Comparing the Apgar Score Representation in HL7 and OpenEHR Formalisms

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Abstract. Semantic interoperability, a prerequisite to eHealth projects, relies on sharing both information and knowledge models between information systems. Two of the standards of information models are HL7 v3 and the European norm, EN13606/OpenEHR. The paper compares both standards on a fragment of the prenatal medical record, the Apgar score. Two factors are compared: the formal representation of both information models, and the binding to knowledge models. The HL7v3 perinatology DMIM specification and the OpenEHR Apgar archetype were used. HL7v3 appears to be more formal than OpenEHR and able to represent in an easier way the clinical context. For both standards, the binding to reference terminologies such as LOINC is poor. We provide recommendations to improve the standards.

Keywords. semantic interoperability, information model, health information system, HL7, OpenEHR

1. Introduction

The semantic interoperability of Health Information Systems (HISs) is a major prerequisite to eHealth projects. Semantic interoperability is mainly conditioned by two factors [1, 2]. The first factor corresponds to the formal representation of both information and knowledge models, on which HISs are built. For instance, concerning information model, the version 2 of HL7 standard has evolved to version 3, adopting class-object modeling. The same trend is also present for knowledge models with SNOMED-CT evolving toward a formal ontology thanks to the use of description logic. The second factor consists in the binding between the data elements defined in information models and terminologies and concepts defined in the knowledge models.

Several standards of Health Information Models are available nowadays for implementation by industrials [3]. Selecting the appropriate information model is the question. In this paper, we compare the representations of a fragment of the prenatal medical record (the Apgar score) in two relevant standards: the HL7v3 and EN13606/OpenEHR, in terms of the formalism of the information representation and the binding to knowledge models. This work is part of the feasibility project on a shared prenatal medical record in Brittany.

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2. Material and Method

The APGAR score [4] was designed to quickly evaluate the newborn’s physical condition after delivery. The test is usually evaluated 1 and 5 minutes after birth, occasionally ten minutes after birth. The APGAR score is based on five factors: muscle tone, heart rate, breathing rate, skin coloration and reflex, each factor being scored between 0 and 2. The APGAR score is equal to the sum of the five factors’ scores, 10 being for a healthy newborn and 0 for a newborn requiring emergency care.

The HL7 organization is aimed at developing international healthcare standards. The HL7v3 standard is based on a formal information model, the RIM (Reference Model Information). The RIM is first derived in domain-specific models called DMIM (Domain Message Information Model), from which are only extracted the classes required for the representation of the information (RMIM for Refined Message Information Model). HL7 is therefore a multi-model standard.

The OpenEHR framework is based on a two-level model: the reference model and the archetype model. The reference model (RM) is equivalent to the HL7 RIM. Even though it is specific to the medical domain, the RM remains quite general, being composed of four classes: COMPOSITION, SECTION, STRUCTURE and ENTRY. Clinical data are represented in the ENTRY class, composed of four sub-classes: OBSERVATION, EVALUATION, INSTRUCTION and ACTION. An archetype derives from one or more RM sub-classes. The archetype is composed of three main sections. Description is mainly textual, such as unique identification, version, objective of the archetype. Definition defines the attributes of the class (for the OBSERVATION class, data specifications such as temporality or allowed values). Ontology corresponds to the vocabulary used in the archetypes’ instances and includes the binding to terminologies. The formal language used to describe the archetypes is the Archetype Definition Language (ADL).

The two models of the APGAR score to be compared are, for OpenEHR, the APGAR archetype [5] and for HL7v3, the DMIM model from the prenatal model published by Goosen [6]. The comparison will be made on the data representation formalism and the binding to knowledge models.

3. Results

3.1. The APGAR Score Modelled by HL7v3

The APGAR score \([A_{APGAR\_score}]\) is derived (type_cd=DRV) \(\bullet\) from the ACT class \([x_{Apgar\_score}]\) (Figure 1). \([x_{Apgar\_score}]\) is composed of several attributes: class_cd=OBS indicates the score is an observation, mood_cd=EVN that each score is an event (measured at time T). The dotted line around the ACT class \([x_{Apgar\_score}]\) means the score can be measured at 1, 5 or 10 minutes after birth. The APGAR score is a component of the newborn file \([A\_Birth\_Data]\) through the relationship of type COMPOSITION \([A_{\_Has\_Apgar\_score}]\) \(\bullet\) with attribute type_cd=COMP. The \([X_{Apgar\_score}]\) class \(\bullet\) models the time series of events (a measure at time 1, 5 or 10) while the actual measured score is modelled by the \([A_{Apgar\_score}]\) class \(\bullet\). The \([A_{Apgar\_score}]\) class is composed of the five factors, all derived from specific classes s.a.\([A_{Heart\_Frequency\_score}]\). Each
class has additional attributes such as value. The APGAR score is stored in the [A_APGAR_score] class in which its mathematical derivation\(^6\) is expressed. Only the APGAR scores at 1, 5 and 10 minutes ([x_Apgar_score] class) are bound to their corresponding semantic concept in the LOINC terminology, (e.g., cd=9272-6 for [A_Apgar_score_1min]\(^7\)).

