

Using SNOMED CT to identify a Crossmap between two Classification Systems: A Comparison with an Expert-Based and a Data-Driven Strategy

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Abstract

A crossmap between successive versions of classification systems is necessary to maintain the continuity of health care documentation. A reference terminology can serve as an intermediary to support this task. Within this study we evaluated the use of SNOMED CT to create a crossmap between two versions of an intensive care classification system. Firstly, the SNOMED CT crossmap was compared with an expert-based and a data-driven crossmap. Next, the influence of these crossmap strategies on the health care outcome was evaluated. For 50% of the analyzed cases, the three mapping strategies resulted in the same crossmaps. In other cases, there was an overlap between the SNOMED CT crossmaps and the crossmaps provided by one of the two other strategies. Differences in the crossmap results had however no significant influence on the health care outcomes. SNOMED CT can be used as an intermediary to solve the problem of crossmapping between versions of classification systems.

Keywords:

SNOMED CT, Classification, Intensive Care, APACHE II, APACHE IV

Introduction

In the healthcare setting, clinical encounters are increasingly documented using classification systems to serve purposes such as mortality and morbidity statistics or financial reimbursement. A classification system is defined as a systematic arrangement of objects or concepts based on their essential characteristics into groups of concepts, called classes [1]. As with all terminological systems, a problem with classification systems is the compatibility between two versions. The 9th revision of the International Classification of Diseases, ICD-9, for instance, was published in 1977 and has been succeeded by the 10th revision, ICD-10, in 1999. The ICD-10 was much more detailed than its predecessor and included alterations in the coding rules, the underlying classification, the number of disease and diagnostic codes, the code structure, and the naming of disease chapters and categories [2]. Health care settings

use the ICD classification systems to compile health statistics and to monitor health spending and outcomes. Consequently, the versioning of the ICD has a direct impact on the health care systems in that the changes produce inconsistencies and discontinuities in the health care statistics [3-5].

Versioning may also be a problem for domain specific classification systems. In the intensive care (IC), for instance, different versions of the APACHE classification system are used to code the reasons for IC admission, which is an important covariate in the APACHE prognostic models. The APACHE prognostic models (e.g. APACHE II and IV) are applied to calculate case mix (i.e. severity of illness, age, and the primary reason for IC admission) adjusted mortality in order to assess the quality of health care [6]. The APACHE IV prognostic model is almost backward compatible with its predecessor, the APACHE II prognostic model, meaning that covariates for APACHE II prognostic model are also used in the APACHE IV prognostic model. The covariate "reasons for IC admission" forms an exception in that it requires another classification system. Therefore, although the detailed registration of the reasons for admission in the latest APACHE IV classification system enables a more accurate prediction of mortality risks, to enable trend analyses, also the older APACHE II classification system is still concurrently applied.

In both the ICD and the APACHE example, a crossmap between the two versions of the classification systems is necessary to preserve the continuity and interoperability of health care documentation and to avoid double registration. Yet, accurate 1-to-1 crossmaps between (versions of) classification systems may be difficult because these systems have different levels of granularity and the mapping can be influenced by the structure and content of both systems [7, 8]. It has been argued that a reference terminology can serve as an intermediary to support the creation of a mapping between two (versions of a) classification systems [7]. Reference terminologies provide detail and precise meaning to data by formal concept definitions, required for complete and consistent coding of clinical data [9]. An advantage of using a reference terminology to create a crossmap is that once a mapping has been created between the target classification system and the reference ter-

minology, this mapping can be re-used to identify crossmaps between all other (versions of) classification systems which are also mapped to the reference terminology (dashed arrows in Figure 1).

