Design and implementation of a comprehensive outpatient Results Manager

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Abstract

Prior research has demonstrated that clinicians often fail to review and act upon outpatient test results in a timely and appropriate manner. To address this patient safety and quality of care issue, Partners Healthcare has developed a browser-based, provider-centric, comprehensive results management application to help clinic physicians review and act upon test results in a safe, reliable, and efficient manner. The application, called the Results Manager, incorporates extensive decision support features to classify the degree of abnormality for each result, presents guidelines to help clinicians manage abnormal results, allows clinicians to generate result letters to patients with predefined, context-sensitive templates and prompts physicians to set reminders for future testing. In this paper, we outline the design process and functionality of Results Manager. We also discuss its underlying architectural design, which revolves around a clinical event monitor and a rules engine, and the methodological challenges encountered in designing this application.

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1. Introduction

Failure to follow-up on abnormal diagnostic test results represents one of the most problematic safety issues in the practice of outpatient medicine [1]. When test results are not acted on in a timely and appropriate manner, patients’ safety and satisfaction are jeopardized. Prior research has shown that both patients [2] and physicians [3] are concerned with this issue, and results from other studies [4–7] further highlight the ongoing need to address this gap in quality. Moreover, this issue is beginning to receive more national attention. The Agency for HealthCare Research and Quality (AHRQ) [8], in a recent set of recommendations issued to patients on how to prevent medical errors, recommends to patients that ‘no news (on test results) is not good news,’ suggesting that existing results follow-up systems are inadequate to protect patients’ safety.

An examination of the traditional paper-based result management system offers some insights into the challenges faced by outpatient physicians as they manage test results for their patients. These results typically become available at varying times between patient visits, when the patient is not in the office to prompt the physician to review these results. To ensure timely review of these results, many clinics devote significant resources to organize the streams of incoming reports from different paper-based sources. For clinics without such resources, the onus falls upon the individual physician to assume that responsibility. Unfortunately, these paper-based systems are not robust and are subject to the frailties of human vigilance and memory [9]. These deficiencies in existing systems are not trivial given the high volume of data that each physician is responsible for reviewing. In a recent review of tests...
performed on patients followed at the internal medicine practices at the Brigham and Women's Hospital in Boston, MA, we found that a full-time primary care physician on average reviews 930 pieces of chemistry/hematology data and 60 pathology/radiology reports in a typical week. Moreover, prior research indicates that a significant number of physicians employ largely deficient systems to manage test results: 36% of clinicians do not routinely inform their patients about test results, and only 23% of primary care physicians have a reliable method to ensure that abnormal test results receive the appropriate follow-up [10].

In terms of patient outcomes, research also shows that clinicians need to improve the way they follow-up on abnormal test results [11]: about one-third of abnormal TSH [6], pap smears [12], and mammograms [5] do not receive timely follow-up in accordance with established clinical guidelines. This represents an important quality and safety issue in the outpatient setting as data from malpractice carriers point out that 30% of office-based diagnosis-related malpractice cases can be attributable to failures in the follow-up system [13]. The changing guidelines on disease management offer yet another layer of complexity to this issue.

While test results viewers have been one of the most widely used informatics applications in healthcare [14–16], there is, to our knowledge, very limited material in the informatics literature that describes applications designed to help clinicians actively and comprehensively manage all of their patients’ test results. Result viewers in typical information systems, for example, are designed only for passive retrieval: clinicians need to access, on their own initiative, the electronic medical record for each patient to see if new results are available for review. While a few institutions have implemented systems that actively notify clinicians about life-threatening test results in the inpatient setting [17–21], these systems have generally only addressed selected results that somehow indicate gross deviation in a patient’s status from expected norms. In outpatient clinical practice, however, results of different types may be important for decision making, even if they are normal or slightly abnormal [22]. Furthermore, the follow-up tasks in the outpatient setting are inherently different from the inpatient setting as physicians cannot closely monitor their patients and follow-up actions require the active and willing participation of the patients [23].

