Enhancing laboratory report contents to improve outpatient management of test results

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ABSTRACT
In today’s environment, providers are extremely time-constrained. Assembling relevant contextual data to make decisions on laboratory results can take a significant amount of time from the day. The Regenstrief Institute has created a system which leverages data within Indiana Health Information Exchange’s (IHIE’s) repository, the Indiana Network for Patient Care (INPC), to provide well-organized and contextual information on returning laboratory results to outpatient providers. The system described here uses data extracted from INPC to add historical test results, medication-dispensing events, visit information, and clinical reminders to traditional laboratory report results. These “Enhanced Laboratory Reports” (ELRs) are seamlessly delivered to outpatient practices connected through IHIE via the DOCS4DOCS clinical messaging service. All practices, including those without electronic medical record systems, can receive ELRs. In this paper, the design and implementation issues in creating this system are discussed, and generally favorable preliminary results of attitudes by providers towards ELRs are reported.

Primary care physicians (PCPs) face increasing demands of their time with a concurrent escalation in scope of provided services. Decisions are sometimes made on the fly, often without complete patient data. Studies show that follow-up of abnormal diagnostic test results represents one of the most problematic safety issues in outpatient medicine practice.1,2 This problem is exacerbated by several factors, namely: (a) patient information is often incomplete—many institutions generate clinical information relevant to patient care (from other providers, pharmacies, to acute care hospitals), and data from these sources might be unavailable to the PCP during a patient’s visit3; (b) patients often see multiple physicians in any given year—it has been shown that patients with several chronic diseases can see as many as 16 different physicians in a year, and that up to 34% of Medicare beneficiaries do not have a clearly designated PCP4; and (c) it is difficult to coordinate between providers—an analysis of Medicare claims data showed that in 2005, the typical primary care physician had 229 other physicians from 117 practices with whom care had to be coordinated.5

Examination of provider attitudes regarding the management of returned laboratory results has also been done previously. One study showed that in a survey of 15 internal medicine practices, only 41% of physicians reported being satisfied with how they managed test results. Furthermore, these providers spent an average of 74 min per clinical day managing those results. In another study, the majority of surveyed pediatricians reported safer and more effective care after implementation of an electronic results manager.6

These findings demonstrate a clear need to improve the way outpatient test results are handled. In this proof-of-concept case report, we tackled the problems of incomplete patient information and coordination of care issues during management of results ordered in the outpatient setting. We leveraged information stored in the Indiana Network for Patient Care (INPC) repository7—which serves the Indiana Health Information Exchange8—to identify relevant contextual information for returning laboratory results. This contextual information was incorporated into an Enhanced Laboratory Report (ELR) which was then delivered to the provider who had ordered the test via a widely used clinical-messaging program called DOCS4DOCS.9 The DOCS4DOCS application delivers results through a web portal and also via secure faxes, hence enabling practices without EMRs to be part of the health information exchange. The premise behind ELRs was that data available through a health information exchange network could be used to facilitate better clinical decisions, improve efficiency of care, and decrease errors—especially for practices with no EMRs.

In this paper, we describe the design, creation, and pilot evaluation of the ELR system. We specifically outline technical considerations and challenges in developing this system, and end-user attitudes towards the generated ELRs.

CASE DESCRIPTION
ELR processor components
Creating ELRs involved identifying the most relevant data elements to incorporate into the enhanced reports. Because the process of making a decision on a returned laboratory result often requires knowledge of historical laboratory results and relevant medications, we ensured that these elements were incorporated as part of the enhanced report. We included historical visit information as the third additional element. Clinical reminders were added as the final element to provide result-specific decision-support to providers viewing the result.

We developed an ELR processor to aggregate these additional elements into the original result. The processor analyzed all HL7 laboratory result messages flowing into INPC and identified those which needed to be enhanced. For these target results, the ELR processor extracted relevant data from various sources within INPC and appended them to the original result message. The sources of the extracted contextual information from INPC were: (a) the laboratory repository for historical laboratory
results; (b) the “Medication Hub” which contained data from RxHub\textsuperscript{10} and dispensing information from local pharmacies; and (c) the Master Encounter file which contained historical visit information. In addition, the ELR processor used the G-CARE decision-support engine\textsuperscript{11} to generate laboratory-specific reminders to be incorporated into the ELRs. With this additional information, the ELR processor generated a new HL7 message which contained the original result plus the appended contextual information. This “enhanced” HL7 message was transmitted by the ELR processor to DOCS4DOCS, which delivered the enhanced report to the ordering provider (see figure 1).

