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Map-Assisted Generation of Procedure and Intervention Encoding (Magpie): An Innovative Approach for ICD-10-PCS Coding

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Abstract

ICD-10-PCS coding is challenging because of the large number of codes, non-intuitive terms and paucity of the ICD-10-PCS index. We previously repurposed the richer ICD-9-CM procedure index for ICD-10-PCS coding. We have developed the MAGPIE tool based on the repurposed ICD-9-CM index with other lexical and mapping resources. MAGPIE helps the user to identify SNOMED CT and ICD-10-PCS codes for medical procedures. MAGPIE uses three innovative search approaches: cascading search (SNOMED CT to ICD-9-CM to ICD-10-PCS), hybrid lexical and map-assisted matching, and semantic filtering of ICD-10-PCS codes. Our evaluation showed that MAGPIE found the correct SNOMED CT code and ICD-10-PCS table in 70% and 85% of cases respectively, without any user intervention. MAGPIE is available online from the NLM website: magpie.nlm.nih.gov.

Keywords:

Controlled vocabulary, Operative Surgical Procedures, Clinical Coding

Introduction

In the U.S., ICD-9-CM procedure codes (also known as ICD-9-CM Volume 3, or ICD9V3 in short) had been used for over 30 years to encode hospital-based medical procedures and interventions for administrative and reimbursement purposes. In 2015, together with the replacement of ICD-9-CM Volumes 1 and 2 diagnosis codes by ICD-10-CM, ICD9V3 was replaced by ICD-10-PCS. Despite the similarity in name, ICD-10-PCS is not an evolutionary descendant of ICD9V3, but a brand-new procedure coding system [1-3]. While the tabular list of codes in ICD9V3 is a tree-shaped taxonomy similar to ICD-9-CM diagnosis codes or ICD-10-CM, ICD-10-PCS is built on a multi-axial structure. ICD-10-PCS codes are composed of seven characters. Each character is an axis of the classification that specifies some information about the procedure performed. Within a defined code range, an axis specifies the same type of information in that axis of classification. Within the Medical and Surgical Section (the first character is 0), which contains 87% if all ICD-10-PCS codes, the details of seven axes are shown in Figure 1.

Compared to ICD9V3, coding in ICD-10-PCS is more challenging because of three reasons. Firstly, there are 20 times more codes in ICD-10-PCS (78,705 codes in the 2018 version) compared to ICD9V3 (3,882 codes in the last updated version in 2013). Secondly, the terms used in ICD-10-PCS are not clinically intuitive. For example, in the clinical discourse, the three operations, extraction, removal and extirpation, are very close in meaning and can sometimes be used interchangeably. In ICD-10-PCS, those three operations are called 'root operations' and have very specific definitions within the coding system:

- Extraction - Pulling or stripping out or off all or a portion of a body part by the use of force
- Removal - Taking out or off a device from a body part
- Extirpation – Taking or cutting out solid matter from a body part

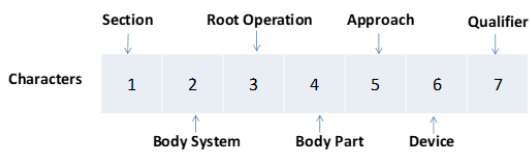

Figure 1— seven axes in ICD-10-PCS codes

This can be confusing to users of ICD-10-PCS, especially clinicians who may not be familiar with the definitions of root operation. For example, cataract removal is coded as extraction and not removal. Non-excisional wound debridment is coded as extraction, not excision or removal. Extraction of embolus (embolectomy) is coded as extirpation. Another area of potential confusion is the difference between resection and excision, which are mostly used interchangeably in clinical discourse. In ICD-10-PCS, excision is defined as "the cutting out or off, without replacement, a **portion** of a body part"; while resection is "the cutting out or off, without replacement, **all** of a body part". As a result, the removal of the appendix is coded as resection while partial nephrectomy as excision.

The third reason why ICD-10-PCS coding is more difficult is that the ICD-10-PCS index is not as rich as ICD9V3 index. The ICD9V3 index contains a lot of detailed terms that are commonly used in clinical records, including abbreviations and eponyms (e.g., Polya gastrectomy). As an example, Figure 2 and Figure 3 show the comparison of the entry for 'Gastrectomy' in the two indexes.

