

An Easily Adopted Markup Discipline For Annotating Electronic Medical Records with Ontological and Epistemological Qualification:

Toward Disciplined Asterisks, Parentheticals, Marginalia, Footnotes, and Hashtags

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Abstract— Structured data and controlled vocabularies in medical records are common goals, but widespread and eager clinical adoption might require more modest, incremental change.

One small step along the path to structured data is a voluntary discipline of annotation, supported by simple, user-friendly, dynamic text affordances. A second step is to discipline the meta-vocabulary rather than the clinical vocabulary: one can target the epistemological attitudes (probability, degree of uncertainty, pedigree of claims) and ontological criteria (fuzziness or vagueness, version of definition, reporting standard) for optional markup, and even plain text can support disciplined annotation.

The methods seem especially useful for summary views of patient records that have multiple authors, contributing at different times, using various criteria. The methods may also support more nuanced outcomes research and reporting, and aid transitions between policies, regulations, and billing codes.

It may be too difficult to impose ontologies on so many different participants in medical record-keeping, all at once, with little room for customization. A more organic, evolutionary path to the same end starts with the smaller step of asking medical records keepers to settle on the common annotations. Even as a crowd-sourced meta-language takes shape, the freedom to use epistemic and ontological qualifiers makes controlled terminologies and vocabularies, with discrete and structured data, easier to live with.

Keywords—*electronic medical records; ontologies; structured data; discrete data; meta-data; markup; annotations; reporting; billing; qualification; assertion; uncertainty; footnotes; hashtags*

I. INTRODUCTION

Considerable effort has been given to the production and perfection of controlled vocabularies, ontologies, standard terminologies, and the discretization of medical data [1, 4, 5, 6,

10, 13, 16, 19, 20, 21, 22, 23]. Naturally, the electronic medical record (EMR), or electronic health record (EHR), has been assumed to be the beneficiary. SNOMED-CT and ICD-10-CM are the prominent examples, though Semantic Web and other XML-based languages seek to impose additional discipline.

The ambition of providing a comprehensive and universally acceptable vocabulary for medical records that merges clinical notation and billing coding is a great ambition; perhaps too great in the short term. Ontologies for technical disciplines are useful but also controversial. There are many goals that would be met with controlled vocabularies: data interchange, standardized reporting, interoperability, and portability. However, it may be that smaller steps could be taken that would yield immediate practical benefits; small steps would also be more easily adopted.

Rather than address the ontology of medical content, one can address a few of the persistent meta-issues. Specifically, there are qualifications of assertion that could benefit from controlled vocabulary. Some assertions are probable; others are “morally certain,” and others might be conjectures. Some descriptions use a term that is almost, but not entirely right; others might interpolate two discrete choices; others are classic examples. Philosophers refer to certain kinds of qualifications as “propositional attitudes,” because they describe the attitude that the author or speaker takes toward the proposition or assertion. The two main attitudes are epistemological (the quality of one's knowing something), and ontological (the adequacy of the terms being used). Epistemic attitudes include degrees of belief, degrees of confirmation, or probability. But they also include pedigree, authority, argument, and persistence. Ontological attitudes include degrees of membership, fuzziness, and prototypicality. But they also include definitional standards, temporal qualification, and exception.

The suggestion in this paper is to permit annotation of clinical observations and other patient data with some of these qualifiers. The idea is more modest than the adoption of a fully controlled meta-vocabulary. The proposal is only that there be the user-interface, display markup, and database support for annotating claims with these kinds of considerations. In the author's experience, working with the design of discrete medical reporting data for a leading hospital system, allowing "shading" of assertion makes any controlled terminology more natural. When faced with an imperfect choice of terms, users can be more and accurate if they can add qualifications. This can also save time because annotation is faster than belabored choice. Annotating the authority of observations seems particularly important when notes from different sources are merged into a single view.

Even without enforcing a terminology, and without technological support, manual annotations in plain text can be helpful in datamining and automated analysis. A voluntary discipline of citation and regularized pattern of reference is the usual precursor to automation that is natural to users, that is a help rather than a hindrance.

The language that epistemologists, linguists, and philosophers of science use to describe assertions is not recommended (one finds "doxastic," "aleatory," and "alethic" distinctions, linguistic and ontic "modalities," and other nuances); the idea of meta-vocabulary will have practical benefit, but any additional detail would be burdensome to practitioners. Rather than import the philosopher's language, in the next two sections, examples are given of epistemic and ontological annotations that might be helpful additions to a medical record. All of the scenarios discussed are actual cases from the author's experience with medical records.

