Embracing Change in a Health Information Exchange

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ABSTRACT

Managing changes in source system terms and surveilling for associated deviations in HL7 reporting is an essential, but difficult aspect of a health information exchange. We analyzed the mapping records of the Indiana Network for Patient Care in order to characterize the evolution of radiology and laboratory system terms after initial implementation with regard to term mappings and changes in units of measure. Overall, we added half as many new post-implementation terms (9909) as we added for initial system implementations. As a group, INPC institutions have not slowed much in their rate of adding new terms after initial implementation. In general, we encountered unit-related exceptions less frequently than new, unknown terms. Our study highlights the ongoing effort required to keep up with evolving source system terms in a regional HIE and the need to willingly embrace change along the way.

INTRODUCTION

Interoperable health information exchange networks are a cornerstone of the strategy for developing a National Health Information Network in the United States.[1] Achieving the vision of consumer-centric and information-rich healthcare depends upon linkages with semantic interoperability across the many independent electronic systems that store health information. Too often, however, these linkages are not in place, and valuable data like laboratory and radiology results are unavailable to clinicians when they need it.[2] A comprehensive health information exchange must coalesce all of the disparate sources that produce health data and overcome the barrier of myriad idiosyncratic conventions for identifying identical concepts in separate electronic systems. Mapping local observation terms to a standard vocabulary provides a bridge across the many islands of data, but the constant evolution of local data sources means that the bridge's foundation rests on shifting sand.

The Indiana Network for Patient Care[3] (INPC) is an example of a community-wide health information exchange (HIE) that has been operating in central Indiana for over thirteen years. The INPC includes data from five major hospital systems (over twenty different hospitals and more than a hundred clinics), the state and county public health departments, Indiana Medicaid, and RxHub. The federated INPC repository now stores more than a billion clinical observations. INPC data are made available through services such as emergency department abstracts, clinical messaging, and notifiable condition reporting that are demonstrating emerging clinical,[4, 5] financial,[6] and public health[7] benefits.

Within the INPC collaborative, Regenstrief Institute serves as a neutral third party convener, helping to stitch together many of the sources that produce health data in our community. Regenstrief receives clinical messages streams from all of the participating systems and integrates the data by mapping the idiosyncratic local terms to a common master dictionary based on LOINC® (Logical Observation Identifiers Names and Codes), a universal code system for identifying laboratory and other clinical observations.[8] Presently, Regenstrief receives 3.9 million HL7 clinical result messages monthly from over one hundred source systems within the INPC.

We have found managing the mappings from all of these source systems to be a challenging aspect of operating an HIE. Our centralized approach consolidates the expertise and tools necessary for the task, but still requires substantial effort and domain expertise. The mapping effort is usually largest during the initial system integration, but each source continues evolving after that point. INPC participants retain control over their institution's local term dictionaries and naming conventions, with authority to add, delete, and edit terms to meet their own needs. Ideally, source systems would give the terminologists who manage the common dictionary advanced notice to enable coordinated changes, and additionally would follow terminology development principles that allow "graceful evolution."[9] In practice, we have found the combined work of managing changes in source system terms and surveillance for associated deviations in HL7 reporting to be an essential, but difficult aspect of a HIE.

Because many HIE initiatives currently underway are in the early stages[10] and because it is tempting to consider HIE a destination rather than a journey, we sought to leverage the experience of operating the INPC to characterize the nature of changes to source system terms that we have encountered. For the purpose of this analysis, we focused on the kinds of issues resolved by the terminologists responsible for maintaining the common master dictionary and its mappings. We previously reported[11] some initial observations on radiology terms included in a primary evaluation of a tool for mapping local radiology tests. Here we present a more comprehensive analysis of source term changes emphasizing laboratory observations, but also with an expanded description of radiology terms.

Specifically, the purposes of this study were to characterize the evolution of radiology and laboratory system terms after initial implementation with regard to term mappings and changes in units of measure.