**ELR knowledge base design**

To create the knowledge base for elements included in historical laboratory results and relevant medications, we used two medical domain experts who were both board-certified Internal Medicine physicians. We started with a list of 10 laboratory tests to enhance: Creatinine, Hematocrit, International Normalized Ratio (INR), Phenytoin level, Phosphorous, Potassium, Thyroid Stimulating Hormone (TSH), Valproate level, Vitamin B\textsubscript{12} level, and White Blood Count (WBC). These tests were chosen by several criteria, namely: they were commonly ordered in ambulatory care practices; typically required historical data for medical decision-making; and involved varying degrees of complexity for interpretation. For each test selected for enhancement, we created relevant lab and medication associations which we called the “ELR Test Sets” and the “ELR Drug Sets,” respectively. The “ELR Test Sets” represented other tests identified by the domain experts as relevant to interpreting the laboratory test being enhanced, while the “ELR Drug Sets” represented relevant medications of consequence.

Table 1 represents an example of an ELR Test Set (TS) and Drug Set (DS) created for TSH. In this example, a TSH test result would trigger the ELR processor to refer to both ELR\_TS\_TSH and ELR\_DS\_TSH concept sets in the Regenstrief concept dictionary. By referencing the ELR\_TS\_TSH concept set, the processor would then extract and aggregate the corresponding child elements of historical TSH, free T4, T3, anti-TPO, and antithyroglobulin results for information on historical laboratory results. Similarly, the ELR Processor would reference the child elements in the ELR\_DS\_TSH concept set for relevant medications.

The third component of our enhanced reports entails the inclusion of historical encounters to providers within INPC. The number of previous clinical visits by the patient to be incorporated into ELRs was easily configurable, and was defaulted to display the last five clinical encounters. These encounter summaries include the encounter location and date, and the name of the physician who saw the patient.

The fourth and last step of knowledge-building involved the creation of clinical reminders. Using G-CARE rules developed at Regenstrief,\textsuperscript{11} we created automated reminder messages to help give guidance to clinicians as they interpreted the ELRs and made medical decisions. An example of a care-rule used for a TSH enhanced report is shown below:

\begin{verbatim}
[IF LAST "TSH" WAS GT 5.0 AND "AGE" IS GE 60 THEN REMIND Patient is over 60 years old, advise cautious dosing of

\end{verbatim}

![Diagram](Image)

**Table 1** ELR Test Set (ELR\_TS\_TSH) and Drug Set (ELR\_DS\_TSH) for thyroid stimulating hormone (TSH)

<table>
<thead>
<tr>
<th>ELR_TS_TSH</th>
<th>ELR_DS_TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSH</td>
<td>Thyroid meds</td>
</tr>
<tr>
<td>Free T4</td>
<td>Thyroid extr</td>
</tr>
<tr>
<td>T3</td>
<td>Levothyroxine</td>
</tr>
<tr>
<td>Anti-TPO</td>
<td>Levotyroxin inj</td>
</tr>
<tr>
<td>Antithyroglobulin</td>
<td>Thyroral 1</td>
</tr>
<tr>
<td>Antithyroid meds</td>
<td>Strong iodine</td>
</tr>
<tr>
<td>Propylthiouracil</td>
<td>Methimazole</td>
</tr>
<tr>
<td>Thyrolar 1</td>
<td></td>
</tr>
</tbody>
</table>

ELR, Enhanced Laboratory Report.
thyroid meds. Recommend waiting at least 4–6 weeks after thyroid medication adjustment prior to rechecking TSH.

In this case, the G-CARE rule would be triggered by a returned TSH result. The rule would check if two conditions were satisfied: first, if the returning TSH level was greater than 5.0, and second, if the age of the patient was greater than or equal to 60. If both conditions were satisfied, then the processor would automatically generate the message “Patient is over 60 years old, advise cautious dosing of thyroid meds. Recommend waiting at least 4–6 weeks after thyroid medication adjustment prior to re-checking TSH.” This message would be appended to the ELR.

The ELR processor created a new HL7 message with the original result plus the aggregated information and sent it to DOCS4DOCS. The DOCS4DOCS application then delivered the ELR to the provider identified in the message as the ordering provider for the test (see figure 2).

**EVALUATION**

To evaluate potential impact of ELRs, we ran the ELR processor on a retrospective sample of laboratory results that flowed into INPC from one major laboratory source. All results for inpatient providers and all tests with no assigned providers were filtered out. We took 10 random reports for each type of the enhanced lab, and further analyzed them to determine the different types of enhancements per report. Descriptive statistics are used to report these findings.

We also selected a convenience sample of nine primary care physicians who were users of DOCS4DOCS to review a subset of these reports for evaluation and feedback purposes. Inclusion criteria for the selection of participants included practicing primary care physicians, physicians who receive messages through DOCS4DOCS, and were primarily practitioners in the outpatient setting. Participants were asked to review these enhanced reports and rate the ELRs on the organization of the contents, the value of the added content, and potential workflow efficiency benefits of receiving enhanced reports in comparison to traditional (non-enhanced) reports. The respondents were reimbursed for their time. Descriptive statistics are used to summarize survey responses.

**RESULTS**

The ELR processor has been implemented at the Regenstrief Institute and works in real time. We have created the necessary knowledge bases for the ELR Test and Drug Sets and coded them into the Regenstrief concept dictionary. As the processor triggers upon the specified laboratory results, it refers to these coded sets,
extracts the relevant information from INPC repositories, and aggregates them into enhanced reports. These enhanced reports are delivered to providers through the DOCS4DOCS clinical messaging service, including providers without EMRs.

