LOINC in Prehospital Emergency Medicine in Germany – Experience of the `DIRK’-Project

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1. Introduction

1.1 Electronic Documentation in Pre-hospital Emergency Medicine

Pre-hospital emergency care has noticeably shifted towards innovative technologies and procedures [1–6]. Electronic pre-hospital emergency medicine patient care systems (e-PEM-PCR) in particular have greatly improved and gained considerable attention and adoption [7].

Despite the fact that 90% of documentation in emergency medicine in Germany was still recorded on paper in 2010, the change towards telecommunication and electronic documentation devices is apparent: 78% of the directors of the regional rescue districts in Germany are planning the acquisition of electronic documentation devices (5). As of 2006, almost half of the states in the USA collect their emergency medical services (EMS) data electronically [7].

The following problems concerning e-PCRs exist both in the United States and Germany: Although electronic documentation is possible, integrating the data into a hospital information system is difficult due to technical barriers such as lack of interfaces as well as gaps in mobile broadband coverage and organizational issues [7].

1.2 Electronic Communication between Rescue Service and Clinic

Studies conducted on stroke unit patients clearly show the importance and advantage of digital data transfer ahead of arrival of the patient at the clinic. The inner clinical processes are being accelerated to increase the number of patients benefitting from thrombolytic therapy [6]. Although this project called “stroke angel” has been extended to other clinical cases such as “trauma angel” or “cardio angel”, it is restricted to disease-specific parameters and special participating hospitals. We would like to expand this positive effect to the entire field of pre-hospital emergency medicine.

1.3 Kind of Data to be Transferred

The German Interdisciplinary Association of Intensive Care and Rescue Medicine es-
tablished a nationwide uniform core data-set for pre-hospital reporting, called MIND (German: Minimales Notfalldaten-satz) [8]. There is a roughly comparable standardized data dictionary in the United States developed by National EMS Information System (NEMSIS) to represent key data fields regarding the rescue service [9]. However, the electronic transfer of these data sets and integration into the health information system (HIS) is not the main focus of NEMSIS. It rather focuses on the introduction of electronic documentation in emergency services and creating a national database.

1.4 Project DIRK

The aim of the project 'Data integration from the Rescue service to the Clinic' (DIRK) is to develop a generic communication model to enable a digital data transfer of all relevant rescue specific parameters to the receiving clinic. Since this system should not just be a theoretical model but be applied in the field, the work implies legal aspects such as data confidentiality and authorization, software generation to facilitate the data transition into the HIS, as well as the creation of a syntactic and semantic standard. We aim to transfer the data with Health level 7 version 2 (HL7 v.2) as it is the most widely used syntactic communication standard used in Germany. In the long run, we intend to use Clinical Document Architecture (CDA), to keep up with the next software generation.

The first step when thinking about creating a model for digital data transfer to institutions within the health care environment would be forming a semantic standard for the MIND protocols. For this purpose we contemplated already existing terminologies with the following fundamentals: Standards should be supported by HL7; they should be accepted internationally, be free of charge, be easily obtainable and be continually maintained and updated. We are not able to use the widespread international Systematized Nomenclature Of Medicine Clinical Terms (SNOMED CT), since Germany has no nationwide license. Logical Observation Identifiers Names and Codes (LOINC) [10–12] is an international standard developed for identifying laboratory and clinical observations and seems to be the most suitable terminology to map the MIND protocols.

The LOINC codes are not intended to be used by emergency personnel directly. They keep using the MIND data-set that they are familiar with. Using our mapping we can assign the appropriate LOINC code to all items entered for subsequent data transfer and analysis. In practice, the mapping will be done in either data-entry devices or after digitizing the handwritten protocol. Therefore, there is no increased time demand during rescue operations.

Arbitrary hospital information systems will not be able to interpret the LOINC-values out of the box. They can however be configured to do so by mapping the LOINC codes to their internal data structure (parameterization). This mapping is a common requirement for every new set of patient data to be transferred from or to a hospital information system. In order to enable data transfer from all rescue services to all the hospitals they transport patients to, one would have to repeat this process in every hospital for every rescue service. Since rescue services transport patients to a variety of hospitals, this number is potentially infinite. Establishing a nationwide standard reduces the parameterization to one data-set to be implemented in every hospital or rescue service and thus insures interoperability.

2. Objectives

Objective of this paper is to test the suitability of the international nomenclature Logical Observation Identifiers Names and Codes (LOINC) to encode the rescue service protocols MIND 2 and MIND 3. Furthermore encoding diagnosis and medication categories using ICD-10 and ATC are assessed.