METHODS

Mapping and Terminology Management in the INPC

As new data sources are integrated into the INPC, each local system observation code is mapped to a term in the INPC common master dictionary, whose terms are also mapped to LOINC®. The INPC dictionary expanded from the Regenstrief Medical Record System[12] dictionary, in use since the early 1970's. For mapping purposes, we typically collect term information from system master files as well as large volumes of sample HL7 messages. Our mappings are primarily based on OBX codes, but we also evaluate the OBR/OBX pair because of the cases (such as blood gases) where the same OBX code has different clinical meaning depending on the battery code (arterial vs. venous blood). Thus, in our mapping tables, each record (term) is actually an OBR/OBX pair. Because clinical system terms are in constant flux and many are infrequently used, we focus our efforts on the most common tests first.[13]

After the initial mapping is complete and an INPC system is brought into production, our HL7 message processors monitor the clinical data flows and generate exception errors when things are amiss, such as an unmapped term or a units exception (i.e. when sent units do not match the stored units). In practice, we receive advanced notice for few of the new terms appearing in the INPC exchange; most are first identified by our exception processors.

New local observation terms are carefully evaluated and either mapped to an existing master dictionary term, mapped to a new master dictionary term (created based on the local code), or flagged to ignore (for terms that do not carry any actual clinical results). Evaluating the full HL7 message, dialogue with the source system, and independent research is often necessary to make these evaluations. Our system allows unmapped results to be displayed to clinicians as 'miscellaneous test', but for all aggregation purposes, local terms must be mapped to our common dictionary. Exceptions that flag units of measure errors are similarly evaluated and either a unit override is added to the local observation code (done judiciously) or the producer must correct and re-send. In addition to unmapped terms and unit errors, there are a variety of other exception types that need special attention and processing by the terminologists. As one might expect, the esoteric issues are often the most time consuming to solve. After finding an appropriate solution, the messages are reprocessed for storage in the repository.

Within the past year, we have greatly refined a program in .NET that provides a suite of tools for monitoring exceptions from all INPC data streams. The Exception Browser contains a sortable grid of active exceptions, views to see HL7 messages with error tags, user-specific tagging and reporting capabilities, a function to insert local terms into our mapping tables, and message reprocessing capabilities. These tools have made managing observation errors much more efficient.

Data Sources

To characterize the changes in source system terms, we extracted the mapping records from the INPC master dictionary for four laboratory and four radiology systems. We included all laboratory terms from two institutions (A and B) representing autonomous and competing healthcare systems, a regional laboratory from whom we receive all laboratory testing for two other healthcare systems in the INPC, and terms from a national reference laboratory from whom we receive results directly for institution B and another healthcare system in INPC. The INPC laboratory results for these institutions contain data from both the inpatient and outpatient setting. We included all radiology system terms from four INPC institutions. The extracted terms included primarily diagnostic radiology report codes, but also interventional radiology and nuclear medicine terms.

The extracted data were loaded into a Microsoft Access™ database for processing. We then used SQL statements to obtain subsets of the data for analysis.

Measures

Using term creation dates from the master dictionary and knowledge of when each system was moved into production status, we flagged all observation codes from each institution as either "pre" or "post" - implementation. Both our regional and reference laboratory systems send data into the INPC for more than one institution. These data are acted on by institution-specific message processors, but the regional laboratory and reference laboratory each use a common code set for the various institutions they serve. In our analysis of the regional and reference lab data, we chose the implementation date of the most recent institution from which we received data as the cut point for "pre" and "post" –implementation status. The implementation dates used in our analysis were thus: regional lab (5/2000), lab A (1/2003), lab B (5/2003), reference lab (2/2006), radiology A (3/2001), radiology B (10/2003), radiology C (12/2005), and radiology D (12/2005).

We then determined the number of pre and post - implementation terms and evaluated the growth over time. For new source system terms encountered after initial system implementation, we calculated the percent mapped to existing master dictionary terms versus those that needed new terms.