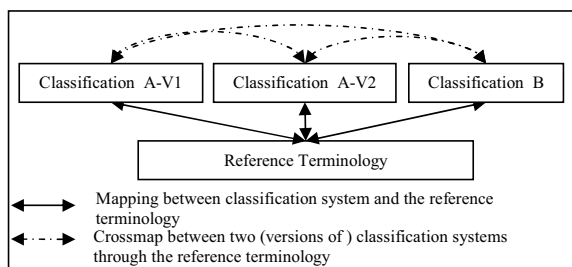


Figure 1- Using a reference terminology to identifying crossmaps between different (versions) of classification systems

SNOMED CT is regarded as the most comprehensive reference terminology for coding clinical data. Our goal within this study was to evaluate the use of SNOMED CT as an intermediary to create an n-to-1 crossmap between the two IC specific classification systems, i.e. from APACHE IV to APACHE II. Firstly, we compared the SNOMED CT crossmap with a manual expert-based and a data-driven crossmap. Secondly, the influence of these cross-map strategies on the calculation of case-mix adjusted mortality risks for quality of care assessment was evaluated.

Materials and Methods

SNOMED CT

The January 2008 release of SNOMED CT, which was used in this study, contains 284,777 active medical concepts associated with 737,695 active terms and interrelated by 860,865 active hierarchical (i.e. IS-A relationships) and non-hierarchical (i.e. Attribute relationships) relationships. SNOMED CT is a compositional terminology, i.e. it supports post-coordination, the use of composite expressions of concepts to define and refine (new) concepts.

APACHE classification systems

The APACHE classification systems are used to code the reasons for IC admission, one of the predictor variables in the APACHE prognostic models [6]. The APACHE II reasons for IC admission classification system is used in the APACHE II prognostic model and contains 54 diagnostic categories, each classified as nonoperative or postoperative, next by body system (e.g. cardiovascular disorder) and then by diagnosis (e.g. sepsis). The APACHE IV reasons for IC admission classification system is used in the APACHE IV prognostic model and contains 445 diagnostic categories, each classified as nonoperative or postoperative, next by body system (e.g. cardiovascular disorder) or a transplant or trauma-related category, and then by diagnosis (e.g. gastrointestinal sepsis). A residual "other" category is used in both classification systems for unlisted diagnoses within the main category (e.g. other

listed diagnoses within the main category (e.g. other cardiovascular disorder).

Data

In 1996 the Dutch National Intensive Care Evaluation (NICE) foundation started collecting data on patients admitted to Dutch intensive care units (ICU) in order to monitor and improve the quality of care provided by the participating ICUs. For each ICU admission, the responsible intensivist or IC nurse collects the demographic, physiological and diagnostic variables required among others to calculate mortality predictions according to the APACHE II and IV prognostic models.

Since 2007, the APACHE IV variables can be recorded voluntarily and since 2008 all participants are obliged to record the APACHE IV reasons for ICU admission in addition to the APACHE II reasons for admission, which is recorded since 1996.

This study used a dataset from the NICE registry with data on all patients admitted to the Dutch ICUs between January 1, 2007 and July 1, 2009 for whom the APACHE II and IV variables were collected and who satisfied the inclusion criteria (e.g. excluding burns and re-admissions) of both the APACHE II and the APACHE IV prognostic models.

Data-driven crossmap

In the NICE database, for each IC admission, the reasons for admission have to be collected both according to the APACHE II and APACHE IV reasons for IC admission classification systems. To create the data-driven crossmap, a cross table was created with the APACHE IV categories against the APACHE II categories from the NICE database.

Expert-based crossmap

We used an expert-based crossmap that had been created for the NICE registry. Two intensivists, both experienced in the APACHE II and APACHE IV classification systems, independently mapped each APACHE IV category to exactly one related APACHE II category. The final map was based on consensus between the two intensivists.

SNOMED CT crossmap

As part of a larger study, we first created a manual mapping from the APACHE II and APACHE IV categories to SNOMED CT concepts (Figure 2 I). Each APACHE category was aligned with one or more SNOMED CT concepts. The categories were first matched to pre-coordinated concepts. In case no pre-coordinated match was available, a post-coordinated match was searched for. Concepts that did not exist in SNOMED CT were eventually matched to the appropriate superordinates [10]. To generate the crossmap between the APACHE IV and the APACHE II classification system, for each SNOMED CT concept that did not directly map to a APACHE II or IV category, first the closest superordinate with a pre-coordinated APACHE II mapping and the closest superordinate with a pre-coordinated APACHE IV mapping was identified (Figure 2 II).

