An interface terminology for medical imaging ordering purposes.

Nicolas GRIFFON, MD, MSc[1], Céline SAVOYE-COLLET, MD, PhD[2], Philippe MASSARI, MD[1], Christel DANIEL, MD, PhD[3,4] and Stéfan J. DARMONI, MD, PhD[1]
[1]CISMeF, Rouen University Hospital, Rouen, France & TIBS, LITIS EA 4108, Institute of Biomedical Research, Rouen, France; [2]Rouen University Hospital, Radiology Department, Rouen, France; [3]INSERM, UMR_S 872, Eq. 20, Paris, F-75006 France; [4]Université Paris Descartes, Paris, F-75006 France

Abstract

The need for structured data in electronic health records has not been fully addressed by reference terminologies (RT) due to difficulties of use for end-users. Interface terminologies (IT), built for specific usage and users, and linked to RT, may solve this issue. We propose an IT for medical imaging prescription, based on the French nomenclature for procedure (CCAM), and its qualitative evaluation. The creation and evaluation processes were adapted from published guidelines. Prescription IT is available on the web (http://pts.chu-rouen.fr). It contains 290 orderable terms linked to 249 CCAM codes. The synonymy of prescription IT is significantly richer than the CCAM one and labels are significantly shorter. The main problem came from the CCAM, which is dedicated to billing purposes. We are planning to map prescription IT to other international RT such as RadLex or SNOMED. Prescription IT might quicken the adoption of computerized ordering processes in France.

Introduction

There is a strong need for structured vocabulary and terminology in order for the computerization of health records to achieve its goals: increasing patient safety, reducing medical errors, improving efficiency and reducing costs[1]. Besides allowing computer reasoning, terminologies are of great interest in interoperability achievements[2]. Recent years have seen a multiplication of terminologies in health and medicine (one hundred and sixty health terminologies/ontologies are included in the Unified Medical Language System[3]). Some of these have reached the status of reference terminologies (RT) defined by Rosenbloom et al.[4] as "terminologies designed to provide exact and complete representations of a given domain's knowledge, including its entities and ideas, and their interrelationships, and are typically optimized to support the storage, retrieval, and classification of clinical data". RT completeness is a strength but also a weakness as it impedes use by end-users, and it does not preserve them from a lack of terms in specific areas of knowledge[1, 5]. The idea of interface terminologies (IT) or "a systematic collection of health care–related phrases (terms) that supports clinicians' entry of patient-related information into computer programs"[1] is emerging. IT are built for specific usages and users and mapped to RT: instead of using complex RT to code their Electronic Health Records (EHR), physicians may use an IT adapted to their language and restricted to accurate concepts for a dedicated task[1].

One particular use case of IT is computerized physician order entry (CPOE): Orderable drugs, tests and procedures are legion and terms referring to such orderables may be non-intuitive for users in classic RT, problems that an IT may resolve. Some work has already been carried out on drugs with RxTerm[6], an American prescription IT, but almost nothing has been done as regards medical imaging. It is possible to use RadLex, a terminology designed for imagery describing and indexing[6]. However, with regard to CPOE, RadLex Playbook does not yet cover the broad scope of imaging procedures that might be ordered by clinicians and is limited to scanner orderables[8]. This lack of shared prescription IT may be one cause of the time and cost of CPOE installation and configuration[9].

Prescription will soon be computerized at Rouen University Hospital (RUH) using McKesson solution: Horizon Expert Orders (HEO), leading us to replace prescription paper forms by CPOE using prescription IT. The lack of available solutions has forced us to build our own prescription IT.

The aims of this study are (1) to adapt the generic methodology proposed by Bahkshi-Raiez et al.[5] to the development of an IT for CPOE in the medical imaging domain and (2) to evaluate the quality of this IT using commonly accepted indicators for terminology evaluation[10, 11, 12, 13].

