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# An Ontology for Healthcare Quality Indicators: Challenges for Semantic Interoperability

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**Abstract.** Semantic interoperability, a popular research area for electronic health records, can also be a challenge for quality indicators. We analysed attributes and relationships in a diverse set of over 200 healthcare quality indicators and created a searchable ontology. The ontology is intended to help reduce duplication of effort in healthcare quality monitoring. We describe issues with coding the indicators and specifying inclusion and exclusion criteria and propose some solutions.

**Key Words:** Quality Indicators, Health Care; Medical Records Systems, Computerized; Ontologies; Quality Assurance, Health Care

## Introduction

Healthcare quality indicators are often measured electronically, with the same type of information being written into separate queries for different indicators. An ontology, a specification of a representational vocabulary for a shared domain of discourse [1], can support semantic interoperability and automated quality monitoring by categorising and establishing relationships between concepts. An ontology can also be used to reduce duplication of effort in healthcare quality monitoring [2]. While health informatics research on semantic interoperability tends to focus on electronic health records (EHRs) [3, 4, 5, 6], our approach explores attributes of healthcare quality indicators.

We developed a pilot ontology that emphasises relationships between layers of inclusion and exclusion criteria for a large, diverse set of English healthcare quality indicators. The ontology has the potential to reduce duplication of effort to find data for indicator components and to link to EHRs through clinical codes. Unpredictable changes in the quality indicators, lack of previous ontology development experience, our level of medical knowledge and quality of available metadata about the indicators were some of the challenges to our research. We describe challenges with coding the indicators and specifying inclusion and exclusion criteria in this paper.

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## 1. Methods

### 1.1 *Methontology, Indicator Set and Development Platform*

Methontology was chosen as the method to develop a pilot ontology for a 2009 set of healthcare quality indicators made available on the English National Health Service Health and Social Care Information Centre (NHS HSCIC) website. The indicators, originating from different sources ranging from the UK Renal Registry to the NHS Quality and Outcomes Framework, are measures related to processes and outcomes. The NHS HSCIC identified each indicator with a mnemonic combination of letters and numbers. For example, QOF DM 7 represents the seventh indicator in the Quality and Outcomes Framework, intended to measure an aspect of care for Diabetes Mellitus.

We categorised the indicators by NHS Dimension [7], NHS-specified clinical pathway [7] and by United States Institute of Medicine purpose [8]. Relationships between indicators were identified, as well as an initial set of inclusion and exclusion criteria. Protégé, a freely available ontology development platform, was selected to create the ontology. Clinical codes were assigned to the concepts by one of the researchers with experience in conceptual classification.

## 2. Results

### 2.1 *The Ontology*

The pilot ontology currently has four classes (major concepts) of Indicators, Purpose, Clinical Pathway and Dimension. It has eighteen subclasses and a total of 39 slots and subslots (properties). Formula and Inclusion/Exclusion Criteria are examples of a slot and subslot for the class of Indicators. Along with being designated as classes, Purpose, Clinical Pathway and Dimension were also designated as slots, due to their being properties of indicators as well as major concepts. NHS quality indicators that share some of the same criteria were made searchable, along with broader and narrower related criteria. Up to six layers of inclusion and exclusion criteria were specified and incorporated into the ontology. Search capabilities were created for indicators originating from the same source and from more than one source, along with indicators assigned to specific care pathways. The major concepts and properties are described in a separate article [9].

### 2.2 *Evaluation*

Along with calculating baseline metrics, such as number of classes and slots, we developed competency questions to assess whether the ontology fulfils its purpose. We created six questions to determine whether we could search for indicators with common criteria, broader or narrower criteria, indicators containing a key word, indicator dimension/pathway, and indicator purpose. For example, the competency question, ‘Which of this set of NHS healthcare quality indicators have inclusion criteria containing a particular term or set of terms?’, can be answered by creating a query using key terms for the slot, `Inclusion_Criteria_Full`, for the Indicators class. To test this, we created a sample query showing common inclusion criteria for cardiac

infarction (STEMI) patients and for thrombolytic treatment. We also evaluated the ontology for consistency, conciseness, completeness, expandability, and sensitivity. The definitions for the slot of Formula and its subslot, Inclusion/Exclusion Criteria, are inconsistent, with Formula having a true definition and Inclusion/Exclusion Criteria having guidance for determining its metadata. Conciseness could be improved by removing the slots of Purpose, Dimension and Clinical Pathway, while keeping them as classes. While the ontology showed some weakness in these areas, the competency questions show that the ontology is worth further development. Stakeholder and expert feedback indicated that the ontology could be very useful, though it has some issues with conciseness in that it has some duplication and excessive properties.

### 3. Discussion

We created a searchable ontology for a large, diverse set of English NHS quality indicators. Poor interoperability between quality indicators and EHRs interferes with automated healthcare quality monitoring. Improved access to the quality indicators themselves, along with components of the indicators, may improve interoperability and data extraction. We assigned clinical codes to concepts in the indicators to support interoperability with EHRs. Granularity/choice of clinical codes and semantics of inclusion/exclusion criteria are two important considerations for interoperability.