As we map local terms to the INPC master dictionary and to LOINC, we submit for new LOINC codes wherever needed and appropriate. Thus, for each laboratory system, we identified the percent of post-implementation local terms for which a new LOINC code was needed. Our prior analysis of laboratory result volumes in the INPC[13] demonstrated that a modest set of terms accounted for 99% of the volume at each institution, and that this same set of terms also captured all lab results for more than 99% of patients at that institution. Because of these findings, we determined how many of the lab tests accounting for 99% of the total result volume were post-implementation terms (excluding the reference lab terms). We also calculated the number of units of measure changes made after system implementation.

RESULTS

Overall, there were 28,629 terms from these eight systems in the INPC mapping tables. In total, we encountered 9,909 new terms after initial system implementation. Table 1 shows the number of pre and post –implementation terms for each institution.

Table 1. Pre and post-implementation terms by institution.

	Pre-Implementation (n)	Post-Implementation (n)
Regional Lab	2288	2088
Lab A	1046	1868
Lab B	7673	829
Reference Lab	1489	677
Rad A	1022	880
Rad B	3402	2286
Rad C	865	272
Rad D	935	1009
TOTAL	**18720**	**9909**

Combined, these four laboratory systems and four radiology systems create a constant stream of new terms. Figure 1 shows the growing number of post-implementation terms, aggregated by quarter. Of particular note is that this graph *excludes* all of terms that must be mapped in order to bring these system to implementation, but demonstrates the cumulative effect of adding new institutions into the INPC.

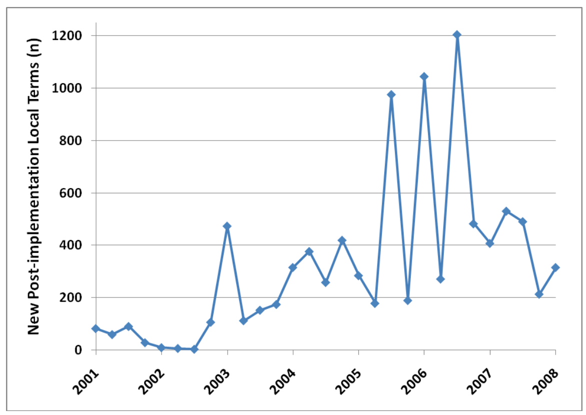

Figure 1. New post-implementation terms by quarter.

To examine how steadily new terms are created after system implementation, we plotted the combined number of post-implementation terms on a common axis of 'months post initial system implementation,' shown in Figure 2. We observed a slight overall downward trend (see trendline), but relatively large fluctuations. The peaks were mostly attributable to asynchronous boluses from individual (different) institutions, not coordinated term additions across systems.

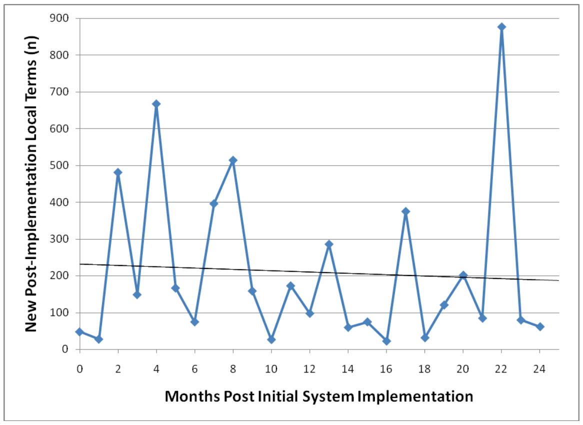

Figure 2. Post-implementation terms from all sources over time since implementation.

We have mapped most new terms encountered in message flows since implementation into our master dictionary. The percent of post-implementation terms mapped ranged from 93.7% to 98.6% for the laboratory systems and from 84.1% to 98.3% for the radiology systems. Reasons new terms were not mapped include: the term did not carry clinical results (flagged to ignore), not enough information was availble to assign a map, or the mapping was still "in-progress" at the time of this analysis. For post-implementation terms that were mapped, Table 2 shows the distribution of those that could be mapped to existing master dictionary terms and those for which a new master dictionary term was created.

