Quality assurance of biomedical ontologies (and derived artifacts) in the era of Meaningful Use of Electronic Health Records data

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OUTLINE

- Meaningful Use
- Standard vocabularies in Meaningful Use
- Value sets for clinical quality measures
- Quality assurance of biomedical terminologies
- Quality assurance of value sets
MEANINGFUL USE
“Meaningful Use”

◆ Health Information Technology for Economic and Clinical Health (HITECH) Act
  ● Eligible health care professionals and hospitals can qualify for Medicare and Medicaid incentive payments when they adopt certified EHR technology and use it to achieve specified objectives

◆ Two sets of regulations
  ● Incentive Program for Electronic Health Records
    Medicare and Medicaid Services (CMS)
  ● Standards and Certification Criteria for Electronic Health Records
    Office of the National Coordinator (ONC)
### Meaningful Use stages

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2011-2012</strong></td>
<td><strong>2014</strong></td>
<td><strong>2016</strong></td>
</tr>
<tr>
<td>Data capture and sharing</td>
<td>Advance clinical processes</td>
<td>Improved outcomes</td>
</tr>
</tbody>
</table>

#### Stage 1: Meaningful use criteria focus on:
- Electronically capturing health information in a standardized format
- Using that information to track key clinical conditions
- Communicating that information for care coordination processes
- Initiating the reporting of clinical quality measures and public health information
- Using information to engage patients and their families in their care

#### Stage 2: Meaningful use criteria focus on:
- More rigorous health information exchange (HIE)
- Increased requirements for e-prescribing and incorporating lab results
- Electronic transmission of patient care summaries across multiple settings
- More patient-controlled data

#### Stage 3: Meaningful use criteria focus on:
- Improving quality, safety, and efficiency, leading to improved health outcomes
- Decision support for national high-priority conditions
- Patient access to self-management tools
- Access to comprehensive patient data through patient-centered HIE
- Improving population health
CMS MEDICARE AND MEDICAID EHR INCENTIVE PROGRAMS: STAGE 2 FINAL RULE

On August 23, 2012, the Centers for Medicare & Medicaid Services (CMS) announced a final rule to govern Stage 2 of the Medicare and Medicaid Electronic Health Record (EHR) Incentive Programs. The rule specifies the Stage 2 criteria that eligible professionals (EPs), eligible hospitals, and critical access hospitals (CAHs) must meet in order to continue to participate in the EHR Incentive Programs.

Rule Provisions

Through the Stage 2 requirements of the Medicare and Medicaid EHR Incentive Programs, CMS seeks to expand the meaningful use of certified EHR technology. Certified EHR technology used in a meaningful way is one piece of a broader health information technology infrastructure needed to reform the health care system and improve health care quality, efficiency, and patient safety. Highlights of the rule’s provisions follow.

Stage 2 Timing

In the Stage 1 meaningful use regulations, CMS established an original timeline that would have required Medicare providers who first demonstrated meaningful use in 2011 to meet the Stage 2 criteria in 2013. The Stage 2 rule gives providers more time to meet Stage 2 criteria. A provider that attested to Stage 1 of meaningful use in 2011 would attest to Stage 2 in 2014, instead of in 2013. Therefore, providers are not required to meet Stage 2 meaningful use before 2014. The table below illustrates the progression of meaningful use stages from the first year a Medicare provider begins participation in the program.
Clinical Quality Measures (CQMs)

Measure Sets and Reporting

The rule finalized that:

- EPs must report on 9 out of 64 total clinical quality measures (CQMs)
- Eligible hospitals and CAHs must report on 16 out of 29 total CQMs

In addition, all providers must select CQMs from at least 3 of the 6 key health care policy domains from the Department of Health and Human Services’ National Quality Strategy:

- Patient and Family Engagement
- Patient Safety
- Care Coordination
- Population and Public Health
- Efficient Use of Healthcare Resources
- Clinical Processes/Effectiveness
ONC Fact Sheet:
2014 Edition Standards & Certification Criteria (S&CC)
Final Rule

Summary
The 2014 Edition S&CC final rule completes the Office of the National Coordinator for Health IT's (ONC) second full rulemaking cycle to adopt standards, implementation specifications, and certification criteria for EHR technology. This final rule complements the newly released Centers for Medicare & Medicaid Services (CMS) final rule which establishes Stage 2 of the Medicare and Medicaid Electronic Health Record (EHR) Incentive Programs, updates Stage 1, and includes other program modifications.

