Achieving Logical Equivalence between SNOMED CT and ICD-10-PCS Surgical Procedures

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Abstract

Surgical procedures are coded in SNOMED CT in the electronic health record and in ICD-10-PCS in administrative systems. We compared the logical definitions of SNOMED CT concepts to the ICD-10-PCS axial components to identify overlap and gaps. The biggest discrepancy was in the surgical approach which was specified in all ICD-10-PCS codes but only in 8.7% of SNOMED CT surgical procedures. Among the top 100 commonly used ICD-10-PCS codes, 25% could be matched fully in meaning and logical definition to pre-coordinated SNOMED CT concepts. Using post-coordination, it was possible to represent the full meaning of 86% of ICD-10-PCS codes. Logical mapping between SNOMED CT and ICD-10-PCS is feasible but will be more productive if more SNOMED CT concepts can become fully-defined. Short of full logical matching, partial logical matches can also be useful in suggesting candidate maps for expert review and to support interactive post-coordination.

Introduction

The Standardized Nomenclature of Medicine, Clinical Terms (SNOMED CT) is steadily gaining momentum as the emerging international clinical terminology standard. The number of member countries has more than tripled (increased from 9 in 2007 to 30 in 2017) since the establishment of the International Health Terminology Standards Development Organisation (IHTSDO) in 2007. In early 2017, the IHTSDO has acquired the new name SNOMED International. SNOMED International now covers most primarily English speaking countries.[1] In the U.S., the Meaningful Use of Electronic Health Record (EHR) incentive of Centers for Medicare and Medicaid Services (CMS)[2, 3] specifies SNOMED CT as the terminology for the encoding of problem lists and procedures for the EHR, among other data elements. A similar effort is underway in Belgium to encourage the meaningful use of EHR and the use of standard terminologies like SNOMED CT.[4] The adoption of SNOMED CT for clinical documentation is anticipated to increase steadily as the number of member countries continues to grow.[5, 6]

In the U.S. and in Belgium, for administrative and reimbursement purposes, hospital-based medical procedures are being reported in ICD procedure codes. Since 2015, ICD-9-CM procedure codes have been replaced by ICD-10-PCS (International Classification of Diseases, 10th Revision, Procedure Coding System) in both countries. ICD-10-PCS is a brand-new procedure classification system created by the U.S. Centers for Medicare and Medicaid Services (CMS) through a contract with 3M Health Information Systems.[7] Other countries that have been using ICD-9-CM are expected to make similar transition to ICD-10-CM and ICD-10-PCS. For example, Spain has made the switch in 2016 and Portugal in March 2017.

While SNOMED CT and ICD-10-PCS are both used to encode procedures, they are designed with different principles to serve their specific purposes. It is likely that both coding systems will continue to be used. One way to mitigate the problem of having clinical and administrative data coded in disparate coding systems is to develop a map between the two systems. Under SNOMED International, there is a SNOMED CT to ICD-10-PCS Mapping Project Group with participation from U.S., Spain and Belgium to explore the creation of such a map.[8] The group has studied various ways of automatically mapping between the two terminologies. These methods include lexical matching of the ICD-

10-PCS index, indirect mapping through the General Equivalence Map (GEMs, published by CMS) and ontological alignment between the SNOMED CT attributes and ICD-10-PCS axes.[9-11] Among these approaches, lexical mapping has higher precision (89% of maps are useful) but low coverage (only 3% of SNOMED CT surgical procedure concepts can be mapped). Indirect mapping through GEM has lower accuracy (76% of maps are useful) but can find map for 10% of SNOMED CT surgical procedures. Ontological mapping has the lowest accuracy (45% of maps are useful) but can find map for 46% of the SNOMED CT procedure concepts studied.

In this study, we are expanding on our effort in ontological mapping. There are two prerequisites in order for ontological mapping to work. First, there has to be a high degree of similarity or compatibility between the underlying concept models of both systems. Second, the existing contents must be modeled adequately to support automatic mapping between both systems. Based on a list of frequently used ICD-10-PCS surgical procedure codes from a hospital information system, we assessed the extent to which the SNOMED CT concept model can cover the meaning of ICD-10-PCS codes. We also examined the degree of modeling of existing (pre-coordinated) SNOMED CT concepts and the feasibility of using post-coordination to achieve logical equivalence between SNOMED CT and ICD-10-PCS surgical procedures. We report our findings here and discuss the implications of our findings with respect to the quality of SNOMED CT modeling and the practicability of ontological mapping.