It should be noted that HL7 is a meta-language that imposes a different meta-theory on health data (it contains tags that describe information exchange rather than assertional qualification). HL7 does have an uncertainty code, and SNOMED_CT has a FINDING CONTEXT that can be uncertain. ICD coding typically permits "unspecified," "other," or "not elsewhere classified." But this paper tries to step back from taxonomic regimentation and instead considers simple modification of current, common practice.

II. EPISTEMIC QUALIFICATION

A. Patient Reports

Scenario. The patient is asked for relevant family medical history. The patient thinks the estranged father might have had diabetes and believes two uncles died of heart attacks at an early age.

An aggressive recording of family history would record anything that is plausible and sufficiently precise. A cautious recording would omit anything that isn't both specific and highly probable. An intermediate approach, which records more information and requires less real-time decision, is to tag these

history claims with their imperfect epistemic pedigree, as **#says-patient** and **#according-to-patient**. In a later section, options for displaying these tags are discussed, as well as the evolution of standardized terminology and the post-hoc inference rules that support coalescence of synonymous terms.

B. Error-Corrected Data

Scenario. A sweep of the database discovers data entry errors with obvious corrections: systolic and diastolic blood pressure numbers reversed, use of centimeters instead of inches, typos that insert an extra digit, etc.

The policy of the database team is not to correct any of the original data, to preserve data integrity and permit downstream interpretation. However, some authorities might be permitted to make changes. How should they indicate the change? The epistemic revision should require a tag **#corrected-from** as well as a **name** (or **id**, such as initials and disambiguating digit), **date**, and medical **rank**, **previous** value, and **reason**.

C. Poor Measurement

Scenario. A blood sugar test is done reporting a high value that the physician doubts to be accurate. The patient confesses eating an entire cheesecake the night before, even though the patient fasted for the recommended FBS 8 hour period.

One solution is to discard the measurement; another is to enter it into the record but add the context in the notes. A tag such as **#probably-skewed** or **#possible-error** should be added, to indicate fallibility.

D. Old Data Possibly Persistent

Scenario. A dashboard view can use an old smoking pack years estimate to populate a field in the display, but that estimate should be updated, and in fact, the intake nurse should be reminded to ask the patient.

The tag **#prior-value**, **#prior-observation**, or simply **#dated** or **#past** would more faithfully depict the situation (the use of "old" could bias cursory views in some cases). Each field would potentially have a different "timeout" or "shelf life" period that determines when values and observations grow stale. Most conditions are understood to be recorded at a time and not necessarily persistent, such as trauma, bleeding, pregnancy, or menopause; these often do not require tagging because the viewer understands that they record an incident or prior condition, not necessarily a current condition. Many data however are ambiguous with respect to persistence, such as stress, depression, even marital status. These tags refer to epistemic corrigibility.

E. Medical Rank

Scenario. A medical resident's notes are being integrated with a specialist's observations in a single view. There is a possibility of difference of opinion, or simply different degrees of

caution. A minor disagreement might even arise from variation of codes, or omissions, on problem lists.

The header information that would normally be available for each note in a multi-provider system must be integrated into this view. Each contributor's **name** (or **id**), medical **rank** at the time, and **date** would be added as annotation. Here is a case where it would make sense to abbreviate, such as just showing the rank or initials, with a user-interface affordance (such as a click) to reveal full information. Some abbreviations of rank might be **#attending**, **#primary**, **#consulting**, **#RN**, **#LPN**, **#resident**, **#fellow**. Annotating omissions from one source that were included in another, presumably concurring source, is more difficult. **#unreported-by** might be a neutral tag in this case, along with the **name** (or **id**) and **rank**. In a collaborative record, such a tag should only be used when omission is significant.

A formal policy document from the University of California on legal medical record standards [24] lists 37 types of providers who may enter “multidisciplinary” notes, from “home health coordinators” to “pastoral care providers” and “emergency trauma technicians.” Apparently not just the doctors and nurses will be distinguishing their contributions to the patient record.

F. Informal Diagnosis or Unrecognized Authority

Scenario. A patient describes having had an event that is a classic minor TIA, observed by a medical student in a foreign country, but without formal diagnosis or documentation.