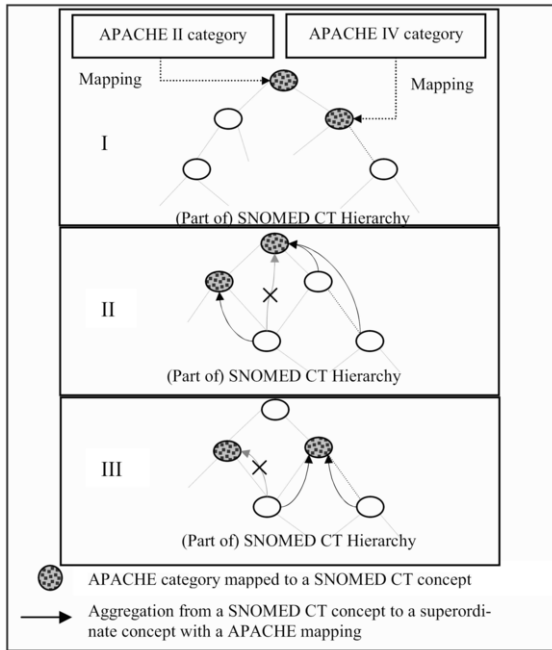


Figure 2-1: Mapping from APACHE categories to SNOMED CT concepts, I: Aggregation from a SNOMED CT concept to the closest superordinate with a pre-coordinated APACHE mapping, III: Aggregation from a SNOMED CT concept to the closest superordinate that results in highest mortality risk.

In case of multiple matches, the superordinate with a pre-coordinated APACHE II or APACHE IV mapping that resulted in the highest predicted mortality was selected in order to achieve a unique match (Figure 2 III). Next, the matched SNOMED CT conceptIDs from the previous step were used to generate a cross table with the APACHE IV categories against the APACHE II categories to identify the crossmap. Table 1 provides an example of such a crossmap through SNOMED CT.

Table 1 – An example of a crossmap between APACHE IV and APACHE II categories through SNOMED CT

| SNOMED CT concept | APACHE II category | APACHE IV category |
|---------------------|--------------------|--------------------|
| Urosepsis 371093006 | Sepsis | Urosepsis |

Analysis

Comparison of the mapping strategy

The SNOMED CT crossmap was compared to the expert-based manual crossmap and the data-driven crossmap. To this end, for each APACHE IV category, the matched APACHE II categories were identified according to the three crossmap strategies.

Influence of the crossmap strategy on the outcome

To evaluate the influence of the crossmap strategy on the mortality risk predictions, for all included admissions from the NICE database, an APACHE II predicted mortality was calculated based on the APACHE II categories from the NICE database and the APACHE II categories derived from the expert-based mapping and the SNOMED CT mapping. The predicted mortality risks were then compared for the three crossmap strategies. To this end, mortality risks were expressed as mean ±SD. T-test statistics was used for the comparison and a p-value of 0.05 was defined as statically significant.

Results

Data

From January 1st 2007 to July 1st 2009, 41,211 patients were recorded in the NICE registry who met the general inclusion criteria for the APACHE II and APACHE IV model and for whom an APACHE II and an APACHE IV reason for admission were recorded.

Not all APACHE IV categories occur frequently in the Dutch ICUs. Therefore, although for all APACHE IV categories a crossmap was developed, in here we will analyze and discuss the results for the most frequently occurring pre-coordinated postoperative and non-operative categories in each body system, transplant- or trauma-related class.

Comparison of the crossmap strategies

Table 2 provides the results of the three crossmap strategies. For some APACHE IV categories more than 1 match was available in the data-driven crossmap and SNOMED CT crossmap (i.e. expressed in “Number of different APACHE II matches”). For 10 APACHE IV categories, the three crossmap strategies resulted in the same APACHE II categories. In case of disagreement, generally, there was an overlap between the SNOMED CT matches and the matches provided by the two other strategies. An exception was the APACHE IV category “Genitourinary surgery”, which was matched to APACHE II category “Renal surgery” in the SNOMED CT crossmap and to “Cardiovascular surgery” in the other crossmap strategies.