Methods

ICD-10-PCS is a radical departure from ICD-9-CM in terms of structure and design. Each procedure is defined by seven components (axes) namely section, body system, root operation, body part, approach, device and a 7th character for a qualifier if applicable.[12] On the SNOMED CT side, procedure concepts are similarly defined by components (attributes) such as procedure site, method, access, device etc.[13, 14] The basis of ontological mapping is to align the ICD-10-PCS axes and SNOMED CT attributes in order to identify equivalence in meaning by comparing the logical definitions of concepts. In this study, we did a quantitative analysis of the attributes used in existing SNOMED CT surgical procedures and compared them to the corresponding components in ICD-10-PCS to identify overlaps and potential gaps.

We acquired a list of ICD-10-PCS codes with usage frequencies extracted from the data warehouse of Nebraska Medicine - Medical Center, a 600 acute-care bed facility with more than 1,000 physicians in all major specialties and subspecialties. In our study, we focused on medical and surgical procedures from section 0.The various sections can be distinguished by the first digit of the ICD-10-PCS code (e.g., 0 = medical and surgical, 1 = obstetrics, 2 = placement, etc.). Medical and surgical procedures represent the majority (86%) of all ICD-10-PCS codes. We identified the 100 most frequently used ICD-10-PCS medical and surgical procedures (codes beginning with 0). For each ICD-10-PCS code, two authors (JX and FA) independently looked for the SNOMED CT concept that most closely matched the meaning of the ICD-10-PCS procedure (**meaning match**). The meaning of the SNOMED CT concept was determined by its fully-specified name. The meaning match was characterized as exact or partial. For exact meaning matches, the logical definition of the SNOMED CT concept was examined to see whether it captured the full meaning of the ICD-10-PCS procedure (**logical match**). If the logical definition did not completely match the ICD-10-PCS procedure, it was extended according to the SNOMED CT concept model[15] to see if full logical equivalence could be achieved. If full logical equivalence could not be achieved, the reason was recorded. The reasons might include: limitation of SNOMED CT concept model, missing necessary attribute, missing necessary value. For cases that the closest SNOMED CT concept was a partial meaning match, that SNOMED CT concept was used as the template to construct a post-coordinated SNOMED CT expression to capture the meaning of the ICD-10-PCS code as fully as possible. If full logical representation was not possible with post-coordination, the reason of failure was recorded. Results from the two reviewers were compared and differences discussed with a goal to reach consensus. A third reviewer (KWF) cast a third vote if consensus could not be reached. All three reviewers (all physicians) together discussed cases in which there was exact meaning match but incomplete logical match to see if the missing defining element was clinically significant. We found this to be necessary because some of the ICD-10-PCS component values were clinically trivial and missing them would not cause ambiguity in the clinical context. For example, circumcision was defined in ICD-10-PCS as having the external approach. Since there was no other approach to perform circumcision,

missing the external approach in the logical definition was considered not clinically significant. The review procedure is summarized in figure 1.