Method

Bakhshi-Raiez et al.[5] proposed a development process for interface terminology in 6 steps: (1) domain analysis, consisting in the identification of the relevant information for the IT, (2) mapping domain concept to RT concept,

(3) creating an RT subset, extracting all the concepts of interest for the IT from the RT, (4) extending the subset with local content, adapting the subset to its interface, (5) constraining the subset, filtering out the amount of concepts and relationships that are irrelevant and (6) deploying the subset in a terminology server. This method was adapted for our specific objectives: a prescription IT for medical imaging, using the “Classification Commune des Actes Médicaux” (CCAM, French nomenclature for procedures in its twenty-third version) as RT[14].

Domain analysis

Two days of paper prescription from the radiology department were collected (n=1,049). Two kinds of prescriptions currently exist at Rouen University Hospital: either free text or structured prescription, using a form. Both are of interest to employ the terms that are used by clinicians in real life to create (or maintain) prescription IT.

Mapping domain concept to RT concept

Every procedure performed at RUH has to be coded using CCAM for reimbursement purposes. This terminology is not easy to use: (1) it contains each medical procedure, not only those performed in medical imaging departments, (2) medical imaging procedures are dispersed among the whole hierarchy which contains 7,718 terms and (3) labels are rather long (mean = 11.7 words, 10.7 when restricting to imaging procedures) and differ only by a few words in some cases. To help radiologists and radiographers code their acts using CCAM, an execution IT has already been created and manually mapped to CCAM by radiologists. This execution IT was extracted from the Radiologic Information System (RIS). As an IT, the execution IT is adapted to radiologists’ and radiographers’ vocabulary, techniques and equipment and is easier than CCAM to use. Nevertheless, this execution IT is not adapted to physicians willing to prescribe one imaging procedure. Mapping was then manually performed between prescription IT and execution IT. Thus, by transitivity, a mapping was automatically created between prescription IT and CCAM (see Figure 1).

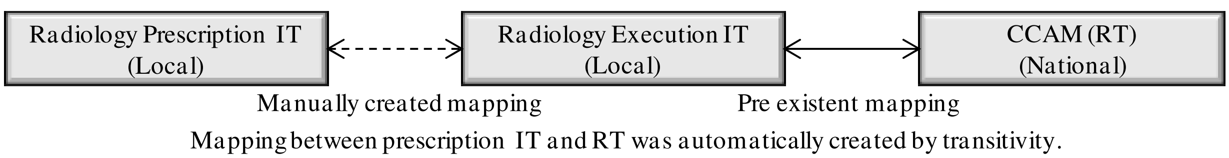

Figure 1. Links between terminologies

Creating an RT subset

As the main objective of this study was to build a prescription IT for medical imaging at RUH, CCAM was restricted to procedures that are actually performed at the medical imaging department of RUH, i.e. those included in execution IT.

Extending the subset with local content

One main principle in the creation of prescription IT is that this terminology describes imaging procedures at their finest level of granularity required for an ordering purpose i.e. a clinician must be able to order a CT-scan of the pelvis without contrast. Nevertheless, the main objective of IT is ease of use: a clinician certainly does not want to have to order four prescriptions if he wants a CT-scan of the abdomen and the pelvis with and without contrast: (1) CT-scan of the pelvis without contrast, (2) CT-scan of the pelvis with contrast, (3) CT-scan of the abdomen without contrast and (4) CT-scan of the abdomen with contrast. Consequently, some regular combinations of prescription at RUH (collected on paper prescription) have been introduced into prescription IT. However, such work may have to be carried out in every hospital according to clinicians’ habits.

Execution IT and CCAM were also used to enrich RUH prescription IT with more terms. Prescription terms were created to ensure that every CCAM procedure that is mapped to a term of execution IT was mapped to at least one term of prescription IT. A specific hierarchy was created for prescription IT. This hierarchy was six-level wide and separated medical imaging procedure first by exam type (CT-scan, magnetic resonance imaging (MRI), X-rays and ultrasonography, doppler) and second by anatomy (head, neck, chest etc). Other levels of granularity were allowed according to the uses of prescription IT: positioning, use of contrast agent etc.