To overcome those challenges, the SNOMED CT to ICD-10-PCS Map Project Group is proposing an innovative solution called MAGPIE (Map-Assisted Generation of Procedure and Intervention Encoding). Our Project Group was formed under SNOMED International in 2015 and has been studying ways to map between SNOMED CT and ICD-10-PCS [4]. We have explored various ways of automatic mapping including lexical matching of the ICD-10-PCS index, ontological alignment between the SNOMED CT attributes and ICD-10-PCS axes, and the use of post-coordination to achieve logical equivalence

[5-9]. The latest study we carried out was repurposing the ICD9V3 index for ICD-10-PCS coding [10].

Gastrectomy (partial) (sleeve) (subtotal) NEC 43.89
with
anastomosis (to) NEC 43.89
duodenum 43.6
esophagus 43.5
gastrogastric 43.89
jejunum 43.7
esophagogastrostomy 43.5
gastroduodenostomy (bypass) 43.6
gastroenterostomy (bypass) 43.7
gastrogastrostomy (bypass) 43.89
gastrojejunostomy (bypass) 43.7
jejunal transposition 43.81
complete NEC 43.99
with intestinal interposition 43.91
distal 43.6
Hofmeister 43.7
laparoscopic, vertical (sleeve) 43.82
Polya 43.7
proximal 43.5
radical NEC 43.99
with intestinal interposition 43.91
sleeve
laparoscopic 43.82
total NEC 43.99
with intestinal interposition 43.91

Figure 2 – ICD9V3 index

Gastrectomy
Partial *see* Excision, Stomach 0DB6
Total *see* Resection, Stomach 0DT6
Vertical (sleeve) *see* Excision, Stomach 0DB6

Figure 3 – ICD-10-PCS index

We harvested the rich ICD9V3 index terms and matched them to SNOMED CT through the UMLS. We mapped the ICD9V3 codes to ICD-10-PCS using the General Equivalence Map (GEM) published by the Centers for Medicare and Medicaid (CMS) (Figure 4) [11]. We showed that the re-purposed ICD9V3 index out-performed the native ICD-10-PCS index in the retrieval of ICD-10-PCS codes based on common surgical procedure names.

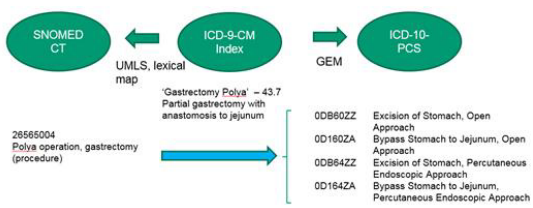

Figure 4– Repurposing the ICD9V3 index and mapping to SNOMED CT and ICD-10-PCS

Based on the repurposed ICD9V3 index and other lexical and mapping resources, we have developed the MAGPIE coding algorithm and tool that allow the user to search for SNOMED CT and ICD-10-PCS codes for a medical procedure or intervention.

Methods

Search Strategies

MAGPIE uses three innovative search strategies to help the user hone in on ICD-10-PCS codes in an interactive manner (Figure 5).

1. Cascading search

Starting from the search term that the user types in, MAGPIE looks sequentially for matches in SNOMED CT, ICD9V3, ICD-10-PCS tables, and ICD-10-PCS codes. The rationale for this approach is that SNOMED CT terms are closest to clinical parlance and meaning, so it is often possible to find a SNOMED CT term exactly matching the input search term. Identifying the correct SNOMED CT concept will help navigate the subsequent search for ICD9V3 codes. Going through ICD9V3 is necessary to take advantage of the repurposed ICD9V3 index and the GEM map. In the next step, MAGPIE will suggest candidate ICD-10-PCS tables that the user can pick to display for individual code selection. After the ICD-10-PCS code(s) are selected, MAGPIE will prompt the user for possible refinement of the SNOMED CT code in cases where the ICD-10-PCS codes selected could lead to a more specific SNOMED CT concept than the one chosen. At each step, MAGPIE will suggest

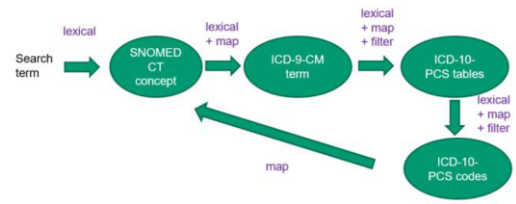

Figure 5 – Overall schema of MAGPIE search sequence and search methods

default codes, if available, based on lexical and map-assisted matching (see below), but the user can change the default if they see better matches. In this way, the user can guide MAGPIE interactively to arrive at the correct ICD-10-PCS codes.