Clinicians clearly need help: a survey performed within Partners Healthcare (Boston, MA) indicated that 59% of primary care clinicians were not satisfied with their current system of result tracking. Given the high volume of data that need to be reviewed, the complexity of the follow-up tasks involved and the quality gaps in the follow-up of abnormal test results, it is not difficult to see why outpatient clinicians need systems to that help them prioritize, review and act upon streams of test result data. To address these issues around workflow and patient safety, Partners Healthcare has developed the Results Manager (RM), a browser-based, comprehensive, provider-centric tool to help clinicians manage patient test results in a reliable and efficient manner. This paper will highlight its design process, functionality, decision support features and underlying architectural design. It will also discuss the methodological challenges encountered in the design, implementation and maintenance of RM.

2. Clinical setting

RM has been developed for outpatient practices affiliated with Partners Healthcare in Boston, Massachusetts. Partners Healthcare was formed in 1994 by the Brigham and Women’s Hospital (BWH) and Massachusetts General Hospital (MGH). The Department of Information Systems (IS) at Partners Healthcare is responsible for developing and supporting a large variety of system-wide applications for inpatient and outpatient services, including inpatient physician order entry, patient computing, billing and bed control systems, an integrated patient data repository (Clinical Data Repository—CDR), a results viewer, and a browser-based ambulatory electronic medical record (Longitudinal Medical Record—LMR).

Approximately 1500 physicians working in 24 primary care and 14 subspecialty practices currently use the LMR to view their appointment schedules, record and review visit notes, prescribe medications, and manage problem and medication lists. Results of tests performed at all sites within our healthcare system are stored in the CDR. Prior to the development of RM, access to test results relied on the initiative of the ordering clinician. Moreover, clinicians typically had to access each patient’s CDR records multiple times in order to review results that arrive anywhere from hours to days after the clinical encounter. In order to support clinicians who preferred to receive active notification of test results as they become available, laboratories in our healthcare system would send test results on paper to individual clinics, which in turn would sort and file individual test results for clinicians to review.

3. User requirements specifications

At the beginning of the design process, we consulted key stakeholders of this application to ensure RM would satisfy the needs of its user base. Stakeholders included the medical directors of several primary care clinics, LMR user groups at both BWH and MGH, and the Director of Patient Safety at BWH. Based on iterative discussions with potential end-users, we decided that RM should:
• Present to the extent possible all results to the ordering clinician. These include results of tests ordered at the time of a visit, as well as those ordered between visits.

• Highlight results that require urgent attention by the clinician.

• Present results in the context of previous results, patients’ medication lists and problem lists.

• Allow clinicians to explicitly acknowledge and act on test results, and have their actions documented electronically.

• Re-present previously acknowledged results if the laboratory updates or corrects a result.

• Allow clinicians to track and review new test results on particular patients even if they are not the ordering provider. For example, a supervising attending may want to review results for tests ordered by his/her residents.

• Provide clinical decision support to improve compliance with national guidelines on the follow-up of abnormal results. For example, a physician reviewing cholesterol panel results for a patient should be presented with the LDL goal for that particular patient.

• Provide tools allowing clinicians to remind themselves to perform tasks in the future.

• Improve communication between patients and doctors regarding test results by providing users with tools to generate patient result letters.

• Allow users to mark visits as ‘taken care of’ after all results have been acknowledged and appropriate actions have been taken.

• Support different types of workflow in clinics so that ancillary staff and physician extenders (e.g., nurse practitioners) can review and act on results on behalf of the ordering provider.

• Alert providers whose patients have markedly abnormal results that remain unacknowledged by sending them an e-mail warning.

• Facilitate fail-safe mechanisms at the practice level that are not dependent on individual providers when there are important abnormal results.

