ICD-10 procedure codes produce transition challenges

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Abstract

The transition of procedure coding from ICD-9-CM-Vol-3 to ICD-10-PCS has generated problems for the medical community at large resulting from the lack of clarity required to integrate two non-congruent coding systems. We hypothesized that quantifying these issues with network topology analyses offers a better understanding of the issues, and therefore we developed solutions (online tools) to empower hospital administrators and researchers to address these challenges. Five topologies were identified: "identity"(I), "class-to-subclass"(C2S), "subclass-to-class"(S2C), "convoluted(C)", and "no mapping"(NM). The procedure codes in the 2010 Illinois Medicaid dataset (3,290 patients, 116 institutions) were categorized as C=55%, C2S=40%, I=3%, NM=2%, and S2C=1%. Majority of the problematic and ambiguous mappings (convoluted) pertained to operations in ophthalmology cardiology, urology, gyneco-obstetrics, and dermatology. Finally, the algorithms were expanded into a user-friendly tool to identify problematic topologies and specify lists of procedural codes utilized by medical professionals and researchers for mitigating error-prone translations, simplifying research, and improving quality.
http://www.lussiergroup.org/transition-to-ICD10PCS

Introduction

As of October 2015, the US healthcare systems transitioned from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Volume 3 (**ICD-9-CM-Vol3**) to the ICD, Tenth Revision, Procedure Coding System (**ICD-10-PCS**). However, this transition was costlier and more complex than projected by the Centers for Medicare and Medicaid Services (**CMS**), the government agency that oversees medical coding standards and mandated the migration to the ICD-10-PCS coding platform[1]. To ensure data consistency at the national level during this transition, CMS and the Centers for Disease Control and Prevention (CDC) created General Equivalence Mappings (GEMs) for translating data from ICD-9-CM-Vol3 procedures to ICD-10-PCS and vice versa[2]. Unfortunately, GEMs have limited functionality as more than 97% of the ICD-9-CM-Vol3 codes have only 'approximate' matches to ICD-10-PCS codes[3]. Therefore, the bi-directional examination of the mappings is required to accurately match codes between the two classification systems and address the embedded imprecision. This unsolved problem led the Agency for Healthcare Research and Quality (AHRQ) to develop the MapIT tool kit – a software listing all mappings between the two sets of codes via four different tables. The very nature of the AHRQ software illustrated the complexity of translating an individual code from one system to the other[4] and the lack of an international mapping standard for procedure codes motivated the authors to develop a unifying system for the community[5].

A major – and often overlooked – concern with the transition of ICD-9-CM-Vol3 to ICD-10-PCS is the 18-fold increase in the number of procedure codes in ICD-10-PCS. This 18-fold increase is due to a conscious effort to favor procedural specificity (e.g., exhaustive combinations bundling as one code "approaches" and "explicit body parts"[3,6]). Even though previous publications have focused on simplifying the diagnosis code transition of ICD-9-CM to ICD-10-CM[7], the transition to procedure codes in ICD-10-PCS has not received the same attention, and its impact on patient care, research, and quality improvement initiatives remains largely neglected and not well understood. Perhaps, this neglect can be attributed to physicians using diagnosis codes for clinic visits, which then results in less attention on ICD-10-PCS procedure codes[6]. However, when it comes to hospital reimbursement, procedure codes play a major role in the continuum of care. Physician's notes directly impact appropriate hospital billing of ICD-10-

PCS procedures as they are utilized for identifying the code most closely matching the procedure or the approach (e.g., percutaneous, open, or endoscopic variants of a procedure)[8].

In addition to physician and hospital billing and reimbursement, the ICD-9-CM system is heavily utilized by public health agencies, health care professionals, and the biomedical informatics community for tracking patient interventions and outcomes. For example, researchers must be able to standardize definitions and seamlessly work between coding systems in order to work with datasets encompassing both coding systems. On the other hand, clinical trials and longitudinal studies break down if clinical endpoints, procedural interventions, and patient outcomes do not remain invariant across coding systems. Further, ICD-9-CM documentation inaccuracies have already been previously linked to decreased reliability of patient safety indicators (PSI) reporting[9] and inaccurate documentation of epidemiological research studies which can greatly compromise patient safety and public health. Addressing this via the backward mapping of ICD-10-PCS codes to ICD-9-CM-Vol3 codes would allow for consistent reporting of quality outcomes[10] (e.g., AHRQ PSI in the United States[11] or secondary studies of readmission risks using PSI as an underlying model for investigating discharge documentation). Further, addressing inaccurate mappings would also reduce general inefficiencies in health care administration[12].

We hypothesized that modeling the two systems with network topologies would allow us to better understand how to systematically standardize the two coding systems, and thus fill a major data quality gap in the biomedical informatics community. Therefore, we produced an online mapping tool that translates ICD-9-CM-Vol3 codes to the ICD-10-PCS coding system and vice versa for accurately reporting patient health metrics. This article focuses on (i) the largely neglected implications of the transition between the ICD-9-CM-Vol3 and the ICD-10-PCS coding platforms and (ii) a systematic approach to standardizing bi-directional relationships and mappings across ICD-9-CM-Vol3 and ICD-10-PCS to mitigate error-prone translations, simplify research, and improve quality of care[7]. The procedure codes in the 2010 Illinois Medicaid dataset are used as a validation set to demonstrate the transitional challenges between these classification systems.