Constraining the subset

Many of the terms of execution IT and CCAM have too much grain for the prescription process i.e. no clinician would prescribe a “third trimester routine ultrasonography for a multi-foetal pregnancy” but rather a “routine pregnancy ultrasonography", whether gadolinium should be used for MRI is, in France, a radiologist's expertise, etc. Those execution terms were not included in the prescription IT and gathered in the less specific prescription terms. More generally, non-pertinent prescription terms were deleted.

Deploying the subset in a terminology server

All terminologies considered here, as well as their relations, were stored in the RUH terminology server (URL: http://pts.chu-rouen.fr) [15]. The prescription IT was imported into the McKesson solution: HEO.

Validation-evaluation

The development process of a terminology involves an initial validation-evaluation step. A first validation was performed by a PhD radiologist (CSC) who reviewed hierarchy consistency and organization of the prescription IT.

For self-evaluation, this terminology has been compared to Cimino's desiderata[10, 11]. The first one[10] insists on terminology structure: content, concept orientation, concept permanence, non semantic concept identifier, polyhierarchy, formal definitions, reject "not elsewhere classified", multiple granularities, multiple consistent views, graceful evolution and recognition of redundancy. The second[11] is more about the purpose of terminology. It should support: (1) capturing what is known about the patient, (2) retrieval, (3) aggregation of data, (4) re-use of data, (5) inferencing and (6) storage, retrieval, and transfer of information with as little information loss as possible. These desiderata concern all terminologies, but there are also some specific criteria for IT as detailed by Rosenbloom et al.[12] and Daniel et al.[13]: mapping IT to RT, incorporating assertional knowledge, compositional balance, syntactic consistency, support for human readability, application independence and language independence.

Results

The prescription IT was built following the Bakhshi-Raiez methodology

Imaging procedures available at RUH are described by 249 CCAM codes dispersed among the 7,718 CCAM codes. The construction and validation process lead to a prescription IT of 290 orderable terms. The mean number of words per term is significantly lower for prescription IT than CCAM (respectively 3.6 $CI_{95\%}$ = [3.5-3.8] and 10.7 $CI_{95\%}$ = [10.0-11.5]; $p<10^{-4}$, t-test). The number of synonyms has almost doubled from 255 in the CCAM list of terms to 499 in prescription IT. There are significantly more synonyms per concept in prescription IT than for CCAM (respectively 1.72 and 1.02; $p<10^{-4}$, t-test).

Figure 1 shows the final flow of terminology: from prescription to execution IT through CCAM. Due to CCAM's limits, there is a need for more information than that available in CCAM to perform the right execution for a pr²escription (**A** arrow).

The prescription IT was evaluated using an evaluation framework for terminologies

The criteria for evaluation and their commentaries are summarized in Table 1.

Table 1. Evaluation of the prescription IT according to the selected criteria[10, 11, 12, 13].

Criteria	Commentary
Content	By construction, this prescription IT allows prescription of every procedure that is performed at RUH and has, therefore, a full coverage.
Concept orientation	Yes
Concept permanence	Yes
Non semantic concept identifier	The concept ID gathers information on the type of exam and the anatomical zone.
Formal definitions	The hierarchy supports the only formal definition available in the prescription IT: type of exam and anatomical zone.
Polyhierarchy	Yes

Table 1 (Continued)**.** Evaluation of the prescription IT according to the selected criteria[10, 11, 12, 13].