Fig. 1. Results Manager front screen. View options—currently five options: (1) Open Visit Only—default view. Displays all open visits with results that require review. Clinicians may ‘close’ a visit after all follow-up actions for that visit have been completed. Closed visits are removed from this view. (2) Open and Closed Visits—displays all visits with results even if they have been previously ‘closed’ by a clinician. (3) Visits with User flags—displays all visits for which a user had previously placed free-text user-flags or comments. (4) Patient Watchlist—displays the panel of patients for which a clinician wants to receive all outpatient test results, regardless who ordered the test. (5) Schedule View—displays the list of patients on a clinician’s schedule for a particular day. If results are available for patients, they can also be reviewed from this view. CDR results—denotes that results of various types are available for review. The actual results for a patient can be reviewed by clicking the letters in this column. (1) C—Chemistry; (2) H—Hematology; (3) R—Radiology; (4) P—Pathology. Abn—denotes the degree of abnormality for the most abnormal result associated with the visit (see Table 2). Ack—a checkmark is displayed under this column if all results associated with the visit have been explicitly acknowledged by a clinician. Visit Note—a ‘fountain pen’ icon is displayed if clinic notes dated around the time of the visit are present. Providers may review the contents of the note by clicking on the ‘fountain pen’ icon. Notes that have been finalized are denoted by an ‘F’. Notes that are still in preliminary form are denoted by a ‘P’. An ‘F/P’ is displayed if both finalized and preliminary notes are present. Patient Letter—a ‘letter’ icon is displayed if a result letter has been written through RM. A ‘printer’ icon is displayed next to the ‘letter’ icon if the result letter has been printed. User Flags/Comments—a free-text field which gives the clinician the opportunity to annotate visits. Clinicians may record here the tests that were ordered during the visit, or any outstanding follow-up tasks.
4. User interface and screen flow design

To understand the workflow RM would need to support, we built browser-based mockups of the user interface early in the design process. The design team used these mockups as a tool to communicate our ideas during discussions with the user-base. During these discussions, the mockups served to illustrate how the user-base would use RM—for a full-time physician, RM would likely be used once to twice a day during clinic session 'down times' when clinicians would manage test results that had recently arrived; for a part-time physician, RM would likely be used a few times a week when the physician is away from the clinic. We refined the mockups in an iterative fashion based on feedback collected during seven focus group presentations. These mockups were ultimately incorporated into the technical specifications for our development team. We present here our final designs:

Fig. 1 shows the front screen of RM, which can be accessed with one mouse click from any screen within the LMR. Results on the RM front screen are grouped by their degree of abnormality. (See section below for details on how we classify the degrees of abnormality for results.) Critical and subcritical results, designated by ‘!!’ and ‘!’, respectively, are presented first in order to encourage providers to process them sooner. Within each category of critical, subcritical, abnormal or normal results, results are grouped by clinic visit dates. A result is associated with a particular visit if the result falls within a particular time-window of the visit with the clinician who ordered the test. Results that are ordered outside the time-window of any clinic visit are also listed but marked as having 'no visit.'

When a user has explicitly acknowledged every result associated with a visit, RM marks the visit as 'acknowledged' on the RM front screen. Users can also review notes and letters associated with the visit. Once a user has completed all tasks associated with a visit, s/he can select the visit and 'close' it. ‘Closed’ visits are then removed from the front screen of RM.

Fig. 2 shows the results review screen. The user accesses this screen by clicking the letters in the ‘CDR Result’ column of the front screen. The results linked to this visit are listed on the chooser on the left, with which the user can switch between different results. To provide a context in which to interpret the results, previous results as well as the patient’s problem list and medication list are displayed. A suggested course of action will be displayed in the ‘guidelines and alert’ box, and links to websites pertinent to the result being reviewed will also be displayed in this box (Fig. 3).

Users can indicate they have reviewed the displayed result by clicking the ‘Acknowledge Results’ button. They can also forward the active result to a colleague (e.g., to the nurse practitioner if she reviews and processes all pap smear results). In addition, they can also set a test-based reminder (test-tickler) that will prompt the user for further action in the future if a certain test is...
not repeated within a particular time frame. For example, a physician reviewing a slightly elevated calcium result can set a test-tickler that will prompt the physician in 6 months if the patient does not have a repeat calcium within that time frame.