Methodology, Data, and Implementation

We previously conducted network modeling analyses that unveiled complex, entangled, and non-reciprocal translation mappings between ICD-9-CM and ICD-10-CM billing diagnoses that we termed "convoluted"[7]. Our prior studies[13-18] focused exclusively on medical diagnosis codes, whereas this study focuses on procedure codes. ICD-9-CM Volume 3 procedure codes were subjected to a similar mathematical approach for the transition to ICD-10-PCS (procedure codes), where the relationship between codes are transformed into SQL code and provided in supplement materials[7]. The annotated translation mappings highlight codes at risk of non-straightforward and complex translations. For example, one ICD-9-CM Volume 3 procedure code can map to several ICD-10-PCS procedure codes, and those ICD-10-PCS procedure codes map backwards to other ICD-9-CM Volume 3 procedure codes in a non-reciprocal manner. No mapping occurs when GEM files do not provide any mappings from ICD-9-CM Vol3 to ICD-10-PCS in either direction.

A network map was computationally created to show the complex relationships between ICD-9-CM Volume 3 and ICD-10-PCS based on the combination of four forward and backward GEM files, followed by an computational topological motif analysis. All 3,878 ICD-9-CM Volume 3 codes were organized into five mapping categories according to the observed network topology motifs (**Figure 1**): "identity"(I), "class-to-subclass"(C2S), "subclass-to-class"(S2C), "convoluted(C)", and "no mapping"(NM).[7] The identity transitions are mapping relationships between the two coding platforms where one ICD-9-CM Volume 3 procedure code maps to one ICD-10-PCS procedure code.[7] Compared to convoluted mappings, "identity", "class-to-subclass", and "subclass-to-class" mappings are simpler to track, understand, and use.

Even though CMS GEM files provide forward and backward directional mapping tables from ICD-9-CM Volume 3 to ICD-10-PCS coding systems, these mappings are not necessarily reciprocal as each code could map to multiple codes. Due to the limitations of the CMS GEM files, the AHRQ developed the MapIT tool kit which provides mappings between the two sets of codes visualized in tables[4]. However, several knowledge gaps exist and are not addressed by these tools. Next, we depicted the indirect relationships of ICD-9-CM Volume 3 procedure code 45.16 with other procedure codes (45.14, 45.27, 44.14 and 42.24) and the difficulty of tracking such complex relationships, which is profoundly important for maintaining clinical documentation and accurately billing.

A 2010 statewide Medicaid database from Illinois containing data for 3,290 patients was utilized to evaluate the cost implications of procedures used 10 or more times. The University of Illinois at Chicago approved this research project as exempt. The procedure codes were analyzed for: "identity" (I), "class-to-subclass" (C2S), "subclass-to-class" (S2C), "convoluted" (C), and "no mapping" (NM). The percentage of convoluted procedures is the number of procedures labeled with an ICD-9-CM procedure code that is categorized as convoluted divided by the total number of procedures in that clinical class. The most expensive categories of the ICD-9-CM procedure codes are highlighted and compared to the results from the GEM files analysis.