Reject "not elsewhere classified":	Yes
Multiple granularities	Yes. The provider may order a "CT-scan focused on the head with iv contrast" or just a "CT-scan focused on the head", letting the radiologist do as he wishes.
Multiple consistent views	The prescription IT structure – i.e. directed acyclic graph, allows the existence of multiple consistent views as defined by Cimino et al. [16].
Graceful evolution	Orderable exams are flagged and modifications and date of modification are stored. Motivations of changes are not recorded yet.
Recognition of redundancy	Nothing is done to recognize redundancy.
Support capturing what is known about the patient	Support capturing what is ordered for the patient. This kind of terminology may help radiologists and radiographers in indexing.
Support retrieval	As any kind of annotation prescription IT allow information retrieval (taking into account subsumption). Mapping to an RT also supports retrieval.
Support aggregation of data	Prescription IT hierarchy allows the aggregation of data by type of exam and anatomic zone, Mapping to an RT may allow aggregation of data.
Support reuse of data	Mainly because of mapping with RT, but with some improvements.
Support inferencing	This is not the purpose of an IT, but mapping to an RT may allow inferencing (unfortunately, CCAM does not).
Support storage, retrieval, and transfer of information with as little information loss as possible	For some concepts, RT is less granular than prescription IT, increasing the loss of information.
Mapping IT to RT	There is no terminology for procedures used internationally (most developed countries have created their national terminology, whereas the World Health Organization is currently working on that subject). CCAM lacks some functionalities.
Assertional knowledge	Some attributes enrich prescription IT: gender (e.g. prostatic exam), use of contrast agent, where the act is performed… Some additional information required for prescription is gathered in value set – laterality, for even numbered organs, and viewpoints, for radiography.
Balancing pre/post-coordination	Some complex and frequently ordered exams were pre-coordinated in prescription IT (e.g. CT-scan of thorax, abdomen and pelvis). As it would be counterproductive to create all the possible compositions, the clinician might have to order several exams (e.g. radiography of hands and feet).
Syntactic consistency	As much as possible, labels were structured (first the type of exam, second the anatomical zone and last other elements) and the same terms were spelled likewise.
Support for human readability	Polyhierarchy, multiple granularities and synonymy enhanced human readability.
Application independence	HEO forced the use of an eight character code, but there is no restriction on terms or hierarchies
Language independence	Prescription IT is not independent of French language

Discussion

The prescription IT described here is currently available on the RUH terminology server[15] and will soon be in use at RUH clinical information system. By providing clinicians with a rich synonymy, prescription IT may ease the computerized ordering process and therefore enhance the acceptance of CPOE at RUH.

Mapping with an RT is the real strength of IT. This allows all the functions supported by RT, such as inferencing, re-use of data and limiting information loss, at less cost for clinicians. Even better, in some cases, IT to RT mapping improves RT functionalities, here, prescription IT:

1. Eases patient data capture,
2. Eases information retrieval, since requesting with natural language terms allow the retrieval of RT indexed resources and,
3. Allows some new ways to aggregate data.

Creating or enriching IT by using RT concepts as a starting point (assembling clinically meaningful compositions, appropriate synonyms and linkage between concepts (related concepts or modifiers)) is a labor-intensive approach. The use of an existing IT, as proposed here, may be an efficient way to enhance this process. In addition, for the building of a prescription IT, using this approach of linking every prescription IT concept to a concept of an execution IT (itself linked to an RT concept) guarantees 100% coverage of the prescription IT by the RT. This 100% coverage should be compared to the 92.4% of correct mappings found between MEDCIN and SNOMED CT or the 95.9% between CHISL and SNOMED CT[4].

The impact of the flaws revealed by evaluation is limited: (1) the concept identifier contains semantic information – type of exam and anatomy, nevertheless, a change in concept that would falsify such information must be a new concept. (2) Nothing has been done to recognize redundancy. However, the poor compositionality of the prescription IT limits the redundancy problem. (3) Some functionalities are not supported by prescription IT, but, as discussed above, these functionalities depend on RT, not on prescription IT. (4) Pprescription IT is only available in French. The first aim of an IT is to be adapted to clinicians' words and habits, which depends mostly on language. Moreover, it is not known if such terminology may be shared at a supra-institutional level. Thus, language independence does not seem to be the most important Chute's criteria[17] to complete for IT. (5) Mechanisms of evolution do not allow understanding of the changes made to the prescription IT. This will be added soon. (6) Syntactic consistency must be checked by further evaluation. As the preferred term for one concept should be the most natural for clinicians, it was not always feasible or reasonable to follow the rules expressed in Table 1.