3. Methods

We performed a study of semantic mapping of MIND protocols to LOINC, ICD-10 and ATC. MIND protocols contain a core set of parameters essential for documentation in rescue services. We mapped the upgraded versions namely MIND 2 (2003) [14] and MIND 3 (2011) [15] since they are currently in use in Germany.

First, the protocols of MIND 2 and MIND 3 were merged and broken down into their individual concepts. Identical concepts in both protocols only needed to be mapped once. All concepts were counted, translated and assigned to 10 categories with the following headings: technical data, time schedule, patient data and first assessment, diagnosis, injuries, scores, resuscitation analysis, procedures, handling over and relevant specific information of rescue operation. Then the individual concepts needed to be mapped to LOINC.

After initial testing with Regenstrief LOINC Mapping Assistant (RELMA) we found manual mapping far superior. Hence, we manually mapped concepts to LOINC version 2.38 using the provided search tool [16].

MIND 2 consists of 126 and MIND 3 of 88 concepts, resulting in 214 parameters needed to be mapped to LOINC. Of those 214 parameters, 61 were identical thus only 153 concepts remain.

We did not map structural data or the project ID because they do not contain any relevant information for the admitting hospital regarding the incoming patient. Although Object Identifiers (OID) are not a part of Health Level 7 (HL7), they will be used to encode structural data within HL7 messages at a later stage.

LOINC is too inapt to map the concepts of the disease and the medication section. Thus we considered alternative classification systems and agreed on the following: 57 diseases have been mapped to the International Statistical Classification of Diseases and Related Health Problems (ICD-10) [17] and 134 active ingredients of the medication to Anatomical Therapeutic Chemical Classification System (ATC) [18].

The mapping was done by two independent researchers: one with a medical background; the other with experience in pre-hospital emergency and medical informatics. In case of discrepancies a physician with IT background was consulted to reach a consensus.

We assessed the percentage of ’mappable’ concepts. Either the parameters could be mapped ("Can be mapped") or mapping was not possible ("Can not be mapped"). The results of the LOINC mapping are displayed in the 10 categories mentioned above.
4. Results

In total 153 concepts were mapped to LOINC, 57 diseases to ICD-10 and 134 active ingredients were mapped to ATC resulting in 344 concepts.

The mappings of researcher 1 and 2 differed for 8 (2%) concepts. The conflicts were resolved by the expert physician.

Of the 153 translated concepts 60 items (39%) could be adequately mapped to existing LOINC codes, 21 (14%) of them were introduced by NEMSIS. For 93 (61%) parameters there was no suitable match in LOINC (Table 1).

Twenty-six concepts (46%) of the disease category could be mapped to ICD-10 codes (Table 1). Six (11%) items could not be mapped because the parameters consisted of several diseases, which the personnel of the rescue services could not distinguish by their symptoms. ICD-10 requires a higher granularity.

The medication category was mapped with a success rate of 81% (108 items) to ATC codes (Table 1). Difficulties occurred due to unspecific pharmaceutical classification groups for example “other anesthetic”. The item “atropine” for treating bradycardia could not be matched to an ATC code.

In total 194 of 344 (56%) concepts of the protocols could be mapped with LOINC, ICD-10 and ATC combined.

5. Discussion

Since the MIND protocols contain a minimum set of data required for quality assurance and research work – one of the major aspects we want to improve with the DIRK project – we can not omit parameters. The entire protocols with all clinically relevant parameters need to be covered by international terminologies.

5.1 Method Discussion

LOINC, primarily developed by the Regenstrief Institute in Indianapolis, contains more than 60,000 items, for identifying laboratory and clinical observations. It consists of the following 6 axes: component, kind of property, time aspect, system, type of scale and type of method. Many LOINC terms are being integrated into SNOMED CT. Furthermore 172 items, specifically designed for emergency services, were introduced to LOINC by NEMSIS since version 2.38. We could cover 14% of the protocol due to NEMSIS input, however the NEMSIS entered LOINC codes are still on trial and thus subject to change. Hence, LOINC seemed an obvious choice to encode MIND protocols.

We chose ICD-10 to encode diagnoses, because it is the standard system for reimbursement in Germany and is used widely throughout publications. ATC was chosen, because it is continually updated by the World Health Organization (WHO).