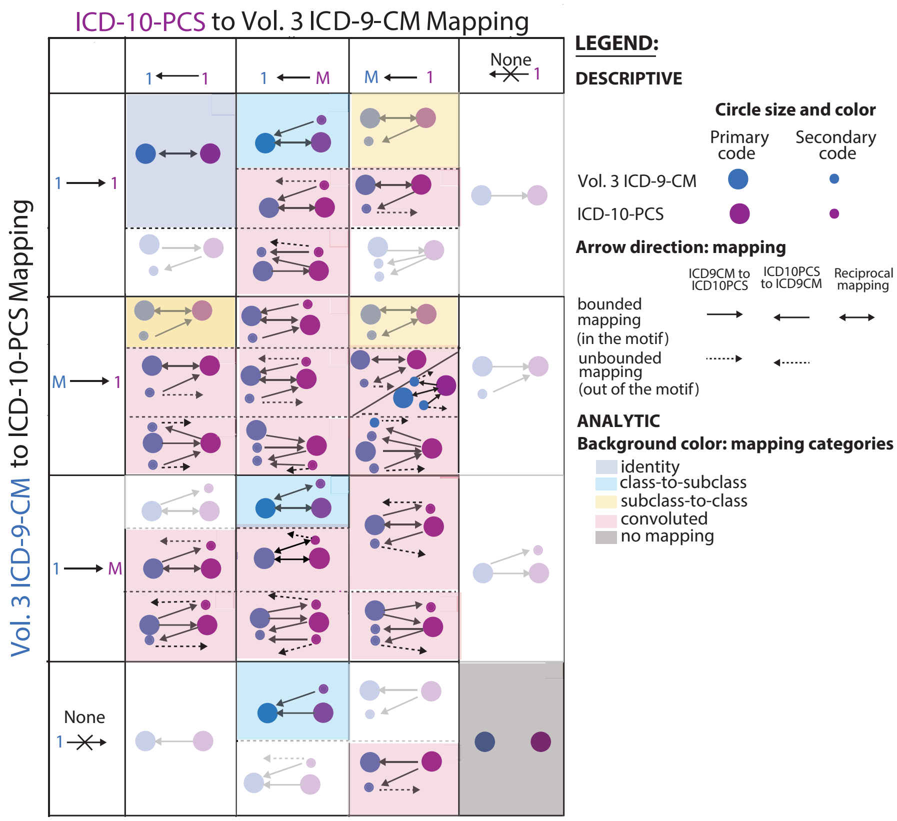


Figure 1. Motif relationship mapping between ICD-9-Vol3 and ICD-10-PCS codes. The mapping of ICD-9-CM-Vol3 to ICD-10-PCS and backward yields complex networks that we simplified into elementary motifs represented in this figure. An ICD-9-CM-Vol3 mapping that proceeds via a convoluted motif leads to a complex interpretation of its corresponding ICD-10-PCS code(s). Due to the non-reciprocal mappings, the majority of convoluted motifs are unbounded (dashed arrows). Unbounded motifs reverberate in the network beyond the illustrated motif (out of the motif) showing unclear reciprocal mapping (A translated to B that translates back to C and C translated to D and so on). faded motifs with white background cells contain no ICD-9-CM-Vol3 codes. Each of the matrix cells comprises one or more mapping motifs that are further synthesized into five mapping categories. The four-color coding corresponds to four categories of complexity of coding as illustrated by the very similar topological motifs of each color (with the exception of the convoluted motif that groups a myriad of unbounded motifs). Blue and yellow colored cells correspond to straightforward subsumptions in a hierarchical classification system.

Results and Discussion

The entire bidirectional mapping network comprises the mappings of 3,878 ICD-9-CM-Vol3 codes to 99,791 ICD-10-PCS codes (**Figures 1-2**). A global picture of the complexity of relationships between the two coding systems ("identity", "class-to-subclass", and "subclass-to-class") is shown in **Figure 2A** (Left network provided in detail on the web portal), whereas **Figure 2B** defines the levels of complexity observed in the analysis of the translation maps. Panel A shows the mapping of the ICD-9-CM-Volume 3 to ICD-10-PCS coding procedures using the science of networks. Analysis revealed that the majority of coding procedures (55%) fall under the "convoluted" category, followed by "simple" (40%), and then "no mapping" (5%). **Figure 2B** provides details of this complexity for each clinical category. The highest percentages of convoluted mappings are found within obstetrical procedures and operations on the eye, integumentary system, and female genital organs (**Figure 2 Panel B**).

While the CMS GEM file only provides simple mappings (**Figure 3A**), the AHRQ MapIT toolkit[4] begins to reveal the complexity of mappings. **Figure 3B** shows how the application provides a complete raw listing as four CMS GEMs tables of mapping relationships between ICD-9-CM-Vol3 and ICD-10-PCS codes for code 45.16

(esophagogastroduodenoscopy with closed biopsy). However, to fully understand the translation challenge, code mappings via both directions need to be viewed simultaneously through a graphical representation. Network visualization and convoluted categorization reveal the true complexity of code 45.16 (**Figure 3C and 3D**). To view the same concept in the AHRQ MapIT toolkit (**Figure 3B**), all four tables would need to be integrated together. Viewing the indirect coding relationships as single lines in a spreadsheet may result in improper translation, further leading to potentially misrepresented patient outcomes used in quality improvement metrics, patient comparison of procedures, and research analytics.