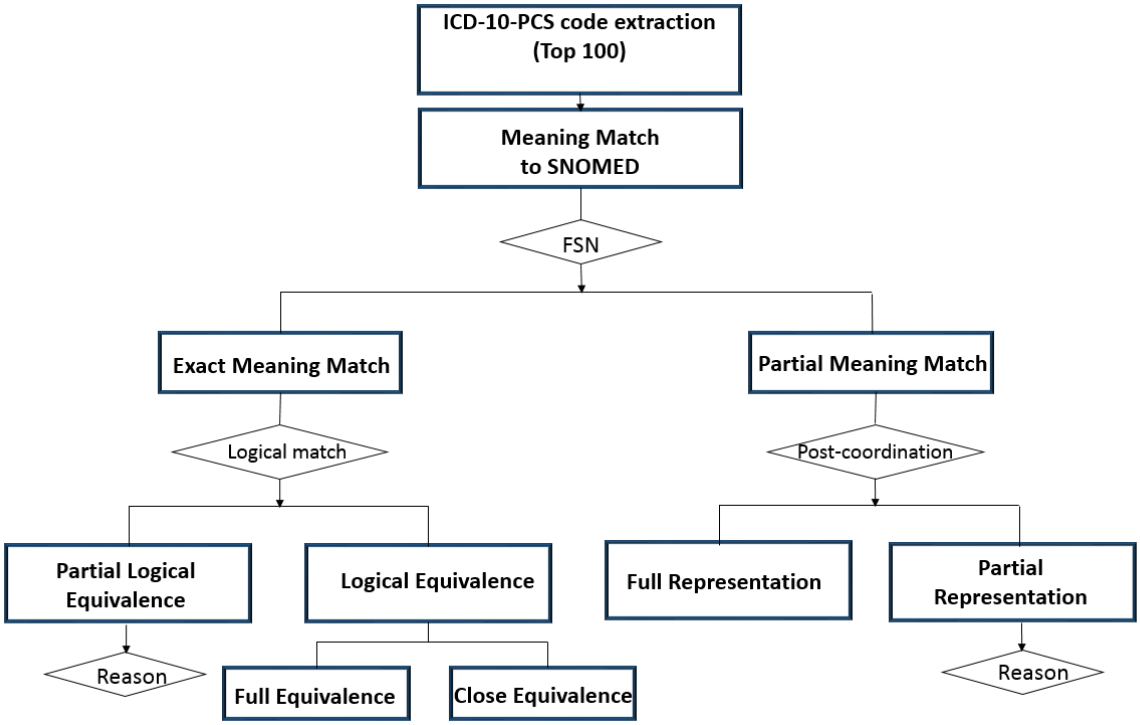


Figure 1. Finding meaning and logical definition match for ICD-10-PCS codes (FSN: fully-specified name)

Results

Concept model analysis

There are 19,796 surgical procedures in the January 2017 release of SNOMED CT identified as descendants of the concept *Surgical procedure (387713003)*. In the SNOMED CT concept model, 24 attributes (excluding the attribute *Is a*) are allowed for the modeling of procedures. (Table 1) The frequency of usage of these attributes is highly variable. For example, while the *Method* attribute is used in all concepts, 9 attributes (e.g., *Procedure morphology*, *Indirect morphology*, *Procedure device*) are used in less than 1% of concepts.

Attribute	% concepts with attribute	Attribute	% concepts with attribute
Method	100.00%	Surgical approach	3.27%
Procedure site - direct	85.23%	Has intent	3.18%
Direct morphology	28.60%	Has focus	1.90%
Procedure site - indirect	13.27%	Procedure morphology	0.69%
Using device	13.14%	Indirect morphology	0.68%
Procedure site	8.80%	Priority	0.36%
Revision status	4.89%	Using energy	0.30%
Using access device	4.48%	Procedure device	0.27%
Access	4.30%	Indirect device	0.08%
Direct device	4.19%	Recipient category	0.03%
Direct substance	3.76%	Has specimen	0.01%
Using substance	3.45%	Route of administration	0.01%

Table 1. Frequency of use of attributes in SNOMED CT surgical procedure concepts

In ICD-10-PCS, there are seven axes each corresponding to a specific aspect of a procedure. (Table 2) The ICD-10-PCS code is made up of seven alphanumeric characters, one for each axis. The first five axes are always populated