In previous publications we had a higher granularity dividing the results into three groups. (“could not be mapped”, “mapping was possible”, “difficulties during mapping”). To achieve a more distinct result the mapping team needed to classify all items to either "mapping was possible" or "could not be mapped". This and the choice for a specific modeling approach lead to varying results. For instance, parameters can be modeled as either several dichotomous parameters (yes/no) or as a larger and more complex value set. We favoured the first. Our new approach with independent mapping by two researchers, only two choices and an enforced decision by a third, improves the validity of our results.

5.2 Analysis of the LOINC Mapping

Analyzing the parameters in respect to their "mappable" properties might help us understand and interpret the results obtained in this study:

We identified the following reasons contributing to an easy LOINC-mapping:

Table 1  Total results of mapping MIND 2 and MIND 3 to LOINC, ICD-10 and ATC

<table>
<thead>
<tr>
<th>Used coding system</th>
<th>Number of concepts</th>
<th>Number of concepts mapped</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOINC</td>
<td>153</td>
<td>60</td>
<td>39%</td>
</tr>
<tr>
<td>ICD-10</td>
<td>57</td>
<td>26</td>
<td>46%</td>
</tr>
<tr>
<td>ATC</td>
<td>134</td>
<td>108</td>
<td>81%</td>
</tr>
<tr>
<td>Total</td>
<td>344</td>
<td>194</td>
<td>56%</td>
</tr>
</tbody>
</table>

Remark: Of the 60 LOINC codes, 21 codes were entered by NEMSIS and are still on trial.

Table 2  Results of mapping the parameters of the MIND 2 and MIND 3 protocols to LOINC, subdivided into ten categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of concepts</th>
<th>Number of concepts mapped</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Technical data</td>
<td>20</td>
<td>2</td>
<td>10%</td>
</tr>
<tr>
<td>2. Time schedule</td>
<td>18</td>
<td>13</td>
<td>72%</td>
</tr>
<tr>
<td>3. Patient data and first assessment</td>
<td>22</td>
<td>13</td>
<td>59%</td>
</tr>
<tr>
<td>4. Diagnosis</td>
<td>10</td>
<td>5</td>
<td>50%</td>
</tr>
<tr>
<td>5. Injuries</td>
<td>6</td>
<td>3</td>
<td>50%</td>
</tr>
<tr>
<td>6. Scores</td>
<td>7</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>7. Resuscitation</td>
<td>16</td>
<td>4</td>
<td>25%</td>
</tr>
<tr>
<td>8. Procedures</td>
<td>32</td>
<td>9</td>
<td>28%</td>
</tr>
<tr>
<td>9. Handing over</td>
<td>14</td>
<td>10</td>
<td>71%</td>
</tr>
<tr>
<td>10. Relevant specific information of rescue operation</td>
<td>8</td>
<td>1</td>
<td>13%</td>
</tr>
<tr>
<td>Total</td>
<td>153</td>
<td>60</td>
<td>39%</td>
</tr>
</tbody>
</table>
The concept in question falls into the domain of LOINC, which was designed for laboratory and clinical observations. (For example vital parameters)

The concept is commonly used in another field of medicine, like general patient assessment [19] or cardiology scores [20].

The concept was introduced by a project covering the same domain – in our case the NEMSIS project [9, 21] (for example time schedules and medical findings).

When mapping concepts with the following criteria we encountered problems:

- The concept is country or system specific without counterparts introduced to LOINC. For example there are emergency physicians routinely deployed in Germany with special permissions and assignments.
- The concept is specific to country or system with a similar counterpart in other countries. For instance, Germany has different educational levels for paramedics resulting in distinct competences and permissions. These differ from the LOINC code 'Crew member levels' introduced by NEMSIS (71580-5.)
- The concept does not have the characteristics displayed by the six axes of LOINC. (For example procedures) Often, only the result of the procedure or the device with which the procedure was conducted can be observed and encoded. For example, the procedure "intubation" could only be mapped to the LOINC name by "Airway device placement confirmation" (LOINC: 71576-3). Either we disregard the impreciseness and apply and use LOINC codes for the results of procedures or we use an entirely different coding system. However we could not find a suitable terminology.
- The granularity was either too fine or too coarse. This problem was also described in other studies [20, 24, 27, 28]. For example, the LOINC code 67548 displays "patient disposition" with its value set including reasons for an aborted rescue operation, possible treatment and whether transportation had taken place. The MIND protocols require separate LOINC codes with a more detailed value set for each of these three aspects due to different financial and legal consequences.

5.3 Analyzing the Mapping to ICD-10

While mapping diseases to ICD-10 we encountered the following rescue-specific problems: Several diseases that could not be distinguished by their symptoms were listed as one item in the diagnosis category.