The physician has no trouble describing this in natural language, but when faced with reporting a prior history of stroke, the affirmative can be qualified. The assertion has **#informal-diagnosis** or **#imperfect-authority**. This and the prior example are social epistemic tags, and may include aspects of dialectic and justification, not just hierarchy and institution.

G. Difficult Diagnosis

Scenario. A patient newly at risk for COPD who has severe asthma presents the problem of differential diagnosis. The GP determines that there is sufficient evidence for Stage II or Stage III COPD severity, but has some doubts.

Although it can appear weak, it is in many cases a virtue to document doubt. One way to be explicit in a way that facilitates processing is simply to add the tag **#probable**. This is epistemic gradation. In legal language, much use is made of standards such as “reasonable suspicion,” “reasonable articulable suspicion,” “probable cause,” “substantial evidence,” “clear and convincing evidence,” “preponderance of evidence,” and “beyond reasonable doubt.” It seems that for most medical epistemic gradation, a reference to confirmation rather than argumentation is more apt: **#evident** would move to **#probable**, then **#certain**. Adding more grades invites inconsistent use, but may yet have good purpose.

III. ONTOLOGICAL QUALIFICATION

A. Coarse Discretization and Missing Dimensions

Scenario. A patient is filling out a form with several choices for the frequency of angina: several times a day, every day, once a week, less often. The patient has trouble choosing because events occur less often than a week, but when they occur, they occur several times in a single day, or over several days.

Quantization is not the only source of hard choices when values are predefined. But they illustrate the problem. When the difficulty is simply the absence of an interpolating value, and the inability to choose a range, the tag **#more-precisely** could be used, with the better description of the value, e.g., more than twice a week. When the choice is simply missing a dimension, **#more-complicated** would indicate that the choice does not permit faithful rendering of the situation. This is an example of ontological granularity and multidimensionality.

B. Outlier

Scenario. An NYHA II patient's BNP level is measured beyond the 95th percentile, but does not otherwise qualify as NYHA III class. The resident would like to note the value as a statistical outlier, not just say that it is elevated.

In this case, the quantity itself, say 6500pg/mL, is sufficient indicator of statistical anomaly to those familiar with the levels. However, in order to be clear, the record can add the tag **#outlier**, to indicate semantic stretch. In some cases, a count or frequency may not have a clear statistical model, and “fuzzy terms” such as “high,” or “frequent” do not capture the extent or degree. In most clinically important gradings there is a standard, such as “stage 1” or “second degree.” But where there is no existing standard, terms such as **#2-sigma** and **#3-sigma** can be useful. It is a bit of a risk, and a burden, to ask the author to estimate actual probabilities and deviations-above-the-mean, even in rough quantizations, because the statistical basis (reference class or reference population) may not be implied.

C. Specific Standard

Scenario. A patient record is being reviewed for registry reporting. The definition for hemorrhagic stroke differs slightly for NCDR ACTION 2.4 and CathPCI 4.4. The former #9032 defines the time frame beginning at arrival; the latter #8021 defines the time frame beginning at start of procedure. This patient had an MRI-documented acute episode after arrival but before the procedure in question.

This example considers downstream data recorded outside of the patient-facing setting. But derived data may also be part of the medical record. Tagging a derived assertion with the standard will be especially useful when definitions change substantially over many years. One way is simply to name the standard, **#cathpci4.4** or **#action2.4**, or to use **#prior-standard** on some cases, especially when there has been a recent change, to indicate different semantic criteria.

D. Atypical Connotation

Scenario. An older patient with a family history of CHF is well known to the clinic as a marathon runner. Suddenly the patient has been unable to complete 5k runs under 25 minutes. Before referring to a specialist, the family doctor would like to note that 25-minute 5k runs are below par for this patient, not just that the patient remains physically active.

This is exactly the kind of note that is easily added in natural language, but the importance of which is difficult to convey using discretized vocabulary. **#unusual-for-this-patient** might be a good way to capture this, or even **#exceptional-case**, because it is a semantic logical exception.

E. New Regulations

Scenario. A hospital database records Hispanicity based on estimation of qualifying cultural heritage, prior to the adoption of a new policy in 2001 that requires Hispanic status to be self-reported. The database administrator would like to distinguish old determinations from new, without creating a new column in relevant tables.