with clinically meaningful values (e.g., stomach, excision). In axis 6 (device) and axis 7 (qualifier), a placeholder value (Z) is allowed for null values when a component is absent (i.e., no device, no qualifier). Table 2 shows the proportion of ICD-10-PCS codes (2016 version) with non-null values for each of the axes, compared to the proportion of SNOMED CT concepts with attributes corresponding to a particular axis. For example, the root operation is always specified in ICD-10-PCS and a *Method* attribute is always present in SNOMED CT. Body system and body part are specified in all ICD-10-PCS codes. In SNOMED CT, body site is modeled by three attributes: *Procedure site* and its two children *Procedure site – direct* and *Procedure site – indirect*. *Procedure site – direct* denotes the body structure that is the direct aim of the procedure. For example, *Amputation of the foot* has *Procedure site - direct = Foot structure*. *Procedure site – indirect* is used when the body structure is not the direct target of the procedure. For example, *Removal of calculus of urinary bladder* has *Procedure site – indirect = Urinary bladder structure*. The more general attribute *Procedure site* is used to model high-level grouper type concepts such as *Procedure on colon*. However, sometimes the use of *Procedure site* and *Procedure site – direct* attributes is conflated. So in our analysis, body system and body part in ICD-10-PCS are considered to be equivalent to any of the three procedure site attributes in SNOMED CT. Overall, 97.1% of SNOMED CT concepts have at least one of the procedure site attributes. In ICD-10-PCS, body sites can also be used in axis 7 to denote the second body part of a bypass procedure (which typically connects two body parts). For example, for *Bypass stomach to jejunum*, axis 4 has the value *stomach* and axis 7 has value *jejunum*. In SNOMED CT bypass procedures, both anatomic sites being connected are represented as *Procedure site – direct* attributes. So in the case of bypass procedures, Axis 7 corresponds to the second (if present) *Procedure site – direct* attribute in SNOMED CT. There are other uses of axis 7 (e.g., diagnostic) which correspond to other SNOMED CT attributes (e.g., *Has intent*). Overall, while there are 17.2% of ICD-10-PCS codes with non-null axis 7 values, while 8.9% of SNOMED CT concepts have some corresponding attributes. The biggest discrepancy between SNOMED CT and ICD-10-PCS is in the surgical approach value, which is present in all ICD-10-PCS codes but only in 8.7% of SNOMED CT concepts.

ICD-10-PCS axis	**% of ICD-10-PCS codes with non-null values**	**Corresponding SNOMED CT attributes**	**% of SNOMED CT concepts with any of the attributes**
1. Section	100%	NA	NA
2. Body system	100%	Procedure site Procedure site – direct Procedure site – indirect	97.1%
3. Root operation	100%	Method	100%
4. Body part	100%	Procedure site Procedure site – direct Procedure site – indirect	97.1%
5. Approach	100%	Access Using access device	8.7%
6. Device	54.5%	Using device Direct device Procedure device Direct substance Using substance	23.5%
7. Qualifier	17.2%	Procedure site – direct* Has intent Direct substance Using substance	8.9%

Table 2. Distribution of non-null components in ICD-10-PCS and their corresponding attributes in SNOMED CT concepts (NA: not applicable)

*counting only bypass procedures with two or more *Procedure site – direct* attributes

Concept matching

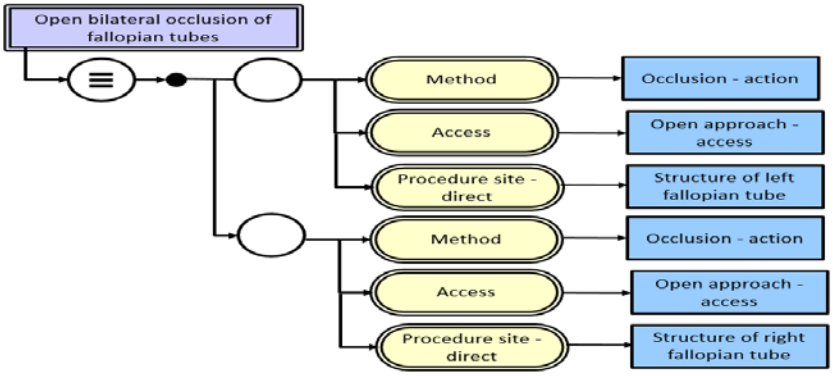
Match category	Number of concepts	Missing attribute					
		Body site	Approach	Device	Intent	Substance	Beyond model
Exact meaning match							
1. Full logical equivalence	1	0	0	0	0	0	0
2. Close logical equivalence	24	2	24	0	7	0	0
3. Partial logical equivalence	7	3	3	3	0	0	1
Partial meaning match							
1. Full post-coordination	56	33	47	3	6	2	0
2. Partial post-coordination	13	9	13	0	0	0	13
Total	100	45	86	6	13	2	14

Table 3. Meaning and logical definition match between SNOMED CT and ICD-10-PCS and the distribution of missing attributes

The following is a detailed explanation of each match category with examples.