Possibly the most important limit of this work is the choice of CCAM as an RT. CCAM is indeed the RT for procedures in France but it is at the intersection between RT, administrative terminology and execution terminology. It has several implications:

1. It has led to an important loss of information at the RT step in the terminology flow (as shown by Kanter et al.[2]).
2. Some of the reuse function of terminologies (as listed by Cimino[11]), such as aggregation of data or inferencing, are difficult with this terminology and therefore, with prescription IT.

One way to avoid (1) loss of information and (2) loss of function is to work on a more granular and structured terminology. Systematized Nomenclature of Medicine 3.5 VF[18], the rights of which were recently bought by France, or RadLex[7], which is freely available, would probably be a better RT between interface terminologies. Unfortunately these terminologies are not as routinely used as CCAM (which is mandatory). Consequently, using another RT would complicate the integration process of prescription IT for interested institution: it would necessitate also the integration of this new RT and mapping any existing execution IT to this RT. In a second step however, mapping prescription IT to another RT would less impede integration: as prescription IT and execution IT are already linked by CCAM, execution IT to RT mapping could be automatically created by transitivity. All the evolved functionalities of RT would then be available.

Even if the RUH terminology server[15] can store and display terminologies/ontologies and their mappings, this tool is not yet adapted to the creation or maintenance of terminology and even less to the creation or maintenance of terminology flow. To our knowledge, such a tool does not exist. It is important to provide terminology developers with terminology services that allow them to manage terminology flow. The TerSan project funded by the French National Agency has this objective for the 2012-4 period.

The crude evaluation part of this study was necessary to allow us to use this terminology for ordering purposes in the new CPOE system at RUH. The production shift that will soon arrive will allow us to make an *in vivo* evaluation and to address the following questions:

1. Do clinicians find what they want to prescribe easily? The practical counterpart of Rosenbloom et al.[12] theoretical "support for human readability".
2. Does the terminology contain every possible prescription? Using prescription forms theoretically leads to good coverage of possible prescriptions by prescription IT. However, if the set used (two days of prescription) is sufficient enough for frequent prescription, such as chest radiography, it may be too limited for rare prescriptions, such as sialography.

Current prescription IT is limited to RUH orderables. This means that some medical imaging procedures that are performed elsewhere are not introduced into this prescription IT. The next step is, as part of the TerSan project, to enrich this prescription IT with those medical imaging procedures to achieve national normalized prescription IT. This should enhance the reusability of this prescription IT, allowing every French(-speaking) hospital to use it[19]. The few constraints from HEO barely impede portability into this new information system. However, some work will always be necessary: choosing the right level of granularity, limiting prescription to exams actually performed in the institution, possibly creating new terms for local specificity… Whether it would take less time and effort than starting from nothing will be studied during the TerSan project. Such normalized prescription IT may ease the adoption of computerized ordering processes that is far from accomplishment in France[20] or in the USA[21, 22].

Conclusion

The prescription IT described here is currently available on the RUH terminology server[15]. It may enhance the adoption of computerized ordering processes in France.

We are grateful to Nikki Sabourin, Rouen University Hospital, for writing assistance and review of the manuscript in English.

Acknowledgments

This work was partially funded by the TerSan project (ANR TecSan program n°ANR-11-TECS-019-03).