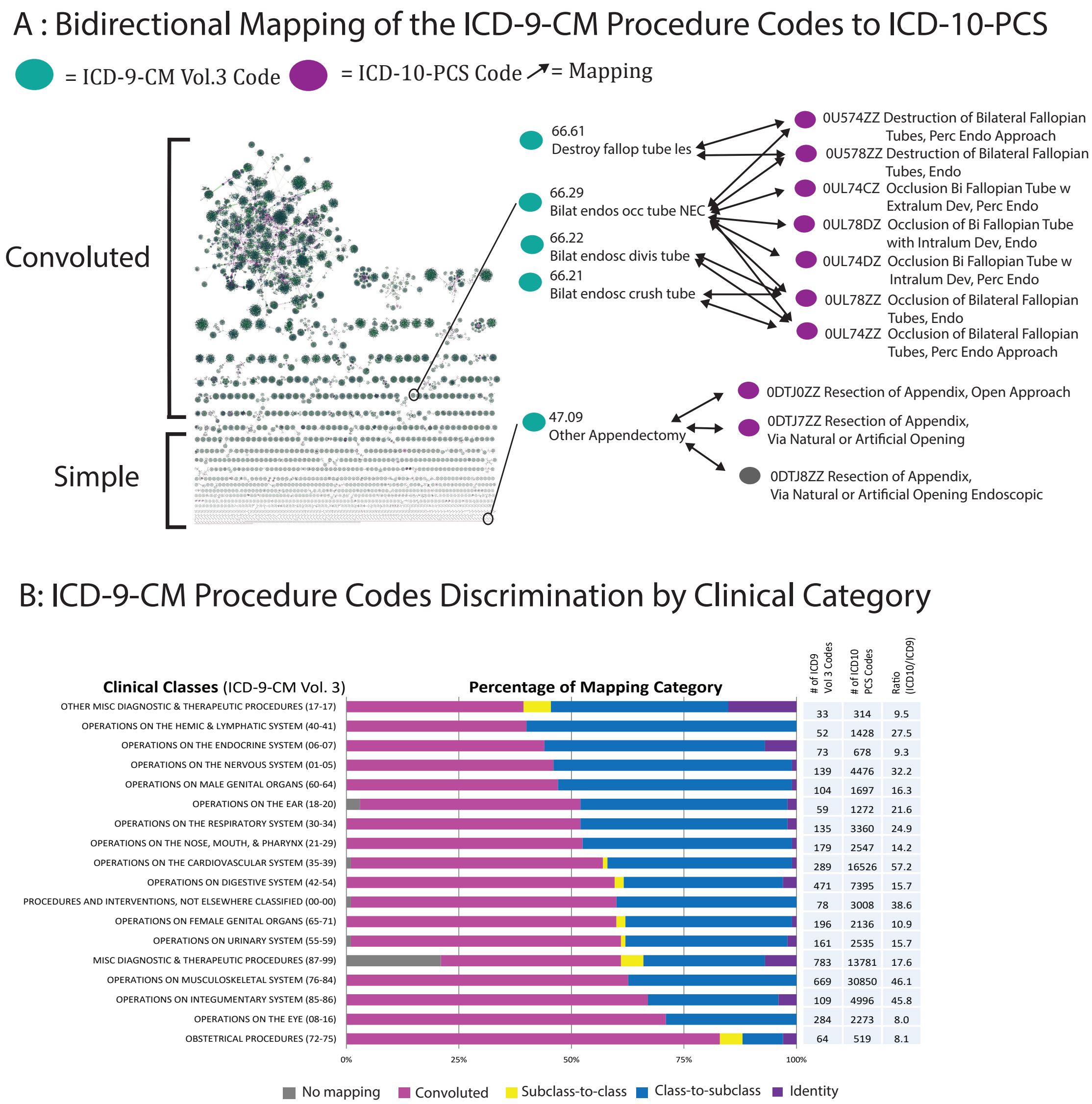
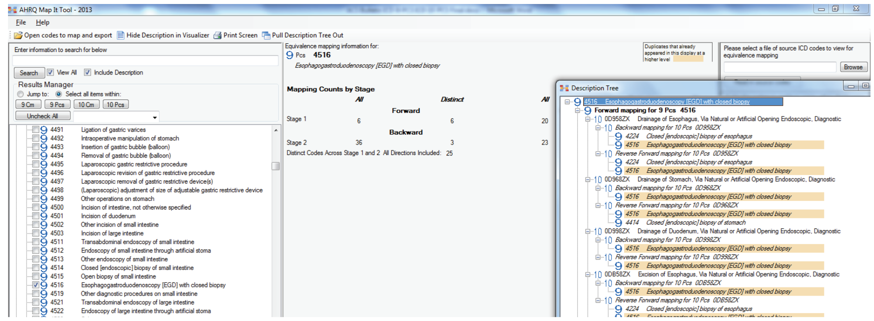


Figure 2. **Objective and subjective measures of the complexity of procedure coding transition to ICD-10-PCS.** Bidirectional mapping and categorical discrimination of ICD-9-CM procedure codes. **Panel A Subjective measures**. The overall complexity of the transition to ICD-10-PCS is represented in this figure. A simple transition example is provided: "Other Appendectomy" (47.09). A convoluted transition example is also provided: Other Bilateral Endoscopic Destruction or Occlusion of Fallopian Tubes (66.29 "Bilat Endosc Tube NEC"). All ICD-9-CM procedure codes are represented by a blue circle. Purple circles represent the ICD-10-PCS codes. The bidirectional black arrows represent the bidirectional transition from one coding platform to the other according to GEMs tables. **Panel B Objective measures**. The complexity of coding of each ICD-9-CM Vol3 procedure code was categorized for "convoluted", "simple", and "no mapping". Each clinical class was evaluated for the percentage of codes that fall into each category to assess the most impacted clinical specialties. Counts and proportions of codes per clinical system are provided according to the complexity category.