The 2014 Edition S&CC final rule reflects ONC’s commitment to reduce regulatory burden; promote patient safety and patient engagement; enhance EHR technology’s interoperability, electronic health information exchange capacity, public health reporting, and security; enable clinical quality measure data capture, calculation, and electronic submission to CMS or States; and introduce greater transparency and efficiency to the certification process.
Goal 3. Integrated Biomedical, Clinical, and Public Health Information Systems that Promote Scientific Discovery and Speed the Translation of Research into Practice

Continue/enhance standards work in response to U.S. government priorities and feedback from “real” use in electronic health records

- e.g., Unified Medical Language System (UMLS), key clinical terminologies (SNOMED CT, LOINC, RxNorm)
STANDARD VOCABULARIES

(Biomedical terminologies and ontologies)
London Bills of Mortality

A general Bill for this present year, ending the 19 of December 1665, according to the Report made to the KINGS most Excellent Majestie, by the Company of Parish Clerks of London, etc.

The Diseases and Casualties this Year:

- Burtse and Stillborne: 617
- Aged: 1445
- Ague and Palsy: 665
- Found dead in Streets, Fields: 26
- Pox: 9
- Apparant and Suddenly: 278
- French Pox: 58
- Bedding: 12
- Frigidity: 14
- Incest: 10
- Gout and Stenuria: 27
- Quinsy: 3
- Bleeding: 19
- Grief: 48
- Riots: 19
- Bloody flux, Scooting & Flux: 18
- Griping in the Guts: 12
- Riding of the Lights: 6
- Burnt & Scaled: 8
- Hung and made away themselves: 7
- Plague: 683
- Scurvy: 4
- Cancer, Gangrene and Fila.tus: 12
- Jaundice: 3
- Hemorrhagia & Muskellfallen: 14
- Scoury: 8
- Canker, and Thrush: 64
- Leprosy: 3
- Childbed: 68
- Killed by several accidents: 46
- Limbs: 24
- Swell. Utsers, broken and hollited: 2
- Cholomas and Infants: 19
- Kings Evil: 5
- Spleen: 11
- Cold and Cough: 63
- Lepore: 26
- Collick and Wiende: 134
- Lecthery: 34
- Contagion and Tisfick: 148
- Liverborn: 33
- Convulsion and Mother: 1032
- Meagrom and Headach: 43
- Scabs: 10
- Dysentery: 22
- Meulas: 5
- Mouthed and Shot: 19
- Murrin: 58
- Dog and Company: 19
- Mustered and Shor: 8
- Overland & Starved: 45
- Venem: 931
- Consumptions: 637
- Burned: 505
- Plague: 683

The Bills of Mortality in the 19th Parish and at the Pest-house this year:

- Males: 488
- Females: 382
- Total: 870

The Bills of Mortality in the 13th Parish and at the Pest-house this year:

- Males: 790
- Females: 970
- Total: 1760
Many biomedical terminologies

- **Diagnoses / Diseases / Conditions**
  - International classification of diseases (ICD)
  - SNOMED CT

- **Procedures**
  - Current Procedural terminology (CPT)
  - ICD10-PCS
  - SNOMED CT

- **Drugs**
  - RxNorm

- **Laboratory tests**
  - LOINC
Standard vocabularies for Meaningful Use

- **Diagnoses / Diseases / Conditions**
  - International classification of diseases (ICD)
  - SNOMED CT
- **Procedures**
  - Current Procedural terminology (CPT)
  - ICD10-PCS
  - SNOMED CT
- **Drugs**
  - RxNorm
- **Laboratory tests**
  - LOINC
SNOMED Clinical Terms
SNOMED CT Characteristics (1)

- Current version: January 31, 2013 (2 annual releases)
- Type: Reference terminology / ontology
- Domain: Clinical medicine
- Developer: IHTSDO
- Funding: IHTSDO
- Availability
  - Publicly available: Yes* (in member countries)
  - Repositories: UMLS
- URL: http://www.ihtsdo.org/
SNOMED CT Characteristics (2)

◆ Number of
  ● Concepts: ~300,000 active concepts (Jan. 31, 2013)
  ● Terms: ~1.1M active “descriptions”

◆ Major organizing principles:
  ● Utility for clinical medicine (e.g., assertional + definitional knowledge)
  ● Model of meaning (incomplete)
  ● Rich set of associative relationships
  ● Small proportion of defined concepts (many primitives)