Unlike formal legislation that bears a name and number, changes in regulations often are distinctive only by year. **#pre-self-reporting** might be a tag that describes the change, but this kind of tag could proliferate undesirably. **#pre-2001** might be a better way of keeping these annotations under control. One would of course have to understand what change happened in 2001 that motivated the nuance. This is an example of mandated linguistic shift, or semantic drift.

IV. EXTENSIONS AND ADDITIONS

For both epistemic and ontological qualification, there will be room to add useful tags. This is not intended to be an exhaustive list. There will naturally be tags that are introduced that become popular, and others that fail to be adopted widely. It is nevertheless important to approach the meta-language in such a way that it does not grow too large.

Rule-based inference can be used to support synonymy as well as subsumption, e.g.

#says-patient iff **#according-to-patient**

if **#says-patient** then **#evidently**

Premature consolidation risks the misinterpretation of terms that are meant to express nuanced difference. Sometimes there is genuine distinction or even polysemy; sometimes there is just unnecessary proliferation of terms. Delaying coalescence of terms permits review, and computer supported automated inference is an easy fix.

V. TECHNOLOGY SUPPORT

A. Input: Templates, Menus, Suggestions, and Predefined Insertions for Plain Text

There are many ways to support the input of the controlled meta-vocabulary suggested here. There are two distinct kinds of input: populating fields in a form, or formatted display; and writing notes in free, natural language text. In both cases, input can be aided by menus of options, though the selection of an annotation is not a forced choice (in many note-taking systems, a template can be generated by name rather than selecting from a menu). In fact, a “write-in” or “add-to-list” option for new tags should be provided. People who invent too many tags that are unshared, or that have incommensurate semantics, will simply be inventing their own syntax, and it will have no power unless others adopt it with the same sort of purpose or signification. The art is to name the tags that are meaningful to others. There is a shared cost of zeal though, because menus are best kept short.

The hashtag is such a cogent, simple way of adding an annotation that it may not even require special input user-interface affordances (the tag may be shorter to type than the name of a template). The main benefits of menus and templates for non-compulsory hashtags are recall, standardization, and correct spelling. One additional affordance would be the ability to view an explanation of each tag, perhaps even a provenance, upon clicking.

Hashtags are currently used for search, especially social search. In current applications, such as social media, innovative hash tags are used, and themes or memes are reused without discipline. Here, hashtags are assumed to be governed by the desire to progress toward a professional discipline; they are for brief and common qualification, not for anchoring search targets.

B. Display: Icons, Dashboards, and Merged Notes

Just as there are many ways of supporting input, there are many ways to support display. Again, there is a distinction: in forms, tags take space that may not be envisioned in advance; in notes, tags can simply be placed inline, in parentheses. In natural language text notes, the tags need not even be hashtags, as canonical parenthetical expressions may be more natural. Footnotes and margin notes are also potential ways of adding tags to free text clinical notes. In the space-limited displays, such as dashboards, problem lists, and patient history summaries, a simple asterisk may suffice. Further inquiry, such as clicking on the asterisk, may reveal the name and explanation of the tag or list of tags. Icons and hues can also be chosen for the most common annotations, so long as the medical record retains a professional look.

Document typography traditionally enforces a restriction on the number of glyphs used for annotation: asterisks, double-asterisks, triple-asterisks, daggers, double-daggers, superscripted letters and numbers. Although authors may add freely to numbered and lettered footnotes, editorial style is structured: an

asterisk will denote something specific throughout the work; the references are limited in some sense to the Latin phrases available: *e.g.*, *i.e.*, *cf.*, *ibid.*, *id.*, *n.b.*, *q.v.*, *op. cit.*, though one might include the common unabbreviated expressions such as legal citation “signals,” *supra*, *infra*, *contra*, *in re*, and philosophers' qualifiers, *ceteris paribus*, *mutatis mutandis*, *prima facie*, *ad hoc*, *ex post*, *ab initio*, etc. There are not as many as one might fear; in fact, the burden of colleagues knowing the Latin meaning places a natural limit.

An important benefit of annotation of claims by epistemic pedigree is that summary views and merged notes become more practicable. Cogent, abridged views are often valuable for holistic comprehension, and switching between notes can consume time and energy. Multi-page views are particularly inefficient for comparisons. But medical practitioners often keep their notes separate in order to understand the time and authority of the observations. Annotating epistemics facilitates merging of clinical notes.