Users can generate result letters for patients with minimal effort. When the user clicks the ‘Add Interpretation to Letter’ button, a letter-writing pad, pre-populated with the patient’s address and salutation (Fig. 4). A pre-generated interpretation of the result is then inserted into the letter. This text is generated by the rules engine (see below) using logic derived from clinical guidelines, and pertains to the result being reviewed. User-defined text (e.g., a paragraph to remind a diabetic patient to visit the podiatrist) can also be added to the letter. Users may choose to publish their
user-defined texts for use by the entire practice. Letters can be printed individually or in batch mode, and are saved into the medical record.

5. Clinical decision support specifications

In the current phase of RM implementation, all chemistry, hematology, pathology, and radiology results are reported to the ordering physician and others who have expressed an interest in the results. For each result reported, RM classifies its degree of abnormality, presents guidelines for managing the result, provides context-sensitive templates for physicians to generate result letters to patients and suggests reminders for repeat testing in the future. These decision support features are driven by predefined clinical rules that we had to develop, since rule sets specifically geared towards the outpatient population were not available. These rules are triggered as RM receives each test result from the laboratory source systems and interprets them. The output of these decision support rules is stored with the test result and RM makes the decision support output available to the user as he or she reviews each test result. The general structure of our decision support rules is presented in Table 1, together of an example of a specific rule handles marginally abnormal mammograms. We will discuss the different components of these decision support rules separately below.

5.1. Classifying the degree of result abnormality

Each result is classified by RM as (i) critical, (ii) sub-critical, (iii) abnormal or (iv) normal. Critical results are those that warrant urgent attention, such as potentially dangerous electrolyte levels. Criteria for critical results have been derived from long-standing guidelines adopted by physicians and nurse practitioners in our internal medicine clinics. Sub-critical results represent conditions that are rarely life-threatening in the short term but almost always require follow-up action. For example, pap smear results suggestive of malignancy would be considered a sub-critical result. Results are considered abnormal if they fall outside of the laboratory defined normal ranges, although clinically insignificant abnormal results (e.g., low alkaline phosphatase) will be suppressed to limit the number of tests unnecessarily marked as abnormal. Table 2 outlines the classification scheme for chemistry and hematology laboratory tests, pap smears, and mammograms.

RM groups test results by the degree of abnormality and patients with the most severely abnormal results are presented first to the users (Fig. 1). For patients with multiple results to be reviewed, RM uses the result with the highest degree of abnormality for a particular patient to determine the order in which it presents the patient to the user. For example, a patient with a critical result and two abnormal results is displayed amongst other patients with critical results.

5.2. Fail safe notification mechanism

To ensure timely review of results that might represent life-threatening conditions, RM notifies clinicians of critically abnormal results by electronic mail every 24 h if these results remain unacknowledged. Results that remain unacknowledged after two repeated attempts are forwarded to a pre-designated representative within the clinic, who will also be notified by email about why results are being forwarded.

To ensure that test results can be reviewed and acted upon even during a physician’s absence, we allow other physicians within the same clinic to process test results on behalf of a colleague. All actions, including result reviews, are logged centrally to ensure accountability and protect patient confidentiality.

5.3. Letter templates

As communication with patients plays an essential role in the follow-up of abnormal test results [7], RM supports the generation of result letters to patients. As each result is interpreted by RM using predefined decision support rules, a short paragraph designed for possible incorporation into a result letter is linked to the result. These paragraphs contain a brief explanation about the test result to the patient and, for certain results including cholesterol and hemoglobin A1c, a comment about how far the patient is from his or her goal level. When the clinician reviews results for a patient, he or she may use the associated predefined paragraphs to generate the result letter. Letters are available in both Spanish and English versions, and clinicians who declare proficiency in Spanish are given access to the Spanish versions of the paragraphs when they generate result letters to Spanish-speaking patients.