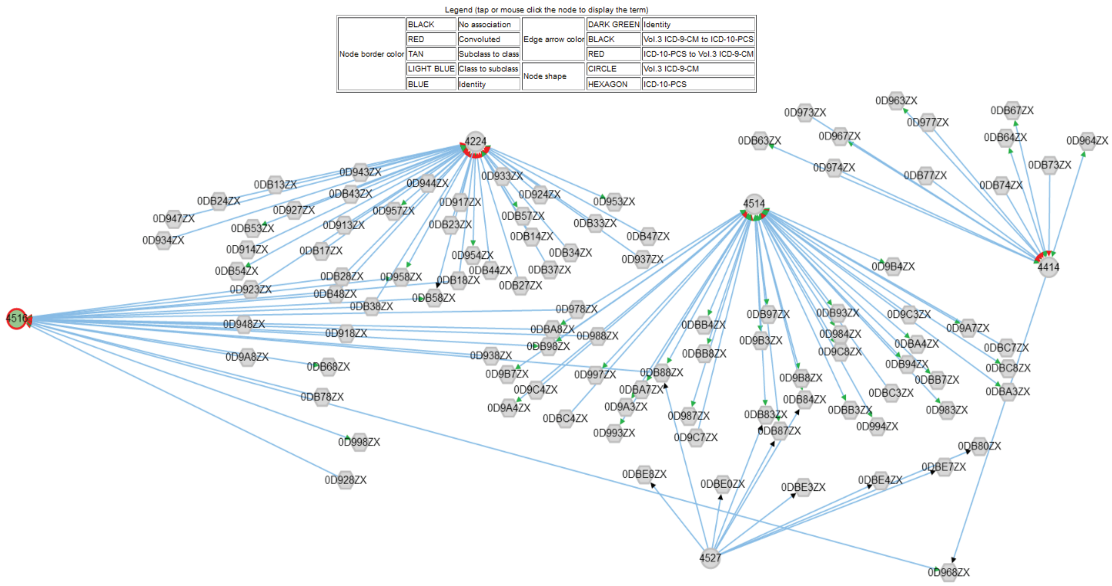
A. CMS file "gem_i9pcs.txt" for Vol. 3 ICD-9-CM code 45.16

...
4515 0DB80ZX 10000
4515 0DB90ZX 10000
4515 0DBA0ZX 10000
4515 0DBB0ZX 10000
4516 0D958ZX 10000
4516 0D968ZX 10000
4516 0D998ZX 10000
4516 0DB58ZX 10000
4516 0DB68ZX 10000
4516 0DB98ZX 10000
.....

B. AHRQ MapIT Toolkit, for Vol. ICD-9-CM code 45.16 with forward, backward, reverse forward, and reverse backward mapping



C. Lussierlab tool derived from GEMs for Vol. 3 ICD-9-CM code 45.16



D. Example of the solution (table) from online tool

Submitted ICD-9-CM-Vol3	ICD9 TERM	Submitted values	ICD-9-CM-Vol3	Relationship	ICD-10-PCS	ICD10 TERM	Mapping Category
			4516	<==	0D918ZX	Drainage of Upper Esophagus, Endo, Diagn	
			4516	<==	0D928ZX	Drainage of Middle Esophagus, Endo, Diagn	
			4516	<==	0D938ZX	Drainage of Lower Esophagus, Endo, Diagn	
			4516	<==	0D948ZX	Drainage of Esophagogastric Junction, Endo, Diagn	
			4516	<==>	0D958ZX	Drainage of Esophagus, Endo, Diagn	
			4516	<==>	0D968ZX	Drainage of Stomach, Endo, Diagn	
			4516	<==	0D978ZX	Drainage of Stomach, Pylorus, Endo, Diagn	
			4516	<==	0D988ZX	Drainage of Small Intestine, Endo, Diagn	
			4516	<==>	0D998ZX	Drainage of Duodenum, Endo, Diagn	
			4516	<==	0D9A8ZX	Drainage of Jejunum, Endo, Diagn	
			4516	<==	0DB18ZX	Excision of Upper Esophagus, Endo, Diagn	
			4516	<==	0DB28ZX	Excision of Middle Esophagus, Endo, Diagn	
			4516	<==	0DB38ZX	Excision of Lower Esophagus, Endo, Diagn	
			4516	<==	0DB48ZX	Excision of Esophagogastric Junction, Endo, Diagn	
			4516	<==>	0DB58ZX	Excision of Esophagus, Endo, Diagn	
			4516	<==>	0DB68ZX	Excision of Stomach, Endo, Diagn	
			4516	<==	0DB78ZX	Excision of Stomach, Pylorus, Endo, Diagn	
			4516	<==	0DB88ZX	Excision of Small Intestine, Endo, Diagn	
			4516	<==>	0DB98ZX	Excision of Duodenum, Endo, Diagn	
			4516	<==	0DBA8ZX	Excision of Jejunum, Endo, Diagn	
			4224	<==>	0D958ZX	Drainage of Esophagus, Endo, Diagn	
			4224	<==	0D913ZX	Drainage of Upper Esophagus, Percutaneous Approach, Diagn	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Figure 3. Visualization of the CMS GEM mappings and web-based tool. Panel A. Simple text provided by the CMS GEM file**. Panel B.** Example of ICD-9-CM Volume 3 to ICD-10-PCS code mapping using the AHRQ MapIT toolkit. The screenshot captures the same mapping relationship between the convoluted ICD-9-CM Volume 3 code 45.16 (Endoscopy with closed biopsy), under Operations on Digestive System category, and relevant ICD-10-PCS and other ICD-9-CM/PCS Volume 3 codes. The tool captures the entire complexity of the mapping, but displays it in a tabular form requiring the integration of four screens to see the complexity of the mappings and what their meaning in terms of cost and operational challenges within clinical documentation and billing. **Panel C.** Example of the solution ICD-9-CM-Vol3 to ICD-10-PCS from http://www.lussierlab.org/transition-to-ICD10PCS web-based tool. The screenshot shows the condensed simple visualization of a single code. **Panel D.** Example of table form solution from the tool.