2. Hybrid lexical and map-assisted matching

The first step of searching for a SNOMED CT code is based on lexical matching alone. (Figure 5) All subsequent steps use a combination of lexical and map-assisted matching. To support **lexical matching**, we have built synonym and entry term tables for SNOMED CT, ICD9V3 and ICD-10-PCS codes based on the UMLS, repurposed ICD9V3 index and ICD-10-PCS index. We use the open-source Apache Lucene information retrieval library functions as the search engine for lexical matching [12]. For each sequential search, we expand the search terms by including the synonyms of the selected code in the previous step. For example, the synonyms of the selected SNOMED CT concept are included in subsequent lexical searches for ICD9V3 and ICD-10-PCS codes. For **map-assisted matching**, we have built pairwise mapping tables between the codes from SNOMED CT, ICD9V3, and ICD-10-PCS based on the UMLS, repurposed ICD9V3 index and GEM. Based on the selected code at an earlier step, MAGPIE looks up the code-mapping tables to find target codes for the next step. For example, the selected SNOMED CT code will help to find ICD9V3 codes through the SNOMED CT to the ICD9V3 mapping table. Lexical matching almost always returns some codes, but the accuracy is variable. Map-assisted matching does not always return target codes but is generally more accurate. If both lexical and map-assisted matching return some codes, codes found by map-assisted matching will take precedence over lexical matching.

3. Semantic filtering

In the GEM map, one ICD9V3 code often maps to many ICD-10-PCS codes because of the different granularity between the two systems. For example, *65.29 Other local excision or destruction of ovary* maps to 21 ICD-10-PCS codes because of the combinations of the various options in laterality (left, right, bilateral) and approach (open, endoscopic, etc.). MAGPIE uses semantic filtering to narrow down the possible choices in the

suggestion of ICD-10-PCS tables and codes. (Figure 5) Semantic filtering is based on some keywords in the user's search string. For example, if the user types in 'left laparoscopic oophorectomy', MAGPIE will recognize the keywords 'left' and 'laparoscopic', and pre-select the ICD-10-PCS code *0UT14ZZ Resection of Left Ovary, Percutaneous Endoscopic Approach* while filtering out other choices pertaining to right ovary, bilateral ovaries, and open approach. To support semantic filtering, we have built keyword tables for body part and approach based on the ICD-10-PCS definition tables.

Evaluation

To evaluate the performance of MAGPIE, we use a list of the most commonly performed surgical procedures from a large health care institution that we have obtained in another project [13]. The procedure names have been manually mapped to ICD-10-PCS codes previously, and the maps are used as the reference standard to assess MAGPIE [10]. The procedure names are entered individually into MAGPIE and we evaluate the accuracy of the default SNOMED CT and ICD9V3 codes suggested by MAGPIE. We also evaluate the accuracy and completeness of the suggested ICD-10-PCS tables and ICD-10-PCS codes. If the correct ICD-10-PCS tables or codes are not found by the default selections, we would make necessary adjustments to the SNOMED CT and ICD9V3 code selections, just like a coder would normally do, to get to the correct codes.

Results

A testing version of MAGPIE was made available through the internet during the period of this study. Since the completion of the study, a stable version is now available from the NLM website: magpie.nlm.nih.gov.

MAGPIE users need to accept the UMLS user agreement since SNOMED CT is copyright protected. The users start searching by entering a procedure name, such as 'cesarean', and the autocomplete feature will show the matching terms based on our list of synonyms and entry terms. The users can either pick from the list or type in something not on the list. Upon submitting the search term, MAGPIE will suggest as default the SNOMED CT concept *Cesarean section (11466000)* and ICD9V3 code *Other cesarean section of unspecified type (74.99)* based on lexical and map-assisted matching (Figure 6).