Table 2. Post-implementation terms mapped to existing and newly created INPC master dictionary concepts.

	Mapped to Existing % (n)	**New Term Needed** % (n)
Regional Lab	71.7 (1415)	28.3 (558)
Lab A	87.3 (1608)	12.7 (233)
Lab B	57.5 (447)	42.5 (330)
Reference Lab	56.7 (377)	43.3 (288)
Rad A	66.2 (573)	33.8 (292)
Rad B	83.1 (1794)	16.9 (365)
Rad C	99.9 (848)	0.1 (1)
Rad D	100 (243)	0 (0)
TOTAL	**77.6 (7275)**	**22.1 (2067)**

For the 5462 new laboratory terms encountered after initial implementation, 468 needed a new LOINC code (8.6%). However, in total only 281 new LOINC codes were needed, because several local terms were mapped to the same LOINC.

For institutions included in our prior analysis of INPC result volume[13], we calculated the percent of post-implementation terms contributing to the most common tests (accounting for 99% of the overall result volume) and found that it ranged from 22.5% to 26.2%. Overall, the percent of terms in this "99% set" with volume from post-implementation tests was 26.7% for lab B, 54.1% for the regional lab (two institutions combined), and 85.7% for lab B.

In addition to encountering unknown local terms, many exceptions were generated by conflicts from units of measure. Table 3 shows unit-related changes made to both pre and post -implementation laboratory terms after the initial system implementation, as well as the overall rate of unit-related changes per month. Overall, these INPC laboratories trigger nearly 30 changes related to units of measure per month.

Table 3. Units of measure-related changes to pre and post-implementation terms and change rate by institution.

	Pre-Implementation Terms Changed (n)	**Post-Implementation Terms Changed** (n)	**Overall Change Rate** (changes/mo)
Regional Lab	246	464	7.5
Lab A	110	199	5.0
Lab B	277	44	5.6
Reference Lab	213	79	11.5
TOTAL	**846**	**786**	**29.6**

DISCUSSION

Successful HIEs must learn to embrace change. In the time that we have operated the INPC, we added half as many new post-implementation terms as those we added for initial system implementations. The rate with which we encounter new terms has increased by incorporating more institutions into the INPC, but as a group, these institutions have not slowed much in their rate of adding new terms after initial implementation. In general, we encountered unit-related exceptions less frequently than new unknown terms, but in combination, they form a large component of the ongoing maintenance burden.

Of the 9372 new post-implementation terms that we mapped to our master dictionary, 7275 (78%) could be mapped to exiting terms. The remaining 2067 (22%) terms required us to create a new dictionary term, which is a much more time consuming process. Fewer terms (8.6% of new laboratory terms) required new LOINC codes, providing evidence for LOINC's relatively complete coverage. Likewise, we have previously demonstrated LOINC's similarly good coverage for diagnostic radiology terms.[14, 15]

New terms added after initial system implementation were not merely esoteric, rarely used tests. Indeed, we observed that 26.7% to 85.7% of the common tests accounting for 99% of the total volume at a given institution had data contributed by post-implementation terms. These new, common terms included point of care tests; new codes for the same test performed with different methodology, instrument, or information systems; and, as is often the case with radiology tests, new codes for tests performed at additional sites within the care system. This last category illustrates one area where terminology needs within an organization (i.e to distinguish the same test performed at different sites) can have a large impact on the effort required for communication within an intra-organizational HIE.

While the surveillance and maintenance of mapping exceptions for an HIE is resource intensive, our centralized approach prevents each local system from having to dedicate the expertise, resources, and tools for the job. We make use of software tools such as the freely available Regenstrief LOINC Mapping Assistant (http://loinc.org) and our newly developed Exception Browser to maximize efficiency. The current growth in the INPC has been supported by efforts four dedicated domain experts and other informatics researchers helping guide the process. We continue developing, evaluating, and refining tools and approaches to help sustain continued growth of our HIE.