Over a 2-week period, a total of 82,566 enhanced reports were generated for data flowing from a single laboratory source. From a sample of 100 randomly selected enhanced reports (10 of each type of enhanced tests) we discovered that a median of 11 data elements were added to all reports: appended laboratory results (median=8, IQR=9.25), appended medications (25% had at least 1, max 15), and appended historical encounters (median=5, IQR=5). At the time of data sampling, the G-CARE reminders were not yet functional, though our most recent ELR iterations include them. As it turns out, the 10 tests we chose to enhance for our study would account for 11.46% of all labs ordered in the INPC for the year 2007.12

Preliminary results from physicians surveyed have been generally favorable. Six of the nine physicians surveyed were internal medicine physicians, two were family doctors, and one was a pediatrician. On a 5-point Likert scale, respondents rated ELRs as well organized (4.2±0.97) and easy to interpret (4.3±0.50). They stated that the additional data elements were valuable: relevant tests (4.2±0.75), contextual drugs (4±0.89), visit histories (3.25±0.71), and computer-generated clinical reminders (3.25±0.71). In comparison to traditional laboratory reports, respondents also noted that ELRs would generally save time (3.78±0.67), reduce the need to search for information (3.67±0.71), and improve the quality of care (3.72±0.67). The best overall indicator of general attitudes towards ELRs was asked by our final question in the survey: “I would prefer to receive Enhanced Reports in place of usual reports” (3.78±0.67).

DISCUSSION

Several key findings should be discussed in relation to our project and results to date. First, our work on ELRs demonstrates that by using novel data aggregation techniques, it is possible to create value out of existing accessible data. The value of these enhanced views of information depends on a well-developed health information exchange in order to deliver relevant information to providers at the right time. Most importantly, this information is specifically targeted and relevant to providers who do not have EMRs and who are simply signed up to receive their results through the DOCS4DOCS clinical messaging program.

As we developed and implemented the ELR processor we discovered challenges and complexities along the way. In the mapping and coding steps of the ELR Test and Drug sets into the Regenstrief concept dictionary, it became apparent that certain ostensibly important terms did not already exist in the dictionary. For example, when we initially conceived of the associated child elements for the CREATinine Drug Set, we included Biguanides, Sulfonylureas, Alpha-glucosidase inhibitors, and Thiazolidinediones. When these terms were being coded in, however, we discovered that the concept dictionary only had one existing less granular grouping for these types of medications: “Oral Hypoglycemics.” Other culprits included medications that involved multiple classes of drugs in combination such as combination antihypertensives (ie, Thiazide/B-blocker), oral hypoglycemics (ie, Sulfonylurea/Biguanide), and cholesterol medications (ie, HMG-Coenzyme A Reductase Inhibitors/Niacin). The hierarchical organization of dictionary terms is a complex issue. This gets to how dictionaries evolve over time—we know that dictionaries need to evolve gracefully,13 but this rarely happens in the real world. The complexities of maintaining dictionaries become apparent when they are utilized for use cases such as ELRs. Efforts are under way to further characterize the current granularity and structure of dictionary terms.

Naturally, more tests will need to be enhanced in addition to the 10 we have started with. Previous work has examined the frequency of tests ordered through all institutions in the INPC: 784 tests accounted for 99% of the volume from all institutions; 244—517 observation codes representing 99% of the volume at each institution also captured all results for more than 99% of the patients at those institutions.12 This work provides a viable and realistic strategy for deciding on which laboratory studies to enhance. If we, for example, targeted those same 244—517 tests to enhance, we would be covering all tests for more than 99% of all patients in the INPC. We naturally will be cognizant of the fact that not all reports would necessarily benefit from enhancement.

Some limitations of this work deserve mention. This paper focuses on the development of the ELR and has a minimal evaluation component. The work is thus preliminary, and results after implementation, especially on quality of care, are needed. The number of enhanced reports so far is small, and the number of providers surveyed is also small. ELRs depend heavily on the well-developed health information exchange and clinical messaging capability, and this might limit the generalizability of our approach.

Looking ahead, we plan to carry out further phases of this project by evaluating a larger cohort of live-implementation ELR users, and increasing the robustness and intelligence of the G-CARE rules into later versions of ELRs. These will likely take the form of rules which incorporate more data elements into the recommendation trees. In this phase, we will attempt to measure impacts to the clinical care process as a result of ELR implementation, specifically looking at time saved during medical decision-making and effect on provider actions when results are delivered to them in an ELR format as opposed to the traditional report with no enhancements.

CONCLUSION

We demonstrate through ELRs that a well-developed health information exchange infrastructure can potentially provide value to practices which do not have electronic medical records. By aggregating and organizing data from multiple sources, ELRs can help ensure that information is available to the right provider at the right time to facilitate the right decisions.

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