In addition, complex mapping relationships present a formidable challenge for researchers. **Figure 4** shows the complexity of the mapping relationships between the convoluted ICD-9-CM Volume 3 and ICD-10-PCS coding platforms. Such complexity is not always captured by commercially-available software designed to track GEM-based code mappings. For example, the ICD-9-CM Volume 3 code 45.16, which is frequently utilized statewide with billing totaling close to $1.5 million, has many complex reciprocal relationships to ICD-10-PCS codes. Further, code 45.16 has indirect links to other ICD-9-CM Volume 3 and ICD-10-PCS codes that are not immediately apparent unless all relevant mappings are diagrammed accurately. Our categorical analysis successfully produces aggregated results for ICD-9-CM Volume 3 classifications of the utmost concern. Other infrequent convoluted procedures are too costly to disregard, such as small bowel exteriorization where each procedure costs approximately $123,000. With such a great financial incentive, hospital administrators would want to track these procedures closely and adjust for the differences in mapping when accounting for cost.

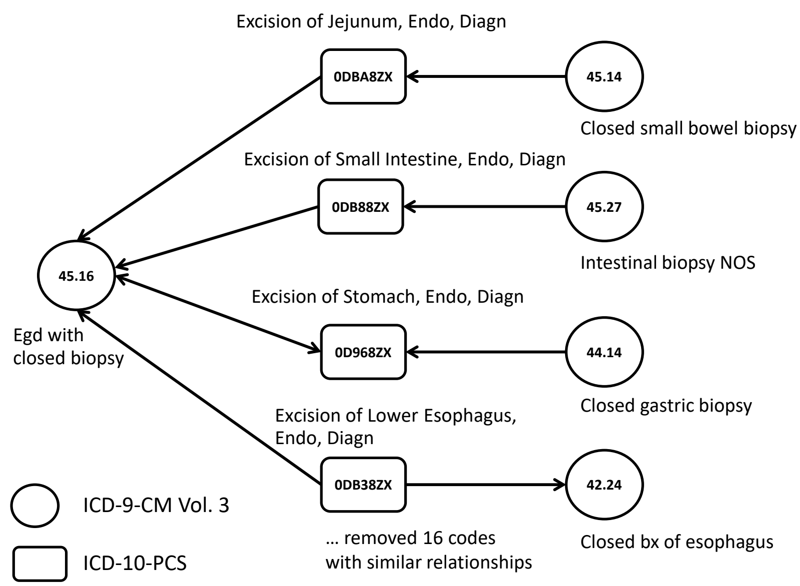


Figure 4. **Example of a frequently utilized convoluted ICD-9-CM-Vol 3 code mapping showing complex and ambiguous coding alternatives.** The ICD-9-CM Volume 3 code 45.16 (Endoscopy with closed biopsy), under Operations on Digestive System category, maps to 0DBA8ZX (Excision of Jejunum, Endoscopy, Diagonal), 0DB88ZX (Excision of Small Intestine, Endoscopy, Diagonal), 0D968ZX (Excision of Stomach, Endoscopy, Diagonal), 0DB38ZX (Excision of Lower Esophagus, Endoscopy, Diagonal), and 16 other ICD-10-PCS codes. These relationships would be identified by GEMs and commercially available ICD-10 mapping tools. However, 45.16 also shares indirect relationships with other ICD-9-CM Volume 3 procedure codes, such as 45.14 (Closed small bowel biopsy), 45.27 (Intestinal biopsy NOS), 44.14 (Closed gastric biopsy), and 42.24 (Closed box of esophagus). Such complex relationships are difficult to track, yet they are frequent and profoundly important in order to maintain accurate billing and clinical documentation practices.

Figure 5 focuses on all procedure codes. A detailed analysis of the codes from hospitals billed to Medicaid revealed a large percentage of convoluted codes (> 50%) in obstetrical, cardiovascular, and digestive system procedures, which present some of the costlier operations (**Figure 5**, **Table 1**: 3,290 patients, 3,984 procedures, 116 institutions).