Our study has some important limitations. First, there many other kinds of processing errors, such as those related to patient, provider, and facility matching, that we did not include in this current report, but that are also essential to operating an HIE. Additionally, some aspects of exceptions managed by terminologists were not captured in our logs adequately enough to enable analysis, such as detailed data on other exceptions like result overwrite errors or the hindrance of poor messaging conformance (e.g. putting all of the results in the NTE segment) on efficiency of problem resolution. We also did not quantify the important role of message pre-processing for certain kinds of results such as microbiology. Furthermore, our experience as a centralized terminology resource may differ from HIEs that use a distributed approach.

CONCLUSION

Integrated HIEs offer great promise for moving us closer to the goal of consumer-centric and information-rich care.[1] Our study highlights the ongoing effort required to keep up with evolving source system terms in a regional HIE and the need to willingly embrace change along the way.

References

1. Thompson TG, Brailer DJ. The decade of health information technology: delivering consumer-centric and information rich health care. Available at: http://www.hhs.gov/healthit/documents/hitframework.pdf. Accessed March 14, 2008.
2. Smith PC, Araya-Guerra R, Bublitz C, et al. Missing clinical information during primary care visits. *JAMA*. 2005;293(5):565-571.
3. McDonald CJ, Overhage JM, Barnes M, et al. The Indiana network for patient care: a working local health information infrastructure. *Health Affairs*. 2005;24(5):1214-1220.
4. Finnell JT, Overhage JM, Dexter PR, Perkins SM, Lane KA, McDonald CJ. Community clinical data exchange for emergency medicine patients. *Proc AMIA Symp* 2003:235-238.
5. Finnell JT, Overhage JM, McDonald CJ. In support of emergency department health information technology. *Proc AMIA Symp* 2005:246-250.
6. Overhage JM, Dexter PR, Perkins SM, et al. A randomized, controlled trial of clinical information shared from another institution. *Ann Emerg Med*. 2002;39(1):14-23.
7. Overhage JM, Grannis S, McDonald CJ. A comparison of the completeness and timeliness of automated electronic laboratory reporting and spontaneous reporting of notifiable conditions. *Am J Public Health*. 2008;98:344-50.
8. McDonald CJ, Huff SM, Suico JG, et al. LOINC, a universal standard for identifying laboratory observations: a 5-year update. *Clin Chem*. 2003;49(4):624-633.
9. Cimino JJ. Desiderata for controlled medical vocabularies in the twenty-first century. *Methods Inf Med*. 1998;37:394-403.
10. AHRQ National Resource Center for Health Information Technology. Available at: http://healthit.ahrq.gov. Accessed March 14, 2008.
11. Vreeman DJ. Keeping up with changing source system terms in a local health information infrastructure: running to stand still. *Stud Health Technol Inform*. 2007;12:775-9.
12. McDonald CJ, Overhage JM, Tierney WM, et al. The Regenstrief Medical Record System: a quarter century experience. *Int J Med Inform*. 1999;54:225-53.
13. Vreeman DJ, Finnell JT, Overhage JM. A rationale for parsimonious laboratory term mapping by frequency. *Proc AMIA Symp* 2007:771-775.
14. Vreeman DJ, McDonald CJ. Automated mapping of local radiology terms to LOINC. *Proc AMIA Symp* 2005:769-773.
15. Vreeman DJ, McDonald CJ. A Comparison of Intelligent Mapper and Document Similarity Scores for Mapping Local Radiology Terms to LOINC. *Proc AMIA Symp* 2006:809-813.

Acknowledgements

The authors thank Larry Lemmon, Mark Tucker, and John Hook, and Theda Miller for assistance in data gathering. This work was performed at the Regenstrief Institute, Inc and was supported in part by the National Library of Medicine (N01-LM-3-3501).