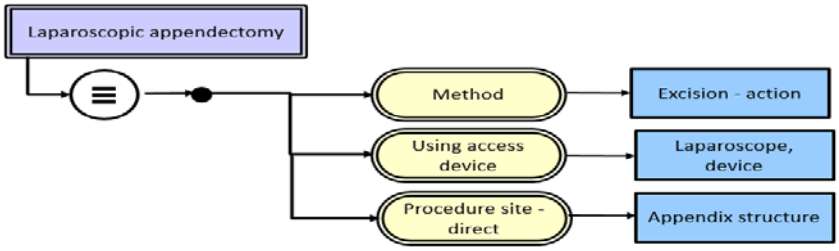
1. Exact meaning match, full logical equivalence (1 case)

The ICD-10-PCS procedure *Occlusion of Bilateral Fallopian Tubes, Open Approach (0UL70ZZ)* matched exactly the meaning of the SNOMED CT concept *Open bilateral occlusion of fallopian tubes (176936004)*. The SNOMED CT logical definition fully captured the ICD-10-PCS components as shown below (drawn according to SNOMED CT Diagramming Guide[16], omitting *Is a* relationships, same below):



2. Exact meaning match, close logical equivalence (24 cases)

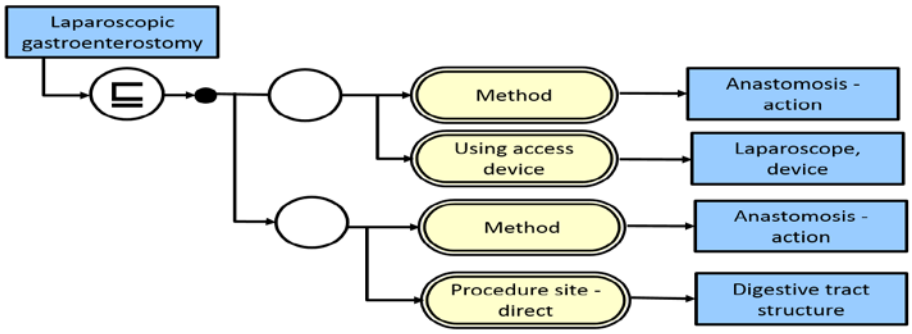
The meaning of the SNOMED CT concept and ICD-10-PCS procedure matched exactly but the SNOMED CT logical definition did not capture all the ICD-10-PCS components. However, the missing component was considered clinically trivial. For example, ICD-10-PCS procedure *Resection of Appendix, Percutaneous Endoscopic Approach (0DTJ4ZZ)* exactly matched the meaning of *Laparoscopic appendectomy (6025007)*, which had these attributes:



Strictly speaking, this was not an exact logical match for two reasons. First, the percutaneous approach was not represented. Moreover, ICD-10-PCS made a distinction between removal of the whole (resection) and part (excision) of a body part. In order to be logically equivalent, *Entire appendix* would have to be used instead of *Appendix structure* for the *Procedure site – direct* attribute. However, we did not consider these differences to be clinically significant because typically laparoscopic surgery was done percutaneously, and appendectomy implied removal of the whole appendix. Omitting these attributes did not significantly change the meaning of the concept. The logical match was close enough in the clinical context. Other examples of close logical matches included omission of the approach for endoscopic procedures (specified as 'via natural or artificial opening' in ICD-10-PCS) and the intent in biopsies (specified as 'diagnostic' in ICD-10-PCS). To facilitate automatic logical mapping, it would be possible to add back the missing attributes algorithmically (see Implications for logical mapping in Discussion).