#### 3.1 Clinical Codes

Assigning Clinical Codes to concepts within the indicators, gives the ontology the potential for some quality monitoring via EHRs. Data quality and availability has been criticised as a challenge for quality monitoring via EHRs [5,6]. Difficulties with clinical coding included lack of medical expertise, lack of UMLS expertise, duplicate concepts for codes from different sources in UMLS and the granularity of indicator text not always being at the same level as the text corresponding to the most relevant clinical code. For example, one indicator included the phrase: “or equivalent test/reference range depending on local laboratory”. Some ranges specified in indicators did not show as an option in UMLS, requiring general codes that result in the same coding for different indicators (for example, aged 53-70). Because UMLS contains clinical codes from many different coding systems, and the code selected was whichever code most closely matched the indicator concepts, rather than selected from only one system, some codes may not be compatible with electronic health records. Typographical errors, outdated codes and incorrectly coded quality indicators are other sources of errors in coding [10]. There is room for further research on clinical code compatibility with health care quality indicators.

#### 3.2 Inclusion/Exclusion Criteria

Our analysis emphasised relationships between layers of inclusion criteria, as few of the indicators specified exclusion criteria. Inclusion of more than one concept in a single layer could reduce reusability of formula components for indicator calculations. However, separating all concepts, without regard for interdependencies could increase the need to write queries to link concepts. If the concepts are already linked within the

ontology, query writing can focus on similar components of different indicators, rather than components within a single indicator; thus reducing duplication of effort required to find data for related indicators.

Dependent concepts were recorded at same level. For example, "the number of doctors washing their hands between seeing patients" shows a dependency between doctors and patients. "Access to scanning within 3 hours of admission" has two concepts that are recorded at same level because "within 3 hours of admission" must apply to scanning.

Semantics of indicator text also resulted in temporal issues being recorded inconsistently. Levels of Inclusion/Exclusion criteria were recorded differently in the following two indicators, due to the use of parenthesis in the second indicator:

QOF BP 4

- 1) patients with hypertension
- 2) in whom there is a record of the blood pressure
- 3) in the previous 9 months

QOF BP 5

- 1) patients with hypertension
- 2) in whom the last blood pressure (measured in the previous 9 months)
- 3) is 150/90 or less

The record of blood pressure in QOF BP 4 appears less dependant on the date of measurement than in QOF BP 5 because the date range of measurement does not appear in parenthesis. QOF BP 5 notes that the last measurement must have occurred within the previous 9 months, showing a greater dependency between the two concepts.

Boolean logic was inconsistently applied for layers of Inclusion/Exclusion criteria, when the term 'or' appeared between concepts, due to dependencies. For example, in Table 1, CV38 has one inclusion layer of Cardiac Rehabilitation Audit and one layer of exclusion criteria. However, QOF STROKE 12, in Table 2, has four layers of inclusion criteria with a separate layer for one OR statement, but not another because both terms on either side of the word 'or' are tied to the same concept for one statement. E.g., A side effect may also be a contraindication. The other statement shows two separate concepts on either side of the word 'or'. E.g., 'non-haemorrhagic is not the same as or similar to TIA.

CV38 Inclusion Criteria	1) Submission of 20 cases or more per month OR more than 70% case ascertainment.
CV38 Exclusion Criteria	1) Submission of less than 20 cases per month

Table 1. CV38

QOF STROKE 12 Inclusion Criteria	1) patients with a stroke
	2) shown to be non-haemorrhagic,
	3) or a history of TIA,
	4) who have a record that an anti-platelet agent (aspirin, clopidogrel, dipyridamole or a combination), or an anti-coagulant is being taken
QOF STROKE 12 Exclusion criteria	1) unless a contraindication or side effects are recorded

Table 2. QOF STROKE 12

Determining layers of inclusion criteria presented a challenge for some indicators with a Dimension of Patient Experience and for complex indicators with definitions for some criteria. Patient Experience indicators tend to use a scale rating system, rather than numerator and denominator. Some fractional indicators included defining criteria for components of the indicators. Incorporating definitions into layers of inclusion and exclusion criteria could be attempted by creating look-up tables.

#### 4. Conclusions

While monitoring for healthcare quality indicators is largely computerised in the English National Health Service, an ontology could reduce duplication of effort and facilitate research towards EHR interoperability. Further research on clinical code compatibility with health care quality indicators could benefit coding quality. Semantics of inclusion/exclusion criteria could be improved through consistent guidelines for indicator authoring or through guidelines written for metadata for quality indicators.

By analysing a diverse set of quality indicators, we have seen that not all indicators are fractional in nature. Some indicators we analysed were based on a ratings scale. It may be worth specifying whether an indicator is determined via a rating scale or fraction within ontologies for diverse healthcare quality indicators. Many of the fractional indicators were complex, involving definitions applicable to a portion of the indicator. Look-up tables for definitions could improve our ontology. This research could complement research on EHR interoperability by informing EHR standards for data availability and definition.

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