A case in point – transient cerebral ischemic attack, intracranial injury and cerebral infarction are pooled together, because differentiation of these diseases requires medical imaging. In many cases the rescue team could not pinpoint a definitive diagnosis, as needed by ICD-10. Hence, utilizing ICD-10 to encode the preliminary diagnosis is questionable. While contemplating alternative classification systems we could not find any standardized system that encodes a compilation of symptoms or observations.

As Lin et al. pointed out, narrative input restricts interoperability [22] and thus their usage should be limited. Our approach is to create a new LOINC code for a suspected diagnosis with a data set containing common diagnoses or observations, similar to "Chief complaint per dispatch" (67570-2). However, using narrative text codes cannot be avoided. An additional LOINC code needs to be requested for items not listed in the data set.

5.4 Analyzing the Mapping to ATC

The ATC coding system does not only comprise active ingredients, but also indications for treatment. This may be the reason why the usage of ATC in HIS is not dealt with widely in literature. However, we could cover a considerable part of the medication category with this classification. If an active ingredient is used for several different indications more than one code is applicable, thus the unambiguouslyness (bijective function) is being lost. Another issue that hindered complete coverage of the medication category was the existence of unspecific pharmaceutical classifications groups (for example "other anesthetics"). This problem could be solved by using ATC codes in the value of a single LOINC code "medication application" instead of in observation identifiers (entity attribute value model). The missing code for atropine treating bradycardia still needs to be applied for. Overall, ATC codes are adequate to cover the medication category and will be suitable for practical use.

5.5 Comparing Studies

Apart from NEMSIS, we could not find any publications about semantic standards with international terminologies for rescue protocols or about creating a syntactic and semantic standard for EMS. It seems yet unattempted.

Still, semantic coding with LOINC is frequently explored in literature. A good coverage of LOINC codes (93%) was shown by a German team analysing document types that occurred more than 10 times in 1.3 million documents in a HIS (24). As anticipated, studies reveal that LOINC is suitable to be mapped to radiology [23] and laboratory terms [22]. Three large institutions could show coverage for laboratory tests between 63% and 88% [22]. However, these institutions have been “intimately involved in LOINC development” and as a result have more local names that match to LOINC. Therefore it is not surprising that our initial coverage is much lower.

Furthermore, literature revealed that by establishing a successful model, different types of data such as patient assessments [25] or nursing assessments [26] could be displayed by LOINC. The project of mapping 569,073 nursing assessment concepts to the 3M Healthcare Data Dictionary showed a success rate of 92%. However, most of the data (52.5%) was mapped with "no standardized terminology representation" while 31.5% was mapped to LOINC codes and 15% to SNOMED CT. Both assessment papers concluded that LOINC is suitable to be mapped to assessment data. Since rescue protocols contain many assessment data items, using LOINC seems even more commendable.
In a Czech pilot study [20] to develop a framework for semantically interoperable HIS, the "Minimal Data Model of Cardiology" (MDMC) was mapped to SNOMED CT, LOINC and ICD-10. Although the coverage of the MDMC was high (85%), the LOINC coverage (28%) is roughly comparable to ours. Additionally they could cover 39% with SNOMED and 16% with ICD-10.

6. Conclusions

Although 39% of LOINC coverage seems to be a meagre result at first glance, mapping has shown that, in principle, the parameters of the rescue service protocol could be displayed by LOINC. Due to NEMESIS, EMS terms are already integrated into LOINC and present a basis on which we like to build. As the next step, we will request to add new LOINC codes to cover missing parameters. The efforts to gain a national license for SNOMED CT should be intensified because SNOMED CT and LOINC complement each other in a certain way. As Mc Donald so aptly described: LOINC provides the questions, other code systems such as SNOMED CT the answers [10].

Formulating a semantic standard is a key aspect in creating a digital system for data transfer to secure interoperability. Should our request for missing LOINC codes be granted, it would be a valuable step towards a generic semantic model connecting the pre-hospital emergency services to the rest of the healthcare environment. Hopefully, this will not only enhance quality assurance, billing and research, but also result in better treatment of patients in the long run.

Acknowledgments

This project is financially supported by a Research Grant of the University Medical Center Giessen and Marburg (UKGM).

Authors’ Contribution

BE: Data analysis for MIND 2, MIND 3, coding, drafted the manuscript; RWM: Study design, review; JA: Coding, review of the manuscript; MRS: Developed a tool to code data analysis; FS: coding; FB: conducted this study, review of the draft; ST, RR: conducted this study, study design, contributed data analysis, contributed to and reviewed the manuscript.

References