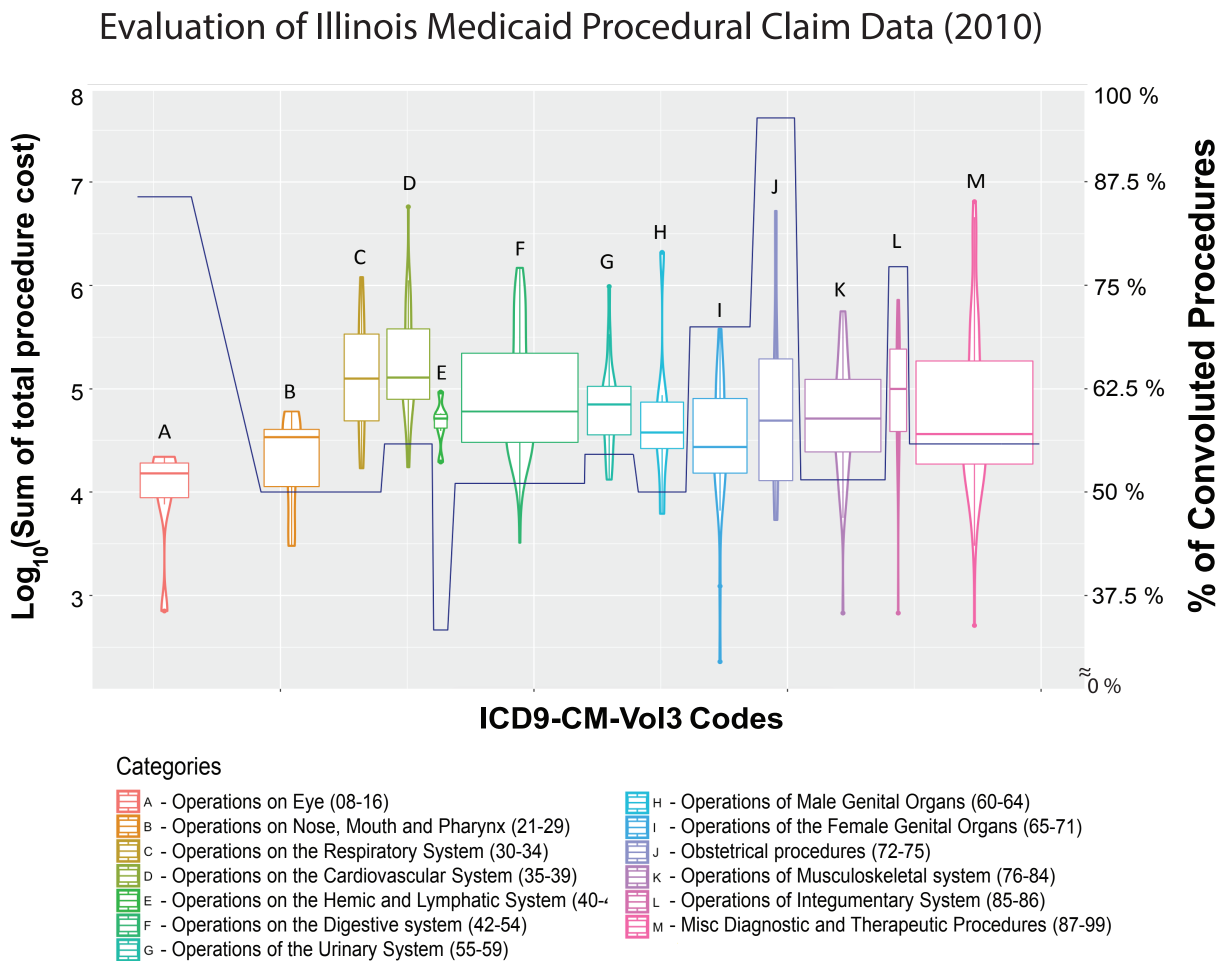


Figure 5. Depiction of costs and complexity of coding per clinical specialty using the Illinois Medicaid procedural claim data set from 2010. The Medicaid reimbursement claims for each category is represented on the logarithmic scale on Y-axis as box-violin plots, whereas the degree of complexity (% of convolution) between the two coding systems is represented on the second Y-axis by a blue line. The horizontal line in each violin-box represents the median value of reimbursement claims for each category. All the procedural categories in ICD-9-CM-Vol3 exhibited more than 50% of convoluted relationships with ICD-10-PCS except the procedures in the Hemic and Lymphatic System category. The procedures in obstetrical, cardiovascular, and urinary systems represents some of the costlier operations as well exhibited highly convoluted relationships to the ICD-10-PCS coding system (>55%).

Furthermore, procedure coding in the ICD-10-PCS platform may impact coder productivity. A recent survey demonstrated a 30 to 40% reduction in productivity of professional coders impacting revenue[13]. Physicians and quality improvement projects should be concerned about the extensive resources required to compare procedure across the ICD-10-PCS transition.

The majority of retrospective population health studies rely on procedure details and clinical documentation accuracy of ICD-9-CM codes such as a population-based study on colorectal cancer surgery[14], surgeons' experience performing endocrine operations[15], a study of causes for reoperations after back surgery[16], and causes leading to low-back surgery[17]. Researchers may also be interested in comparisons among hospital procedures[18], as well as public health topics (e.g., cause of death studies)[19-21]. A number of health outcomes studies rely on ICD data, including development of a clinical comorbidity index based on ICD-9 classification[22], survival and changes in comorbidities after bariatric surgery[23], mortality on prostate cancer risk after surgery for benign prostatic hyperplasia[24], and the impact of hospital surgical volume on operative mortality for major cancer surgeries[25]. Lastly, there is an argument that coding variations lead to differences in reported outcomes of clinical studies, which affects the results of population-based and retrospective studies, especially in longitudinal studies that span years when both ICD versions 9 and 10 were in use[26].

Table 1. High cost procedures associated to convoluted mappings between ICD. Costliest and most frequently billed ICD-9-CM procedure categories based on 2010 Illinois Medicaid reimbursement can be coded as many distinct procedures in ICD-10-CM. Arbitrary coding of convoluted mappings may lead to disputable reimbursements, under- and over-billing, as well as difficulties in measuring performance.