In this case, both through lexical matching using the ICD-10-PCS index, and GEM mapping based on the selected ICD9V3 code, MAGPIE suggests the ICD-10-PCS table *10D Obstetrics | Pregnancy | Extraction*. The user picks the table (only one in this case) for further exploration. On opening the table, the codes found by the GEM map are pre-selected. (Figure 7) MAGPIE highlights the axes where there are multiple values in the GEM suggested codes (the Qualifier axis in this example) and prompts the user to narrow down the choices.

On picking the value 'Classical' for the Qualifier axis, the ICD-10-PCS code Extraction of Products of Conception, Classical, Open Approach (10D00Z0) is recorded by MAGPIE. MAGPIE further checks for potential refinement of the SNOMED CT concept based on the final ICD-10-PCS code. Based on the SNOMED CT to ICD-10-PCS map, the selected ICD-10-PCS code is related to three SNOMED CT concepts that are descendants of the concept Cesarean section (11466000). MAGPIE displays these concepts and asks whether the user wants to use one of these concepts instead. (Figure 8) On picking the refined SNOMED CT concept, MAGPIE displays the final result of the SNOMED CT and ICD-10-PCS codes selected.

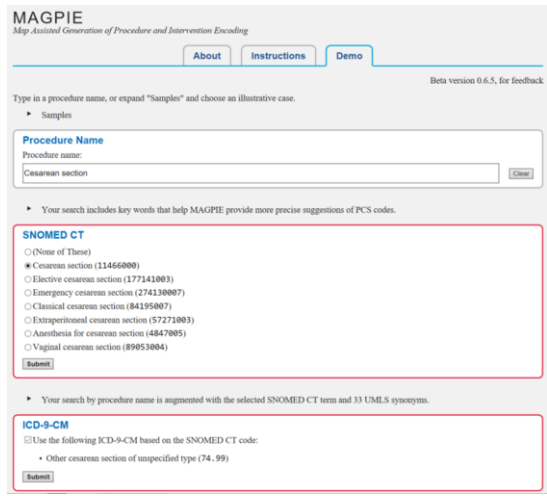

Figure 6 – MAGPIE screenshot 1 - default SNOMED CT and ICD9V3 codes for 'Cesarean section'

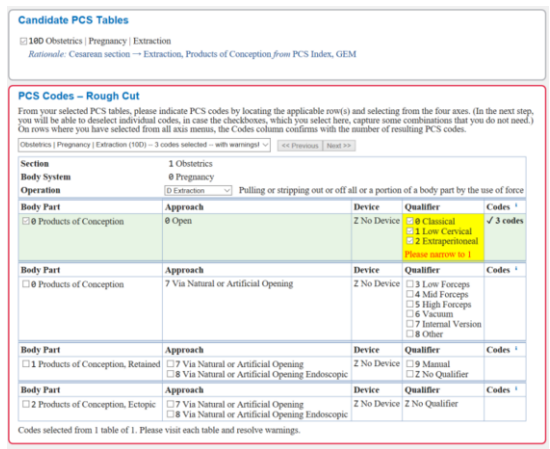

Figure 7 -- MAGPIE screenshot 2 - ICD-10-PCS tables and pre-selected codes for 'Cesarean section'

Evaluation

We used 88 common surgical procedure names to test MAGPIE. First, we evaluated the accuracy of the default SNOMED CT and ICD9V3 codes suggested by MAGPIE. The majority (70%) of the SNOMED CT codes were exact matches, while there were more close matches (48%) than exact matches for ICD9V3 codes (Table 1).

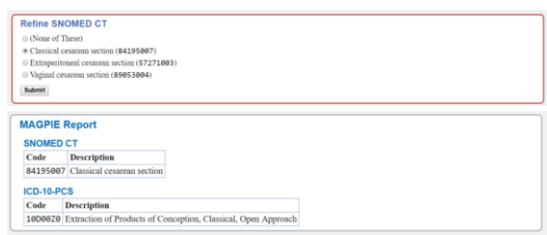

Figure 8– MAGPIE screenshot 3 - refinement of SNOMED CT codes and list of final codes.