3. Exact meaning match, partial logical equivalence (7 cases)

In these cases, the meaning match was exact, but the omission in the logical definition was clinically significant. For example, ICD-10-PCS procedure *Bypass Stomach to Jejunum, Percutaneous Endoscopic Approach (0D164ZA)* matched exactly the meaning of *307195003 Laparoscopic gastroenterostomy (307195003)* with the following attributes:

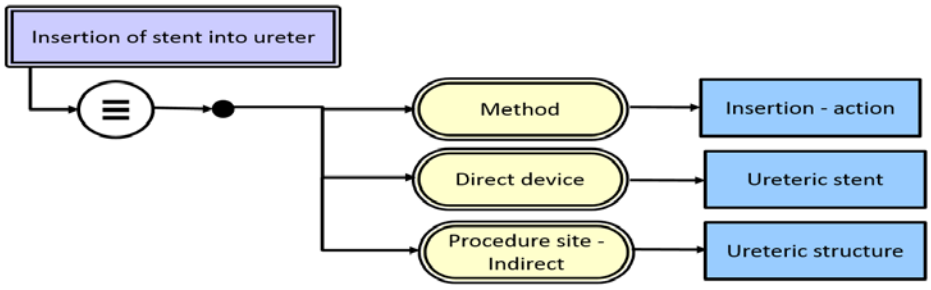


The components of the ICD-10-PCS code could be captured completely by replacing the attribute *Procedure site – indirect = Digestive tract structure* by two attributes *Procedure site – direct = Stomach structure* and *Procedure site – direct = Jejunal structure.* Of the 7 cases we found, 6 cases could have completely matching logical definitions using the existing SNOMED CT concept model. In the remaining case of the ICD-10-PCS procedure *Excision of Stomach, Percutaneous Endoscopic Approach, Vertical (0DB64Z3)*, complete logical representation in SNOMED CT was not possible because the surgical method (sleeve resection or vertical resection) was not available in SNOMED CT to fully represent the procedure in *Laparoscopic sleeve gastrectomy (427074001)*.

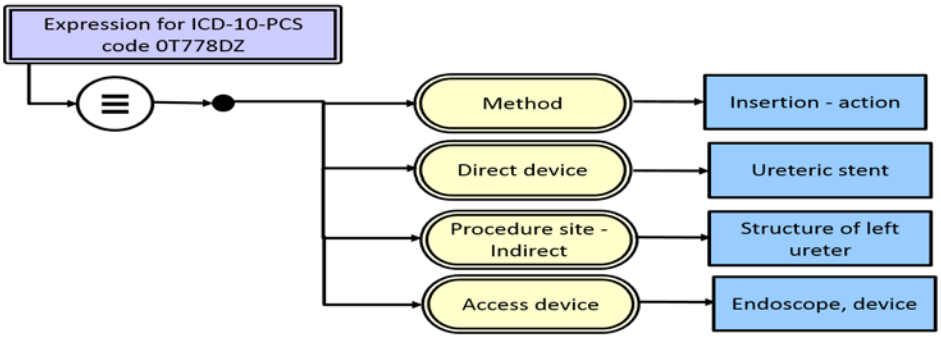
4. Partial meaning match, full representation possible by post-coordination (56 cases)

The SNOMED CT concept matched part of the ICD-10-PCS meaning and a post-coordinated expression could be constructed based on that SNOMED CT concept to represent all the ICD-10-PCS components. For example, the ICD-10-PCS procedure *Dilation of Left Ureter with Intraluminal Device, Via Natural or Artificial Opening Endoscopic (0T778DZ)* was partially matched in meaning to *Insertion of stent into ureter (428817001)*. If we changed the *Procedure site - indirect* attribute value to *Structure of left ureter* and added the attribute *Using access device = Endoscope, device* we could capture all the components of the ICD-10-PCS procedure.

Partial meaning match found in SNOMED CT concept *Insertion of stent into ureter (428817001)*:



Post-coordinated expression could be created to express full meaning of ICD-10-PCS code *Dilation of Left Ureter with Intraluminal Device, Via Natural or Artificial Opening Endoscopic (0T778DZ)*:



5. Partial meaning match, full representation not possible by post-coordination with current SNOMED CT concept model (13 cases)

In these cases, full representation of the ICD-10-PCS meaning was not possible because of one of the following reasons:

- Cardinality – the current SNOMED CT description logic profile was not able to express the exact number of occurrence of an attribute. So it was not possible to capture the number of bypass grafts in this ICD-10-PCS procedure *Bypass Coronary Artery, **Two** Arteries from Aorta with Autologous Venous Tissue, Open Approach (021109W).*
- Absence of body part concept – there was no SNOMED CT body part concept corresponding to the ICD-10-PCS procedure. For example, in the ICD-10-PCS procedure *Insertion of Monitoring Device into **Upper Artery**, Percutaneous Approach (03HY32Z)*, upper artery is defined as any artery above the diaphragm in ICD-10-PCS. In the anatomy model of SNOMED CT, there was no such corresponding body part concept.
- Absence of surgical action concept – the required action concept was not available in SNOMED CT. For example, in the ICD-10-PCS procedure ***Extraction** of Abdomen Skin, External Approach (0HD7XZZ)*, extraction referred to removal by any means other than surgical excision, e.g. debridement. In SNOMED CT, there was no action concept corresponding to 'non-excisional removal'.

Discussion

SNOMED CT distinguishes itself from most other terminologies by its description logic underpinning. The logical definition of concepts makes it possible to compute concept equivalence and subsumption, among other things. ICD-10-PCS is a compositional terminology which makes it inherently computable. This makes it possible, at least in theory, to develop a computational way to link the two terminologies.[17, 18] For this to work, we have to assume that the SNOMED CT logical concept model is able to represent the meaning of ICD-10-PCS procedures and that existing concepts are modeled sufficiently for this purpose. This study examines these assumptions and identifies some hurdles which need to be overcome.

Improving SNOMED CT logical definitions and concept model

Currently, only 42% of all SNOMED CT procedure concepts are designated as fully-defined. This means that in about 60% of procedures, some essential defining attributes are missing and that the meaning of the concept is not fully reflected by the logical definition. Increasing the proportion of fully-defined concepts will improve the capability of SNOMED CT to support computation. The proportion of fully-defined concepts has been recognized by SNOMED International as an important quality metric for SNOMED CT. It is a daunting task to completely model tens of thousands of concepts and some prioritization is necessary. In this study, we have identified some commonly performed procedures in clinical practice which would be a good place to start. In our opinion, the highest priority should be given to those concepts that match an ICD-10-PCS procedure completely in meaning but the logical definition is incomplete because of the omission of some clinically significant attributes (about 7% of cases in our study). These concepts already exist in SNOMED CT and additional work is needed to make their definitions more complete. We are proposing that only attributes which are clinically meaningful and significant to be added, because omitting them can lead to ambiguity in the clinical context. Improving the logical definition of these concepts will not only facilitate mapping to ICD-10-PCS, but will avoid potentially erroneous results in description logic computation e.g., for data aggregation and inferencing. Next-in-line would be the cases with partial meaning matches which can be fully represented by the existing concept model. This represents a larger number of cases (56% of cases in our study) and will require significantly more effort. To match the full meaning of these ICD-10-PCS procedures, new concepts that are sufficiently modeled will need to be added to SNOMED CT. Can we justify the effort? The answer depends on whether adding the concepts will provide high enough utility to SNOMED CT users. We would argue that for procedures that are indeed commonly performed but missing in SNOMED CT, the effort will be worthwhile. Our study data set is based on a single hospital and may not be representative enough. To identify the list of priority concepts to work on, SNOMED International will need to gather more data sets from representative sources.

Cases that cannot be fully represented with the existing concept model present another challenge. We have identified three kinds of reasons for failure. In a small number of cases in our study, full logical representation cannot be achieved because of the problem of cardinality. The current SNOMED CT description logic profile cannot specify the number of occurrence of an attribute. Adding that capability to the SNOMED CT logic profile would be a significant change. We do not think that the ICD-10-PCS mapping use case alone is sufficient to justify this. The other cases in our study involve missing body structure or method concepts. Adding new concepts (provided that they are compatible with SNOMED CT editorial principles) generally requires less effort and causes less disruption. For example, adding the body structure concept *Part of greater omentum* will enable the full representation of the ICD-10-PCS procedure *Excision of Greater Omentum, Open Approach (0DBS0ZZ)*. Adding the method *Sleeve resection* will allow the concept *Laparoscopic sleeve gastrectomy (427074001)* to become fully defined.

Implications for logical mapping

Our study can shed light on the feasibility and expected yield of using ontological alignment to map between SNOMED CT and ICD-10-PCS. In general, the SNOMED CT procedure model aligns reasonably well with the ICD-10-PCS axes. With the existing SNOMED CT concept model and existing attributes and values, 86% of ICD-10-PCS procedures can be fully represented as a SNOMED CT expression. By adding some new body part and method concepts, the coverage can go even higher. This speaks to the overall feasibility of logical mapping.

