independently, and only map records that agree are promoted to publication. Even with the additional check, a significant number of cases were found with age rule missing at the early stage of mapping process. This was the incentive for creating the age rule QA. It turned out to be a big help which identified the bulk of the age rules in the published Map. In the subsequent phase of the project, the age rule QA will be checked periodically while the mapping work is in progress.

So far very few cases had encountered in which the age rule QA failed to pick up maps requiring an age rule (false negatives). One example was "Bronchitis". The age-specific subentry in the alpha index for this condition is "- in those under 15 years age — see Bronchitis, acute", which was not picked up by the age rule QA because it does not contain any of the age-related keywords. However, this kind of cases is generally rare and it is our impression that the recall of the age rule QA should be quite high. The precision of the algorithm is 50.3% (172/342). One way it can be improved is to exclude cases where the age-specific code is the same as the default code (see above - reason 4 under false positives) as they generally do not need age rules. This modification will slightly improve the precision to 52.0% (172/331). There were only 170 concepts being false positive for age rule, out of the 7,277 concepts in preview publication. Since they did not constitute a heavy workload for the project as a whole, the false positives were not considered to be a major issue at this point. All the false positive cases will be flagged as "reviewed" so that they will not show up again in subsequent QA runs.

One unexpected beneficial outcome of the age-rule QA is the discovery of some questionable entries in the ICD-10-CM index which could be real errors. These made up 26% of the false positive cases. a list of such cases will be compiled and submit it to NCHS for review.

One limitation of this study is that the results were based on the judgment of one terminology expert and had not been independently validated. The data in this study was generated by applying the age rule QA to only about half of the concepts that were in scope for this phase of the project. Finally, the concepts that were not picked up by the QA checks have not been systematically reviewed to see if there are false negatives.

CHAPTER 8 CONCLUSION

Healthcare data usually are produced and reside in multiple systems in different format. Accurate and comprehensive healthcare data are important for a variety of purposes. One of the challenges in healthcare documentation is different systems have different ways of identifying the same concept. Lacking of shared Standards have caused many issues like increased paperwork and data collection burdens at the point of care, limited ability to capture the detailed clinical information about the patient, little ability to make multiple uses or link data, limited functionality of computerized manipulation on data statistical analysis and information retrieval for use in improving clinical, financial and administrative performance, limited usefulness of data collected in generating patient-specific assessments or recommendations to facility clinicians in making clinical decisions. It is essential that healthcare documentation to be standardized through coding in health information management for Meaningful Use. Vocabulary, terminology, and classification systems are key in this function. SNOMED CT is a comprehensive clinical terminology that is used to code, retrieve and analyze clinical data. ICD-10-CM is a medical classification used for epidemiology, health management and clinical purposes. Coverage overlapping between SNOMED CT and ICD-10-CM make it suitable to create a crosswalk between these two coding systems.

Creating crosswalk between these two coding systems would support semi-automatic generation of ICD-10-CM classification codes from clinical data encoded in SNOMED CT. The would be beneficial to rapid and efficient identification of ICD-10-CM classification codes for the reporting on diagnostic data for US healthcare sites, to re-use of clinical data for additional US statistical purposes, to promote rapid submission and response to national reporting requirements, to saving time and improving efficiency for the coding professional, to improved accuracy and reproducibility of code mapping from clinical encounters.

Coding and modeling invention difference between SNOMED CT and ICD-10-CM requires specific mapping principle, mapping guidelines and mapping algorithm to overcome the gap between these two coding systems. This research report the development of SNOMED CT to ICD-10-CM mapping methodology.

Summary of Innovative Contributions:

Mapping Guidelines:

Often times, there are multiple ways to map a single source SNOMED CT concept. Different approach would lead to different targets. When correctness can not be absolute defined, mapping consistency takes higher priority. A set of mapping guidelines were developed over time to keep the mapping convention consistent as much as possible. Doing so would potentially reduce the mapping discrepancy between the two independent parallel mapping efforts so the map conflict rate can be lowered. More important, mapping consistency would make it possible that the map set can be used in a meaningful way when data are exchanged.

Legacy Map Generation Via Triangulation

As a built-in mechanism for quality assurance, this projects employed dual independent mapping to reduce the variability in manual mapping. Every concept was mapped concurrently by two map specialists. Only maps that were identical were accepted as final. Any discordance was reviewed by a third specialist, and escalated to wider discussion if necessary. The only exception to the dual mapping process was when an existing, reliable source of maps (which is called “legacy maps”) was available. In those cases, the legacy map is compared to a manually-created map. Only when the two maps were different was it necessary for mapping by a second map specialist. Because of this, having an existing source of legacy map would save time by avoiding a second mapping in some cases.

It is shown that by using the SNOMED CT to ICD-9-CM map and General Equivalence Mappings sequentially, an Indirect Map can be generated from SNOMED CT to ICD-10-CM for a very high percentage of SNOMED CT concepts. Overall, this Indirect Map has a moderate degree of agreement with the Direct SNOMED CT to ICD-10-CM map. However, the indirect synonymy maps have much higher precision and can be used for quality assurance of the three maps.

Age Specification:

In the creation of the SNOMED CT to ICD-10-CM cross-map, it is not always possible to find a one-to-one correspondence between a SNOMED CT concept and an ICD-10-CM code. One SNOMED CT concept may require multiple ICD-10-CM codes to fully represent its meaning. Sometimes, the same SNOMED CT concept can be mapped to several alternative ICD-10-CM codes, depending on patient context and co-morbidities. So the Map needs to be a rule-based map to provide the flexibility and logic required in its usage. One important factor that often affects the choice of ICD-10-CM codes is patient age. Age specification is a critical factor in clinical settings. Same problem or same diagnosis may have different cause, would require different diagnostic measurements, may have different prognosis, would take different treatments approach and the outcome could be very different.

The age rule is the method employed in the SNOMED CT to ICD-10-CM Cross-map to address age-related code refinement in ICD-10-CM. The age rule QA identified 342 out of 7,277 concepts which potentially required age rules, among these 50.3% turned out to be true positives. Without this QA, a large proportion of age rules in the published Map would have been missed.

One unexpected beneficial outcome of the age-rule QA is the discovery of some questionable entries in the ICD-10-CM index which could be real errors. Such cases will be submit to NCHS for review.

Result Dissemination:

The outcomes of this research project include a set of mapping principle, mapping guidelines, and mapping methodology for a rule-based crosswalk from SNOMED CT to ICD-10-CM. All these could be used as a prototype in other cross standard mappings. For example, ICD-10-PCS is a procedure coding system created to replace volume 3 of ICD-9-CM. It provides greater specificity to support research, statistical analysis and administrative uses. In the US, ICD-10-PCS has officially replaced ICD-9-CM from

October 2015 onwards. Belgium has already transitioned to ICD-10-PCS from January 2015, and similar transition is happening in Spain and Portugal. A project is formulating earlier this year (2015) for the purpose of creating the map. Through examining commonly-used SNOMED CT procedure concepts, it is not surprising that tooling, principles and guidelines established in SNOMED CT to ICD-10-CM mapping can be re-used, with modifications, for the PCS mapping process.

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