Table 1 – Accuracy of default codes found by MAGPIE

Match category	SNOMED CT	ICD9V3
Exact match	62 (70%)	34 (39%)
Close match	26 (30%)	42 (48%)
Unrelated	0	12 (14%)
Total	88 (100%)	88 (100%)

Next, we assessed how well MAGPIE performed in finding the ICD-10-PCS tables and codes. Without changing the default SNOMED CT and ICD9V3 codes suggested by MAGPIE, the correct ICD-10-PCS table was found in 75 (85%) cases. The list of suggested tables was ranked by MAGPIE based on the number of corroborating sources. The sources included ICD-10-PCS index, ICD-10-PCS procedure name or GEM. The tables with the highest number of suggesting sources were ranked first. Among the 75 cases where the correct table was among the default MAGPIE suggestions, the correct table was ranked first in 55 (63%) cases. Overall, in 65 (74%) cases, the correct table was found among the top three (Table 2).

Table 2 – MAGPIE performance using the default selections

Result based on MAGPIE default choices	No. of cases (N=88)
Correct ICD-10-PCS table suggested	75 (85%)
- Ranked first	55 (63%)
- Ranked top 3	65 (74%)
Correct ICD-10-PCS codes suggested	25 (28%)

We further assessed the accuracy and completeness of the pre-selected ICD-10-PCS codes (suggested by GEM). Among the 75 cases where the correct table was found by MAGPIE, the pre-selected codes were exactly the same as in the reference standard in 25 (28%) cases. In the rest of the cases, the users need to adjust the pre-selected codes. Generally, the cases that needed user adjustment can be grouped into three categories. First, there were no pre-selected ICD-10-PCS codes because MAGPIE did not find any ICD9V3 codes, and so there were no GEM-suggested ICD-10-PCS codes. Second, the GEM suggestions were incomplete. One example was 'Ligation of Fallopian tube'. The default ICD9V3 code was *Other bilateral destruction or occlusion of fallopian tubes (66.39)*. GEM found only the bilateral codes, missing the codes for left and right Fallopian tubes in the reference standard. And in the last category, some of the GEM suggested codes were not in the reference standard. For example, in 'Hemorrhoidectomy, internal and external, simple', the GEM suggestions included codes for percutaneous approach, percutaneous endoscopic approach and use of extraluminal device, which were not present in the reference standard.

We further analyzed the 13 cases in which the correct ICD-10-PCS tables were not found by MAGPIE using the default selections. In some of the cases, there was more than one procedure involved. One example was 'Complete transurethral resection of the prostate including control of postoperative bleeding' which required two ICD-10-PCS codes for complete coding. MAGPIE was able to find the code for the 'resection' procedure, missing the 'control of bleeding' part. Some failure was caused by procedure names that were under-specified. One example was 'Shaving benign hyperkeratotic lesion, single'. In clinical discourse, this could be understood as referring to a procedure on the skin. However, since the skin was not explicitly stated in the search term, MAGPIE was not able to find the correct table. Had one used the search term 'Removal of skin lesion' MAGPIE would be able to find the correct codes. In some cases, the procedure could be coded in multiple ways in ICD-10-PCS and there was potential ambiguity. One example was 'Dilation and curettage of uterus'. If the operation was carried out in a non-pregnant woman, this would be coded as *0UDB7ZX Extraction of endometrium through natural or artificial opening*. However, if this was done for termination of pregnancy, it would be coded as *10A07ZZ Abortion of Products of Conception, Via Natural or Artificial Opening*.

Discussion

ICD-10-PCS is radically different from ICD9V3 and the traditional approach for ICD9V3 coding may not work equally well for ICD-10-PCS. Searching based on the ICD-10-PCS index will not work well because the ICD-10-PCS index is relatively lacking in useful clinical terms, compared to the ICD9V3 index. Searching based on the names of the ICD-10-PCS codes, which are generated from concatenating the values of the individual axes, will probably not work well either because some ICD-10-PCS terms (e.g., removal, extraction, extirpation, resection, excision) are not well-aligned with their meaning in clinical usage. We have shown in our previous study that recall and precision are both better when searching with the repurposed ICD9V3 index compared to the native ICD-10-PCS index. Based on the repurposed ICD9V3 index and other resources that the SNOMED CT to ICD-10-PCS Map Project Group has developed, we have built a tool that can be used for both ICD-10-PCS and SNOMED CT coding. SNOMED CT is an emerging international clinical terminology standard and is increasingly used in electronic health records. Using the MAGPIE tool, users can compare the two coding systems side-by-side and understand differences in their scope, granularity and organizing principles.