References

1. Rosenbloom ST, Miller RA, Johnson KB, Elkin PL, Brown SH. Interface terminologies: facilitating direct entry of clinical data into electronic health record systems. J Am Med Inform Assoc 2006;13:277-88.
2. Kanter AS, Wang AY, Masarie FE, Naeymi-Rad F, Safran C. Interface terminologies: bridging the gap between theory and reality for Africa. Stud Health Technol Inform 2008;136:27-32.
3. UMLS Source Release Documentation. http://www.nlm.nih.gov/research/umls/sourcereleasedocs Accessed 13 february 2012.
4. Rosenbloom ST, Brown SH, Froehling D, Bauer BA, Wahner-Roedler DL, Gregg WM, Elkin PL. Using SNOMED CT to represent two interface terminologies. J Am Med Inform Assoc 2009;16:81-8.
5. Bakhshi-Raiez F, Ahmadian L, Cornet R, de Jonge E, de Keizer NF. Construction of an interface terminology on SNOMED CT. Generic approach and its application in intensive care. Methods Inf Med 2010;49(4):349-59.
6. Fung KW, McDonald C, Bray BE. RxTerms – a drug interface terminology derived from RxNorm. AMIA Annu Symp Proc 2008;227-31.
7. Langlotz CP. RadLex: a new method for indexing online educational materials. Radiographics 2006;26(6):1595-7.
8. RadLex Playbook. http://rsna.org/RadLex_Playbook.aspx Accessed 5 march 2012.
9. Payne TH, Hoey PJ, Nichol P, Lovis C. Preparation and use of preconstructed orders, order sets, and order menus in a computerized provider order entry system. J Am Med Inform Assoc 2003;10(4):322-9.
10. Cimino JJ. Desiderata for controlled medical vocabularies in the twenty-first century. Methods Inf Med 1998;37:394-403.
11. Cimino JJ. In defense of the Desiderata. J Biomed Inform 2006;39:299-306.
12. Rosenbloom ST, Miller RA, Johnson KB, Elkin PL, Brown SH: A model for evaluating interface terminologies. JAMIA 2008;15:65-76.
13. Daniel C, Buemi A, Mazuel L, Ouagne D, Charlet J. Functional requirements of terminology services for coupling interface terminologies to reference terminologies. Stud Health Technol Inform 2009;150:205-09.

14. Trombert-Paviot B, Rector A, Baud R, Zanstra P, Martin C, van der Haring E, Clavel L, Rodrigues JM. The development of CCAM: the new French coding system of clinical procedures. HIM J. 2003;31(1):1-11.
15. Grosjean J, Merabti T, Dahamna B, Kergourlay I, Thirion B, Soualmia LF, Darmoni SJ. Health multi-terminology portal: a semantic added-value for patient safety. Stud Health Technol Inform 2011;166:129-38.
16. Cimino JJ, Hripcsak G, Johnson SB, Clayton PD. Designing an introspective, multipurpose, controlled medical vocabulary. Proc Annu Symp Comput Appl Med Care 1989;513-518.
17. Chute CG, Cohn SP, Campbell JR. A framework for comprehensive health terminology systems in the United States: development guidelines, criteria for selection, and public policy implications. J Am Med Inform Assoc 1998;5:503-10.
18. http://esante.gouv.fr/services/referentiels/interoperabilite/snomed-35vf [French] Accessed 5 march, 2012
19. Bobb AM, Payne TH, Gross PA. Viewpoint: controversies surrounding use of order sets for clinical decision support in computerized provider order entry. J Am Med Inform Assoc 2007;14:41-7.
20. Nicollet C. Prescription connectée, impact en biologie hospitalière. Spectra Biologie 2007;26:54-9.
21. Jha AK, DesRoches CM, Kralovec PD, Joshi MS. A progress report on electronic health records in U.S. hospitals. Health Aff (Millwood) 2010;29:1951-7.
22. Jha AK, DesRoches CM, Campbell EG, Donelan K, Rao SR, Ferris TG, Shields A, Rosenbaum S, Blumenthal D Use of electronic health records in U.S. hospitals. N Engl J Med 2009;360:1628-38.