◆ Formalism: Description logics (EL++)
SNOMED CT  Top level

138875005  SNOMED CT Concept

- 362981000  qualifier value
- 106237007  linkage concept
- 370115009  special concept
- 48176007  social context
- 419891008  record artifact
- 363787002  observable entity
- 308916002  environment or geographical location
- 123038009  specimen
- 254291000  staging and scales
- 123037004  body structure
- 272379006  event
- 78621006  physical force
- 404684003  clinical finding
- 260787004  physical object
- 410607006  organism
- 71388002  procedure
- 373873005  pharmaceutical / biologic product
- 243798009  situation with explicit context
- 105590001  substance
SNOMED CT  Example

Hierarchy

- 27010001 partial excision of large intestine
- 8613002 operation on appendix
- 80146002 appendectomy
- 82730006 incidental appendectomy
- 49438003 appendectomy with drainage
- 174036004 emergency appendectomy
- 174045003 interval appendectomy
- 6025007 laparoscopic appendectomy
- 235313004 non-emergency appendectomy
- 235314005 inversion appendectomy
- 1299000 excision of appendiceal stump

Definition: Fully defined by ...

- is a
  - D partial excision of large intestine
  - D operation on appendix

Group

- method
  - D excision - action

Qualifiers

- access
  - p surgical access values

- priority
  - p priorities

Codes

- Original SnomedId : P1-57450
- Read Code (Ctv3Id) : X20Wz
RxNorm
RxNorm Characteristics (1)

- Current version: April 1, 2012 (monthly releases)
- Type: Controlled terminology
- Domain: Drug names
- Developer: NLM
- Funding: NLM
- Availability
  - Publicly available: Yes*
  - Repositories: UMLS
- URL: http://www.nlm.nih.gov/research/umls/rxnorm/
RxNorm Characteristics (2)

◆ Number of
  - Concepts: 213,500 drug entities (April 2013)
  - Terms: ~1.3 term per concept

◆ Major organizing principles:
  - Generic vs. brand
  - Combinations of Ingredient / Form / Dose
  - No hierarchical structure
  - Links to all major US drug information sources
  - No clinical information

◆ Formalism: UMLS RRF format
RxNorm Normalized form

- Strength: 4mg/ml
- Ingredient: Fluoxetine
- Dose form: Oral Solution

Semantic clinical drug component

- Strength
- Ingredient: Fluoxetine
- Dose form: Oral Solution

Semantic clinical drug form

- Strength
- Ingredient
- Dose form

Semantic clinical drug
Rx Norm Generic vs. Brand

- **Generic**
  - Ingredient (IN)
  - Clinical drug form (SCDF)
  - Clinical drug component (SCDC)
  - Clinical drug (SCD)

- **Brand**
  - Brand name (BN)
  - Branded drug form (SBDF)
  - Branded drug component (SBDC)
  - Branded drug (SBD)

*tradename_of*
RxNorm  Relations among drug entities
Logical Observation Identifiers, Names and Codes (LOINC)
LOINC Characteristics (1)

- Current version: 2.42 (Dec. 2012)
- Type: Controlled terminology*
- Domain: Laboratory and clinical observations
- Developer: Regenstrief Institute
- Funding: NLM

Availability
- Publicly available: Yes
- Repositories: UMLS

URL: www.regenstrief.org/loinc/loinc.htm
LOINC Characteristics (2)

- **Number of**
  - Concepts: ~70k active codes (2.42) (2 annual releases)
  - Terms: n/a*

- **Major organizing principles:**
  - No hierarchical structure among the main codes
  - 6 axes
    - Component (analyte [+ challenge] [+ adjustments])
    - Property
    - Timing
    - System
    - Scale
    - [Method]

- **Formalism:** “DL-like”
**LOINC Example**

- **Sodium:**SCnc:Pt:Ser/Plas:Qn
  [the molar concentration of sodium is measured in the plasma (or serum), with quantitative result]

<table>
<thead>
<tr>
<th>Axis</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Sodium</td>
</tr>
<tr>
<td>Property</td>
<td>SCnc – Substance Concentration (per volume)</td>
</tr>
<tr>
<td>Timing</td>
<td>Pt – Point in time (Random)</td>
</tr>
<tr>
<td>System</td>
<td>Ser/Plas – Serum or Plasma</td>
</tr>
<tr>
<td>Scale</td>
<td>Qn – Quantitative</td>
</tr>
<tr>
<td>Method</td>
<td>--</td>
</tr>
</tbody>
</table>
QUALITY ASSURANCE OF
STANDARD VOCABULARIES
Analytical framework for QA research