Influence of crossmap strategy on predicted mortalities

The mean (±SD) predicted mortality risk was 0.158 (0.18) for the data-driven crossmap, 0.154 (0.18) for the expert-based crossmap, and 0.158 (0.17) for the SNOMED CT crossmap. For categories where more than 1 match was available, the predicted mortalities represent a weighted average score based on the different matches as shown in Table 2. No significant differences were found in the predicted mortalities for the three crossmap strategies.

Discussion

To preserve the continuity of health care documentation and to avoid registration inefficiency, e.g. double registration, a crossmap between successive versions of classification systems is necessary.

Table 2 – * indicates $\geq 80\%$. The APACHE II categories are: CD: Cardiovascular disorder, CS: Cardiovascular surgery, DK: Diabetic ketoacidosis, DO: Drug overdose, GIB: Gastrointestinal bleeding, GID: Gastrointestinal disorder, HD: Hematological disorder, HT: Head trauma, KTRP: Kidney transplantation, MD: Metabolic disorder, MS: Metabolic surgery, MT: Multiple trauma, ND: Neurological disorder, PE: Pulmonary embolus, PVS: Peripheral vascular surgery, RD: Respiratory disorder, REND: Renal disorder, RENS: Renal surgery, RI: Respiratory infection, RIAS: Respiratory insufficiency after surgery, RS: Respiratory surgery, SCCD: Surgery for chronic cardiovascular disease, SEP: Sepsis, SGID: Surgery for GI disorder, SGIN: Surgery for GI neoplasm, SHD: Surgery for hematological disorder, SHS: Surgery for hemorrhagic shock, SND: Surgery for neurological disorder, SMT: Surgery for multiple trauma, TSN: Thoracic surgery for neoplasm, TRP: Transplant.

| APACHE IV main category | Most frequently occurring APACHE IV category | Number of cases in the NICE database | Data-driven | | Expert-based | SNOMED CT | | |
|-------------------------|----------------------------------------------|----------------------------------------------------------------|---------------------------------------|----------------------------------------------|------------------------------------------------------|---------------------------------------|----------------------------------------------|-----------------------------------------------------|
| | | | Number of different APACHE II matches | APACHE II category (occurrence % ($>5\%$)) | APACHE II category | Number of different APACHE II matches | APACHE II category (occurrence % ($>5\%$)) | |
| Non-operative | Cardiovascular | Vascular disorder | 122 | 15 | CD (*) | CD | 10 | CD (*) |
| | Gastro-intestinal | Upper GI bleeding | 574 | 9 | GIB (*) | GIB | 2 | GIB (*) |
| | Genitourinary | Acute renal failure | 214 | 11 | REND (*) | REND | 3 | REND (*) |
| | Hematology | Hematological disorder | 21 | 2 | HD (*) | HD | 4 | HD |
| | Metabolic | Diabetic ketoacidosis | 367 | 5 | DK (*) | DK | 1 | DK |
| | Musculoskeletal | Cellulitis and soft tissue infections | 47 | 8 | SEP (55) CD (13) MD (9) RD (9) | SEP | 7 | HT (24) RD (17) RI (17) GID (10) CD (7) |
| | Neurologic | Sedatives, hypnotics, antipsychotics, benzodiazepines overdose | 893 | 10 | DO (*) | DO | 2 | DO (*) |
| | Respiratory | Bacterial pneumonia | 715 | 20 | RI (*) | RI | 2 | PE (86) RI (14) |
| | Transplant | Kidney transplant | 5 | 3 | RD (60) CD (20) TRP (20) | CD | 1 | REND |
| | Trauma | Chest/thorax trauma | 238 | 12 | RD (61) MT (23) | MT | 7 | ND (41) CD (25) RD (22) |
| Post-operative | Cardiovascular | Abdominal aortic aneurysm | 2096 | 15 | PVS (76) CS (22) | PVS | 1 | CS (*) |
| | Gastro-intestinal | Gastrointestinal Surgery | 834 | 10 | SGID (70) SGIN (11) | SGID | 2 | SGID (*) |
| | Genitourinary | Genitourinary surgery | 374 | 17 | CS (43) SMT (19) RS (10) RIAS (7) SHS(6) | CS | 3 | RENS (*) |
| | Hematology | Hematological surgery | 8 | 2 | SCCD (75) SHS (25) | SHD | 1 | SHD (*) |
| | Metabolic | Thyroidectomy | 132 | 4 | MS (74) RS (16) CS (5) RIAS (5) | MS | 2 | SGID (50) RS (50) |
| | Musculoskeletal | Orthopedic surgery | 352 | 22 | CS (47) RS (12) SHS (6) MS (5) | CS | 6 | SGID (45) RS (31) SND (18) |
| | Neurologic | Neurological surgery | 215 | 8 | SND (*) | SND | 4 | SND (*) |
| | Respiratory | Respiratory surgery | 546 | 8 | RS (68) TSN (11) RIAS (9) | RS | 2 | RS (*) |
| | Transplant | Kidney transplantation | 92 | 1 | KTRP (*) | KTRP (*) | 1 | KTRP (*) |
| | Trauma | No pre-coordinated APACHE IV category | - | - | - | - | - | - |