ICD-9 Vol. 3 Cat.	Category Description	Total Reimbursement	Total Number of Procedures	Average Payment for Procedure	% of Convoluted Procedures*
72 - 75	Obstetrical Procedures	$13,571,353	917	$14,800	100%
00 - 00	Procedures and Interventions (NEC)	$898,663	16	$56,166	100%
85 - 86	Operations on Integumentary System	$872,952	61	$14,311	100%
65 - 71	Operations on Female Genital Organs	$646,004	33	$19,576	100%
87 - 99	Misc. Diag. & Therapeutic Procedures	$29,292,996	1159	$25,274	82%
35 - 39	Operations on Cardiovascular System	$8,740,992	182	$48,027	55%
42 - 54	Operations on Digestive System	$6,613,899	221	$29,927	42%
60 - 64	Operations on Male Genital Organs	$2,089,573	382	$5,470	0%
01 - 05	Operations on the Nervous System	$1,182,319	75	$15,764	0%
30 - 34	Operations on the Respiratory System	$537,174	11	$48,834	0%

* % of convoluted procedures = number of procedures with convoluted codes divided by the total number of procedures per row

The convoluted coding designations reveal potential challenges in the transition, and comparison of these complex transitions from one coding platform to another requires additional evaluation. While there is a correct notion on the part of some ICD-10-PCS researchers[6] that the majority of these mapping challenges is associated with non-unique details about procedures (i.e., additional information on a smaller subset of well-defined terms), they neglect the operational, quality improvement, and research perspectives of dealing with this complexity on an ongoing basis. Coding complexity is not a one-time implementation and learning process investment; it involves continuous operations with higher complexity that carries a certain cost burden of additional staff as well as a substantial time investment of medical providers at various levels.

Regardless of these challenges, the transition to ICD-10-PCS offers valuable benefits to the US healthcare system such as reduced discharge not final billed rates and fewer denied claims[27]. Additionally, this transition to ICD-10 will significantly impact clinical documentation by requiring increased details for properly coding[27]. Evidence from the Swiss has demonstrated that through additional education and the normal "learning curve," quality of data does improve with the ICD-10-PCS coding platform[28]. Researchers and healthcare professionals must understand how to interpret the data between the two coding platforms to ensure mappings are done accurately in order to guarantee consistency of results.

Limitations

A limitation of this study is the use of a single statewide Medicaid dataset. Many other insurers including Medicare may have varying costs of reimbursement than those of Illinois Medicaid. Variations in hospitals procedure coding across the country could also lead to differences in the percentage of convoluted procedures per category. Additional tools and methodologies need to be developed and published to ensure retrospective studies examining hospital ICD-9-CM Vol3 procedure codes are consistent within studies across the transition between these and ICD-10-PCS.

Conclusion

The ambiguity induced by the asymmetric, convoluted, and incomplete mappings between ICD-9-CM-Vol-3 and ICD-10-PCS has led to inaccurate integrations that prevent researchers and institutions from properly conducting studies on electronic medical records across this change-point in time. These issues are likely to lead to imprecise billing practices which directly impact metrics of patient quality and safety. As quality and safety metrics enable feedback and quality improvement initiatives, these findings may indicate a possible impact on patient care as well. Existing transition tools lack the functionality to show the complex relationships that exist between the two coding systems and fail to highlight the many challenges of this transition. Thus, we quantified these issues via network topology analyses and developed an online tool to help professional coders, hospital administrators, patients, and researchers better navigate the transition and interpret these challenges. A complete view of the network mapping provides a clear understanding of the implications of this coding platform transition, and the mapping categories ("identity", "class-to-subclass", "subclass-to-class", "convoluted", and "no mapping") are beneficial for conducting accurate analyses and interpretations between the two coding platforms. This online tool identifies problematic topologies of procedural codes utilized by physicians, researchers, clinics, or medical centers for mitigating error-prone translations, streamlining research, and improving quality. Without a clear understanding of these complex relationships, we may jeopardize the integrity and reliability of clinical reports and research studies, potentially compromising patient care and health outcomes.

Availability of data and materials

The data was collected from the state of Illinois Medicaid claims. The data use agreements prohibit us from depositing the raw billing data for the individual patient visits. If researchers are interested in the data, please request from the following website:

https://www.illinois.gov/hfs/MedicalProviders/cc/spwd/Pages/DataRelease.aspx

The algorithms to identify the codes as simple, convoluted, and other categories is located:
1. SQL database for the individual motifs http://lussierlab.org/publication/Motif_table_SQLcode/

2. Website: http://lussierlab.org/transition-to-ICD10PCS

Authors contribution

JJL and MB programmed the software; ADB, JJL, JK, MM, CK, JS, RAS, SRZ, and MB contributed to the analyses, figures and tables, ADB and YAL conceived and supervised the study. Every author contributed to the writing of the interpretation and discussion.

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Consent to participate

As this study included data collected as part of routine clinical care and payment, a waiver of consent was obtained through The University of Illinois at Chicago Institutional Review Board, which approved this study (2012-0773).

Competing interests

In 2014, Dr. Boyd was a paid speaker for Epic, which had no input into the design or publication of this manuscript.

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