- Special issue of JBI on “Auditing terminologies”
- Zhu et al. JBI 2009 review article
- Analytical framework
  - What is analyzed
  - Which source of knowledge
  - Which method

What is analyzed

- Term/concept
  - Coverage (missing terms/concepts)
  - Wrong synonymy relation
  - Redundant concepts
- Relation
  - Missing relations
  - Inaccurate relations
- Categorization
  - Wrong categorization
Which source of knowledge

- **Intrinsic** – *the terminology itself*
  - Terms/Concepts
  - Relations
  - Categorization

- **Extrinsic** – *external resources*
  - Corpus
    - Text corpus – identify terms in text
    - Annotation corpus – identify relations from co-occurring terms
  - Mapping
Which method  Main categories

- **Lexical**
  - Properties of the term

- **Structural**
  - Properties of the organizational structure (relations)

- **Semantic**
  - Semantic properties of the concept (semantic type)

- **Statistical**
  - Associations among entities

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Acute Ischemic enteritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic</td>
<td>Ischemic enteritis</td>
</tr>
<tr>
<td>Head</td>
<td></td>
</tr>
</tbody>
</table>
Which method

Main categories

◆ Lexical
  ● Properties of the term

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Which method  Additional methods

- Compliance with ontological principles
  - Operational definitions
- Comparative
  - Comparisons between ontologies (mapping)
- Transformative
  - Representation formalism
- Use in an application

“Each concept, except for the root, must have (at least) one parent concept”
Which method  Additional methods

◆ Compliance with ontological principles
  ● Operational definitions
◆ Comparative
  ● Comparisons between ontologies (mapping)
◆ Transformative
  ● Representation formalism
◆ Use in an application
Which method  Additional methods

Compliance with ontological principles

- Operational definitions
- Comparative comparisons between ontologies (mapping)
- Transformative representation formalism
- Use in an application

Heart in OWL DL

```
<owl:Class rdf:ID="Heart">
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Organ_with_cavitated_organ_parts"/>
        <owl:Restriction>
          <owl:onProperty
            rdf:resource="#constitutional_part"/>
          <owl:someValuesFrom
            rdf:resource="#Wall_of_heart"/>
        </owl:Restriction>
      </owl:Class>
    </owl:equivalentClass>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty rdf:resource="#bounded_by"/>
        <owl:someValuesFrom
          rdf:resource="#Surface_of_heart"/>
      </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty rdf:resource="#arterial_supply"/>
        <owl:someValuesFrom
          rdf:resource="#Right_coronary_artery"/>
      </owl:Restriction>
    </rdfs:subClassOf>
  </owl:equivalentClass>
</owl:Class>
```