Our goal within this study was to evaluate the use of SNOMED CT as an intermediary to create a crossmap between two versions of an IC-specific classification system, i.e. from APACHE IV to APACHE II. For 50% of the most frequently occurring APACHE IV categories, the three mapping strategies resulted in the same APACHE II categories. In other cases, there was an overlap between the SNOMED CT matches and the matches provided by one of the two other strategies. Differences in the crossmap results had however no significant influence on the predicted mortalities.

Although there are no differences in the outcome, the crossmap strategies do differ. This might have a large influence on e.g. selection of patient groups based on reason for IC admission. Each of the crossmap strategies has its own drawbacks. Data-driven crossmapping is highly dependent on the amount and the quality of the underlying data, and on the correct classification by clinicians. For rare clinical encounters, for instance, it is not possible to generate a reliable crossmap. Expert-based crossmapping is time consuming and labor intensive, especially for large classification systems. Furthermore, the reliability of the crossmap depends on the skills and knowledge of the experts. Automated tools might be used to assist this task, however, these tools are usually domain and language specific, and, if not available, costly to build. Besides, manual review is required to validate and complement the output of the automated crossmaps [11]. The SNOMED CT crossmap encloses the same problems as the Expert-based crossmapping, as first a (manual or automated) mapping needs to be created from the source classification systems to SNOMED CT. However, the advantage of using SNOMED CT crossmapping is that once the mapping is generated with the target classification system, it can be re-used to identify crossmaps to all other classification systems that are already aligned to SNOMED CT. E.g. for five classification systems, the use of SNOMED CT as intermediary requires the creation of 5 mappings from these target systems to SNOMED CT, possibly by shared effort, to create the 10 crossmaps. Otherwise, each classification system pair ($n=10$) needs to be crossmapped separately.

When crossmapping two versions of a classification system, an important issue is the relationship between their categories. In general, for the purpose of interoperability, a 1-to-1 crossmap is required. However, a 1-to-1 crossmap between two versions of a complex classification system might not be possible, as the two successor systems not only differ in the level of granularity, but also in the coding rules and structure. In these cases, a n-to-n mapping is generated which requires an additional decision to select the appropriate target links [11].

A key characteristic of classification systems is that they generally serve a specific purpose. DRG-like classification systems for instance are used to generate reimbursement overviews, while classification systems such as the ICD are used for generation of mortality and morbidity statistics [12]. Consequently, the same information is often recorded in multiple systems resulting in multiple registration. Although within this study we focus on the problem of version compatibility of a classification system, our results are also generalizable to set-

tings in which multiple classifications are used for different purposes. Also in these cases, SNOMED CT can serve as an intermediary to support the creation of crossmaps in order to preclude double registration [7]. However, to rule out registration inefficiency completely, clinical information should preferably be captured on a detailed level in daily practice using a reference terminology such as SNOMED CT which holds the promise to (retrospectively) aggregate clinical encounters compatible to different classification systems. Further research is needed to gain insight in the use of SNOMED CT for data collection to serve this purpose.

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