Since the goal of MAGPIE is to look simultaneously for both SNOMED CT and ICD-10-PCS codes, the cascading search approach is a natural choice. This is similar to the approach used in the I-MAGIC tool [14], which starts with a SNOMED CT concept then navigates to ICD-10-CM through a map. SNOMED CT is the preferred starting point because the SNOMED CT terms are closest to clinical parlance. SNOMED CT is also very comprehensive and has good coverage of both clinical diagnosis and procedures. The next link through ICD9V3 is necessary to make use of the repurposed ICD9V3 index and GEM. Since ICD9V3 is no longer in use, the ICD9V3 code is used only as a navigational pointer. In many cases, it is not necessary to find the perfectly matching ICD9V3 code to get to the correct ICD-10-PCS code, and an approximate ICD9V3 code match is sufficient, as shown in our results. While in only less than 40% of cases the default ICD9V3 codes are exact matches, overall 85% of the cases lead to the correct ICD-10-PCS tables by accepting the default values. The use of SNOMED CT and ICD9V3 codes as intermediate steps offers the opportunity for the user to 'correct course' if MAGPIE is going down a wrong path, which sometimes happens due to a vague or potentially ambiguous search term. One example is 'Construction of shunt', which can mean shunts for arteries, veins or the nervous system. The user can help to guide MAGPIE by choosing the correct SNOMED CT and ICD9V3 codes.

The mapping resources that MAGPIE depends on are used in either direction. Using maps in this way can sometimes be

problematic, especially when the source and target terms are not exactly equivalent. Sometimes maps may contain errors too. However, despite these limitations, our evaluation shows the performance of MAGPIE to be satisfactory.

One potential problem of the GEM is that one ICD9V3 code often ends up with multiple ICD-10-PCS codes because of the difference in the granularity of the two systems. In our previous study, three or four times more ICD-10-PCS codes were retrieved by the GEM compared to the reference standard. This is mostly the result of combinatorial explosion i.e., the total number of codes is the product of the number of options for each axis. To mitigate this problem, we use semantic filtering to prune the GEM-suggested ICD-10-PCS codes. If the user types in '*laparoscopic* excision of ovarian cyst', MAGPIE will exclude the options of 'open' or 'through natural or artificial orifice' from the approach axis. Similarly, if the user types in 'Total replacement of *left* hip', MAGPIE will exclude the values of 'right hip' or 'bilateral hips'.

One special feature of MAGPIE is that the final selection of the ICD-10-PCS code(s) can be used to suggest refinement for the initially selected SNOMED CT concept, in a way 'closing the loop' of the cascading search. In coding, one should always use the most specific code possible in a coding system for a clinical concept. However, coders tend to settle on the first code in the picklist that is applicable and do not look further for more specific codes. MAGPIE takes advantage of the information carried in the final ICD-10-PCS code to prompt the user to refine the initial SNOMED CT selection where appropriate. Therefore, in addition to helping with ICD-10-PCS coding, MAGPIE will also improve SNOMED CT coding.

We recognize the following limitations in our study. The list of common procedure names used in the evaluation was taken from one institution and might not be representative of other institutions. The reference standard for the evaluation was based on the judgment of two physicians with terminology expertise and was not independently validated. The assessment of the performance of MAGPIE was based on a single reviewer and a relatively small sample.

Conclusion

To overcome some of the difficulties in ICD-10-PCS coding, we have developed an innovative tool called MAGPIE (Map-Assisted Generation of Procedure and Intervention Encoding). MAGPIE makes use of the repurposed ICD-9-CM procedure index, which is much richer than the native ICD-10-PCS index. In addition, other lexical and mapping resources derived from the UMLS and GEM are also used. MAGPIE applies various innovative approaches to help the user hone in on the correct SNOMED CT and ICD-10-PCS codes. Our evaluation shows that MAGPIE finds the correct SNOMED CT code and ICD-10-PCS table in 70% and 85% of cases respectively, without any user intervention.

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