Heart in Protégé frames

```
(defclass Heart
  (is-a Organ_with_cavitated_organ_parts)
  ...
)

Class (Instance of Metaclass)

[[Heart]
  of Organ_with_cavitated_organ_parts
  (constitutional_part
    Wall_of_heart
    Cavity_of_left_atrium
    Cavity_of_right_ventricle
    Cavity_of_left_ventricle
    Right_coronary_artery
    Left_coronary_artery
    ...
  (bounded_by
    Surface_of_heart)
  (arterial_supply
    Right_coronary_artery
    Left_coronary_artery)
  ...
]`

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Which method Additional methods

- Compliance with ontological principles
  - Operational definitions
- Comparative
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- Transformative
  - Representation formalism
- Use in an application

MAOUSSC: Using UMLS for the description of medical procedures

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Identifying errors in SNOMED CT

Alan Rector's motivation

- Knowledge source for clinical applications (industrial collaboration)
  - Retrieval of clinical records for a given diagnosis
  - Decision support
  - Eligibility for clinical trials
- Development of ICD 11 (WHO Health Information Modelling TAG)
  - Ontological component for ICD 11
  - ICD hierarchies derived from SNOMED CT
Investigation methods

- Technology-assisted review by domain experts
  - With focus on the CORE problem list (clinical relevance)
- Methods
  - Leveraging description logics (stated version converted to OWL, module extraction, OWL classifiers, scripting against OWL API)
  - Lexically suggest-logically refine (association between words from labels and roles)
  - Navigation (up and down the hierarchies for missing/extraneous ancestors/descendants)
Findings – Qualitative (1)

- Errors of omission
  - Primitive concepts
    - Ischemic heart disease: *due to ischemia, but not defined*
  - Missing axioms
    - Morphology
      - acute endocarditis (disorder): not *clinical course = acute; morphology: acute* inflammation
    - Other
      - Myocardial infarction: not *due to ischemia*
Findings – Qualitative (2)

- Errors of commission
  - Wrong
    - Diabetes mellitus isa Disease of the exocrine pancreas (true of type I, not type II)
    - Subdural hemorrhage: finding site Subdural space structure (intracranial is implied by usage, but not formally represented)
  - Wrong (but only indirectly)
    - Hypertension isa disorder of soft issue
      - Hypertension: finding site Systemic arterial structure (→ soft tissue) (not clinically thought of as a disorder of soft tissues)
    - Neoplasm of cranial nerve: isa Neoplasm of cranial nerve: isa Neuropathy (neuropathy denotes functional disorder of nerve)
  - Anatomy (branches inherit from root)
    - Structure of right popliteal artery isa [...] isa Structure of pelvic region (“getting the knee out of the pelvis”)
Consequences

Incorrect inferences

- By omission
  - Search on *Ischemic heart disease* fails to retrieve *Myocardial infarction*

- By commission
  - Search on *Disorder of pancreas* retrieves all cases of diabetes mellitus, including type II

Missing equivalences from post-coordination

- acute endocarditis (disorder):
  - Pre-coord: *morphology*: acute inflammation
  - Post-coord: *clinical course* = acute; *morphology*: inflammation
Identifying errors in RxNorm

Motivation

- Large terminology
- Relies heavily on human editors
- High quality

- Systematic evaluation
- Exploiting the graph structure
Methods

- Normalize multi-ingredient drugs
- Define “meaningful” paths between 2 nodes
- Instantiate all meaningful paths
- Compare alternate paths
  - Alternate (meaningful) paths are expected to be functionally equivalent
Results

- 348 inconsistencies identified (April 2008)
- Reported to the RxNorm team
- 215 (62%) fixed (January 2009)

Example (fixed)
- missing link
  Sochlor → Sodium chloride
- Brand name without a direct relation with an ingredient
VALUE SETS
IN
CLINICAL QUALITY MEASURES
Tools that help measure and track the quality of healthcare services provided by eligible professionals, eligible hospitals and critical access hospitals within our health care system

CQMs measure many aspects of patient care including: health outcomes, clinical processes, patient safety, efficient use of healthcare resources, care coordination, patient engagements, population and public health, and clinical guidelines

[cms.gov]
93 CLINICAL QUALITY MEASURES
in 2014 Meaningful Use criteria

64 for
ELIGIBLE PROVIDERS
(Need to report on 9)

29 for
ELIGIBLE HOSPITALS
(Need to report on 16)
Hemoglobin A1c Test for Pediatric Patients

- Normal glucose levels in blood: Low HbA1c concentration
- High glucose levels in blood: High HbA1c concentration
1. American Association of Clinical Endocrinologists (2002): Recommends that a glycosylated hemoglobin be performed during an initial assessment and during follow-up assessments, which should occur at no longer than three-month intervals.