C. Databases, Derivations, and Cohorts

Adding tags to some databases may be challenging. Where a field was defined to take a single, typed value, it may now take a value and an annotation. In most cases, there can be several annotations, and they may need to be organized in temporal order as an extensible list. In XML-schemata, the problem is not difficult, as elements are easily split into content and annotations, and multiple elements may substitute for a single element. For relational database tables, one possibility is leaving the columns as defined, and adding “doppelgaenger” columns, or even a matching table that mirrors the original, in order to store annotations separately.

A different strategy is to number all annotations by id, and store annotations irrespective of where they occur and what they annotate. This is an easy approach but may have scaling issues, and will not support nuanced search.

Once tags are in place, researchers can use them to improve analysis. For outcomes research, this makes possible more control over patient cohorts. It may also improve logical derivation, when annotations create exceptions to rules, or when annotations permit subsumption under more specific rules.

VI. DISCUSSION AND CONCLUSION

A. The Important and Inherent Trade-off between Precision and Qualification

In measurement, there is a well known trade-off between precision and probability: the more precise the claim, the less probably true; the more probability required, the less precision possible. The same trade-off occurs with controlled vocabulary. The more control, and fewer the choices, the more frequent the need to qualify the choice. Meanwhile, to avoid exceptions and produce unqualified assertion, the vocabulary must range widely, have fine granularity, and permit variation in multiple

dimensions. A workable compromise is to control the terminology, but permit annotations in another controlled terminology.

B. Small Steps to Structured Meta-Data

The author has done original work in the organization of judicial opinions by automatically extracting citations [11]. In these records, a voluntary but strongly disciplined pattern of citation permitted meta-data extraction and the construction of improved search engines (disciplined legal opinions also tend to state the rule of the case with the citation). There has been work on legal ontologies (criminal, civil, commercial, constitutional) that is roughly in the same state of development as clinical medical ontologies. But impressive practical gains have been based on structuring meta-data.

The medical records problem is different in many ways, notably because the meta-data is about assertion, not linkage of cases. Still, the lesson from the legal domain is that voluntary tagging can lead to professional norms, which lead to annotation standards, which result in structured data.

Here is an example (from *Ladue v. Gilleo*) of a disciplined reference in a legal opinion. The unconstrained domain vocabulary is in shadow; all other text is syntactically well-formed according to extant norms:

see, e.g., *Payton v. New York*, 445 U.S. 573, 596-597, and nn. 44-45 (1980); that principle has special resonance when the government seeks to constrain a person's ability to speak there. See *Spence v. Washington*, 418 U.S. 405, 406, 409, 411 (1974) (*per curiam*).

C. Beyond Annotations

Bringay et al. give a fine description of why annotations are important [2]:

“[A] person annotates because:

She cannot, without annotations, add her semiotic production to the document because the data capture does not allow the writer to enter the desired data. It is the case of the too rigid medical forms. Therefore, an annotation is an escape clause if there is no current method to extend forms. ... [An] annotation is also an escape clause if there is no means to code the comments about the documents.”

We split the concerns into the epistemic and the ontic, i.e., the desire to qualify the assertability, and the desire to qualify the terminology. We then suggest that a specific meta-language will evolve among the medical records professionals in much the same way that bibliographic annotations, legal citations, and philosophical vernacular have evolved. At first, there could be linguistic mess, but standards will be easy to impose once the range and frequency have been determined. Some would want to start with standards, which would certainly be possible for the most obviously useful of the meta-language inventory. The main desired result is the same, however: a disciplined, standardized

meta-terminology that improves the fidelity, comprehensibility, and expressivity of the EMR/EHR, which is an easier step than controlled domain terminology, and which makes such standardized terminology an easier pill to swallow.

D. Systematic Terminology for Linearly Ordered Epistemic and Ontological Grades

There is nevertheless room for preliminary standardization of the most important, prevalent, linearly ordered concepts. Specifically,

EM1. PROBABILITY

- probl. (**#certain**)
- problII. (**#probable**)
- problIII. (**#evident/#apparent**)

EM2. PROVABILITY

- proofI. (**#indisputably**)
- proofII. (**#decidedly**)
- proofIII. (**#arguably**)

OM1. PRECISION

- precl. (**#exactly**)
- preclII. (**#very nearly**)
- preclIII. (**#approximately/#roughly**)

OM2. PROTOTYPICALITY

- protoI. (**#normal/#standard/#typical**)
- protoII. (**#atypical/#different**)
- protoIII. (**#deviant/#unconventional/#novel**)

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