![Figure 1. HL7 modeling of the Apgar score within the prenatal medical record DMIM](image)

3.2. The APGAR Score Modelled by OpenEHR

The APGAR archetype derives from the OBSERVATION class \(^1\) under the Definition section (Figure 2). The APGAR score is described as a set of data recorded over time\(^2\), at specific identified POINT EVENT\(^3\). The score is measured at Point Time 1 Minute [PTM1]\(^8\). The set of data consists in a list \(^3\) of six ELEMENTs: the five factors and the APGAR score. Each factor is defined by a unique identifier within the archetype (e.g., [at0005] - heart rate\(^9\)) and a set of possible values\(^9\). The mathematical expression used to calculate the total APGAR score ([at0025] - total\(^10\)) is not provided. Each recording time (1, 2, 5 or 10 minutes) is represented independently to the others and refers to the data ELEMENTs defined in [PTM1] through internal addressing (use_node).

Under the Ontology section, the archetype contains the textual description and label of the data elements (section term_definitions) and their possible bindings to semantic concepts formally expressed in reference terminologies (section term_binding) (Figure 3). Only two bindings are reported in the APGAR archetype, both to the LOINC terminology (section terminologies_available): the APGAR score at 1 mn <[LNC205::9272-6]> and 10 mn <[LNC205::9271-8]>.
4. Discussion and Conclusion

**Information Model Formalism:** *Association to the medical context:* HL7v3 provides a formal and coherent representation of clinical data not achieved by the OpenEHR archetypes, even if the definition of attribute-value-pairs in HL7 is rather open. In the HL7 standard, a DMIM on prenatal medical record is derived from the RIM and the Apgar score is formally associated to the perinatality DMIM. In the OpenEHR standard, there is yet no archetype defined for prenatal domain and the Apgar archetype is not explicitly associated with the prenatal domain. Furthermore, the Apgar archetype is not associated to any other archetype while an archetype exists for “heart rate” but is not related or reused within the Apgar archetype.

*Data elements definition:* The HL7 representation expresses coherence between the data elements: indeed we read that the 5 factors are derived (*type_cd <= DRV*) from the [*A_Apgar_score*] class, and that the Apgar score is calculated by adding the scores of the 5 factors (*derivation_exp*). On the contrary, the Apgar archetype...
“lists” the five factors and the Apgar score with no hierarchy expressed and without providing any derivation expression.

**Semantics:** The data elements in the Apgar archetype contain an implicit semantic specific to perinatology. For instance, the factor “heart rate” can take one of three values provided (such as “no heart beat”). The HL7 representation does not provide this level of description, but only the minimal and maximal values allowed for each factor. On the contrary, the HL7 representation provides a contextual semantic as the Apgar score is attached to the prenatal medical record DMIM representation.

**Model derivation:** Both Apgar score representations are specific to the perinatology domain, either explicitly or implicitly whereas it could have been derived from a generalized modeling of “score”. This derivation function is however currently possible with the Common Message Element Type (CMET) for HL7 or through the definition of generalized archetype “score” for OpenEHR.

**Binding between Information and Knowledge Models:** The binding to terminologies is very poor for both standards. For both standards, only the Apgar score is bound to the LOINC terminology. Other terminologies, such as SNOMED CT, are available, some being in addition ontologies or knowledge models, allowing formal reasoning on the data elements. They are not used here.

The archetype structure includes an **Ontology** section, which according to us is not appropriately named. Indeed the **term_definitions** subsection only contains the interface vocabulary and the textual descriptions in different languages. No formal definitions of concepts are present in this section.

The present study compares the representation of a single fragment of a medical record with two standards. In another yet unpublished work, we analyzed all the six archetypes available for coding the Birth Certificate and found similar results regarding the data representation formalism. As of the binding rate to reference terminologies, only the APGAR archetype is linked to a terminology (LOINC).

Automatic reasoning in Health Information Systems, founded on semantic interoperability, implies formalising the information representation. This paper compares the Apgar score representation with HL7v3 and OpenEHR. We showed that the OpenEHR representation would be improved by stronger coherence and formalism and that both standards are poorly bound to reference terminologies. Both standards could be improved by increasing the binding rate of the data elements to more formal knowledge models. In addition, efforts on the standards formalism could be made by improving relationships between archetypes and their reuse, and for HL7 by more extendedly using abstraction elements (CMET) in the design of the DMIM.

**References**