However, based on the existing modeled content in SNOMED CT, only a small proportion of cases can be mapped completely using the logical definition. This includes the cases we identified as full and close logical definition matches (25% of cases in our study). The ideal scenario is a full meaning and definition match, but it only occurs in one case. The cases with exact meaning match and close definition match are also amenable to logical matching. Since the missing attributes in these cases are clinically trivial, they can be implied and added automatically based on other characteristics of the procedure. For example, *Access = Percutaneous approach* can be added to all laparoscopic procedures, and *Has intent = Diagnostic intent* can be added to all biopsies. This will then allow fully-automated logical mapping to ICD-10-PCS procedures.

To increase the yield of logical mapping for the other cases will be more difficult. One solution would be for SNOMED International to improve the coverage and enrich the logical content of commonly performed procedures as discussed above. Whether this will occur depends on the availability of resources among various competing priorities.

So far, our discussion has focused on full logical equivalence between a SNOMED CT concept and an ICD-10-PCS procedure. However, even with the existing SNOMED CT content, partial logical matches can be found for most cases. Usually, a broader SNOMED CT concept can be found matching some (but not all) of the ICD-10-PCS components. For example, the ICD-10-PCS procedure *Resection of Spleen, Open Approach (07TP0ZZ)* can be matched through partial logical matching to *Total splenectomy (174776001)* in SNOMED CT through the attributes *Procedure site – direct = Entire spleen* and *Method = Excision – action*. The only missing attribute is the open approach. From a mapping perspective, these partial matches can be useful. One potential use case will be to suggest candidate mappings to human reviewers to expedite the creation of a manually-validated map. Another possible use case is to support real-time interactive post-coordination by clinical users. Starting with a partial match, the system can prompt the user to provide additional information until a full match is achieved. For example, when the user types in 'splenectomy', a list of SNOMED CT concepts will appear in a pick list. When the user picks 'total splenectomy', the system will further prompt the user to pick between open and laparoscopic approach. This is because based on the partial logical matching, *Total splenectomy (174776001)* is mapped to two ICD-10-PCS procedures: *Resection of Spleen, Open Approach (07TP0ZZ)* and *Resection of Spleen, Percutaneous Endoscopic Approach (07TP4ZZ)* and the user can click on the appropriate choice to hone in on the optimal ICD-10-PCS code. Furthermore, the system can also add either the attribute *Access = Open approach - access* or *Using access device = Laparoscope, device* to the logical definition of the concept *Total splenectomy*, thus creating a post-coordinated expression that fully captures the meaning of the chosen ICD-10-PCS procedure. In addition to cases with missing attributes, partial logical matching can also handle cases in which an exact match in the value of an attribute cannot be found. For example, an ICD-10-PCS procedure on the left jugular vein can be partially matched to a SNOMED CT procedure on the jugular vein. At the time of data entry, the user picking this SNOMED CT concept will be prompted to specify the laterality, which can also be captured in as a post-coordinated expression. One important consideration when using real-time post-coordination for data capture is to minimize the number of clicks needed to find the optimal code. We are building an experimental tool to study the different ways of presenting and prompting for additional information.

We recognize the following limitations in our study. We only focused on surgical operations in ICD-10-PCS and SNOMED CT but the scope of the two systems includes other types of medical procedures (e.g., obstetrical procedures, imaging studies). Our study sample was based on data from one hospital and the results may not be generalizable.

Conclusion

Logical mapping between SNOMED CT and ICD-10-PCS by aligning the SNOMED CT defining attributes and ICD-10-PCS axes is feasible. The biggest gap is in the surgical approach which is specified in all ICD-10-PCS codes but only in 8.7% of SNOMED CT concepts. However, in some cases the missing attributes are not clinically ambiguous and can be implied. In 25% of ICD-10-PCS codes, there is exact meaning and close logical match to a pre-coordinated SNOMED CT concept. Overall, 86% of ICD-10-PCS codes can be represented completely by the existing SNOMED CT concept model.

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