2. American Diabetes Association (2006): Recommends obtaining a glycosylated hemoglobin during an initial assessment and then routinely as part of continuing care. In the absence of well-controlled studies that suggest a definite testing protocol, expert opinion recommends glycosylated hemoglobin be obtained at least twice a year in patients who are meeting treatment goals and who have stable glycemic control and more frequently (quarterly assessment) in patients whose therapy was changed or who are not meeting glycemic goals.
Hemoglobin A1c Test for Pediatric Patients

# diabetic patients [age 5-17] tested for HbA1c

= 

# diabetic patients [age 5-17]
Hemoglobin A1c Test for Pediatric Patients

Tests for HbA1c

# diabetic patients [age 5-17] tested for HbA1c

= # diabetic patients [age 5-17]

- Type 1 or Type 2 diabetes
- Requires date of birth
- Excludes gestational diabetes
Hemoglobin A1c Test for Pediatric Patients

- Type 1 or Type 2 diabetes
- Excludes gestational diabetes

# diabetic patients [age 5-17] tested for HbA1c

Data element

List of LOINC codes
Tests for HbA1c

List of SNOMED CT or ICD 10 codes

# diabetic patients [age 5-17]
ANATOMY OF A CLINICAL QUALITY MEASURE

Population criteria

- Initial Patient Population =
  - AND: "PatientCharacteristic Birthdate: birth date" >= 5 year(s) starts before start of "Measurement Period"
  - AND: "PatientCharacteristic Birthdate: birth date" <= 17 year(s) starts before start of "Measurement Period"
  - AND: "Diagnosis, Active: Diabetes" starts before or during (MOST RECENT: "Occurrence A of Encounter, Performed: Diabetes Visit" during "Measurement Period")
  - AND: "Encounter, Performed: Diabetes Visit" >= 12 month(s) starts before start of "Occurrence A of Encounter, Performed: Diabetes Visit"

- Denominator =
  - AND: "Initial Patient Population"

- Denominator Exclusions =
  - AND NOT: "Occurrence A of Diagnosis, Active: Gestational Diabetes" ends before start of "Measurement Period"
  - AND: "Occurrence A of Diagnosis, Active: Gestational Diabetes" starts before or during "Measurement Period"

- Numerator =
  - AND: "Laboratory Test, Result: HbA1c Laboratory Test (result)" during "Measurement Period"

- Denominator Exceptions =
  - None

Data criteria (QDM Data Elements)

- "Diagnosis, Active: Diabetes" using "Diabetes Grouping Value Set (2.16.840.1.113883.3.464.1003.103.12.1001)"
- "Diagnosis, Active: Gestational Diabetes" using "Gestational Diabetes Grouping Value Set (2.16.840.1.113883.3.464.1003.103.12.1010)"
- "Encounter, Performed: Diabetes Visit" using "Diabetes Visit Grouping Value Set (2.16.840.1.113883.3.464.1003.103.12.1012)"
- "Laboratory Test, Result: HbA1c Laboratory Test" using "HbA1c Laboratory Test Grouping Value Set (2.16.840.1.113883.3.464.1003.198.12.1013)"
- "PatientCharacteristic Birthdate: birth date" using "birth date LOINC Value Set (2.16.840.1.113883.3.50)"

Value set = List of LOINC codes for HbA1c tests
## Associated Value Set

**Metadata**
- **Name:** HbA1c Laboratory Test
- **Type:** Grouping
- **Note:**
- **OID:** 2.16.840.1.113883.3.464.1003.198.12.1013
- **Developer:** National Committee for Quality Assurance

**Value Set Members**

**Expanded Code List**

<table>
<thead>
<tr>
<th>Code</th>
<th>Descriptor</th>
<th>Code System</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>17855-8</td>
<td>Hemoglobin A1c/Hemoglobin.total in Blood by calculation</td>
<td>LOINC</td>
<td>2.40</td>
</tr>
<tr>
<td>17856-6</td>
<td>Hemoglobin A1c/Hemoglobin.total in Blood by HPLC</td>
<td>LOINC</td>
<td>2.40</td>
</tr>
<tr>
<td>4548-4</td>
<td>Hemoglobin A1c/Hemoglobin.total in Blood</td>
<td>LOINC</td>
<td>2.40</td>
</tr>
</tbody>
</table>
Meaningful Use Criteria - 2014

- **93 CQMs**
  - Developed by some 20 measure developers

- **3,011 value sets**
  - 1,520 unique

- **199,521 codes**
  - 83,723 unique
CURATING VALUE SETS

The NLM Value Set Authority Center
OBJECTIVES OF CURATION

- Ensure referential integrity
  - All codes in a VS are valid codes in the corresponding code system
  - Update VSs when the code systems are updated (no “stale” codes)

- Avoid duplication
  - Find value sets having similar members

- Ensure correctness and completeness
  - Compare intensional and extensional definitions
Code Validation Using Triangulation

Using terminology services to compare codes to reference terminologies
Types of error found in the codes

- Obsolete codes
  - Remap to the current code

- Typo / formatting issue in the code
  - Reformat

- Wrong code system listed
  - Fix code system

- Code/description mismatch
  - Small mismatch: Assign preferred term
  - Large mismatch: Send back to developers
**Impact on Clinical Quality Measures**

Iterative Analysis

- 13 rounds over 4 months
- Reports provided to measure developers
- Orange codes fixed automatically by NLM
- Red codes fixed by measure developers (and rechecked)

- ~4000 errors
- Affecting 70% of the value sets
- And 100% of the measures
- All fixed by October 2012
REVERSE-ENGINEERING OF THE INTENSION
Quality metrics for value sets

Completeness
\[ \text{Compl} (VS_{Ori}) = \frac{|VS_{Ori} \cap VS_{RE}|}{|VS_{RE}|}. \]

Correctness
\[ \text{Correct} (VS_{Ori}) = \frac{|VS_{Ori} \cap VS_{RE}^*|}{|VS_{Ori}|}, \]
where \( VS_{RE}^* \subseteq VS_{RE} \setminus \{\text{singleton nodes}\}. \)
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