5.4. Test-ticklers

Certain patients with abnormal test results should also have further tests performed in the future. To facilitate this follow-up process, RM allows users to set reminders, otherwise known as ‘test-ticklers,’ for tests that need to be performed in the future. Based on the test result being interpreted, RM suggests what further tests should be obtained and when they should occur. The user can accept the default suggestions by RM, or set reminders for other types of follow-up tests. Once the test-tickler is set, if the patient undergoes the follow-up test as planned, the test-tickler is considered fulfilled. However, if the patient fails to obtain the follow-up test, RM will notify the clinician as they invoke RM.
5.5. Guidelines for abnormal test results

RM provides its users with suggestions on how to perform the follow-up of abnormal test results. These suggestions are derived from published clinical guidelines, such as the National Cholesterol Education Program [24], or local adaptations of national guidelines, such as the breast care guidelines published by the Harvard Risk Management Foundation [25], a malpractice insurance carrier. These suggestions are con-

Table 1
Decision support rule structure

<table>
<thead>
<tr>
<th>Rule component</th>
<th>Explanation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule descriptor</td>
<td>Rule name</td>
<td>Marginal abnormal mammogram</td>
</tr>
<tr>
<td></td>
<td>Rule description</td>
<td>Patients with a mammogram coded as BIRAD 3 should have a repeat mammogram in 6 months</td>
</tr>
<tr>
<td></td>
<td>Rule status</td>
<td>Active</td>
</tr>
<tr>
<td>Trigger logic</td>
<td>Trigger data type</td>
<td>Mammograms from radiology source system</td>
</tr>
<tr>
<td></td>
<td>Trigger evaluation logic</td>
<td>Rule evaluated as ‘positive’ if BIRAD code in mammogram report = 3</td>
</tr>
<tr>
<td>Notification logic</td>
<td>Severity flag</td>
<td>Sub-critical (non-urgent follow-up almost certainly needed)</td>
</tr>
<tr>
<td>Action logic</td>
<td>Default letter text (English)</td>
<td>“The mammogram performed on &lt;date&gt; showed a mild abnormality. While the appearance of this abnormality likely reflects benign changes in your breasts, I would recommend a repeat mammogram within 6 months. If you have not made the arrangements to schedule another mammogram within that timeframe, please make an appointment with me so we can make the appropriate arrangements”</td>
</tr>
<tr>
<td></td>
<td>Default letter text (Spanish)</td>
<td>“La mamografía que hicimos el día &lt;date&gt; mostró una anormalidad. Aunque un resultado como este podría representar cambios benignos, le sugiero repetir la mamografía dentro de 6 meses. Si no se han hecho arreglos para otra mamografía, por favor haga una cita conmigo para que nosotros podamos hacerlos”</td>
</tr>
<tr>
<td></td>
<td>Default tickler test type</td>
<td>Mammogram</td>
</tr>
<tr>
<td></td>
<td>Default tickler time-out period</td>
<td>6 months</td>
</tr>
<tr>
<td></td>
<td>Guideline text</td>
<td>“Marginally abnormal mammogram. Short-term follow-up as recommended by radiologist (usually 6 months) recommended”</td>
</tr>
<tr>
<td></td>
<td>Guideline link</td>
<td><a href="http://www.rmf.harvard.edu/rmLibrary/clinical-guidelines/breast-algo/screening/SCREEN_1.HTM">http://www.rmf.harvard.edu/rmLibrary/clinical-guidelines/breast-algo/screening/SCREEN_1.HTM</a></td>
</tr>
</tbody>
</table>

5.5. Guidelines for abnormal test results

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text-sensitive and they take into account the result being reviewed, as well as prior results, patient demographics, problem lists and medication lists. These suggestions are displayed in the alerts and guidelines box as the clinician reviews the test result. We have limited the length of these suggestions to 150 characters to avoid overloading the clinician with too much information. We provide clinicians who want further information about the guideline a link to the website where details of the guidelines can be reviewed (Fig. 2). These guidelines are kept in an on-line dictionary which is updated periodically by physicians on the project team.

6. Software architecture design

To support the workflow and decision support requirements for RM, we made significant investments in software infrastructure. The underlying architecture of RM (Fig. 5) revolves around a clinical event monitor [17,26–28] that processes all test results filed into the CDR for further evaluation by RM. The clinical event monitor then passes the result to the results filter, which will filter out inpatient results and associate results with the appropriate clinicians (Fig. 6). The results filter then passes results to the rules engine, which will apply pre-defined rules to the result (Fig. 5). Rules will determine the decision support parameters that should be displayed when the user reviews the result—these include the abnormal flags, recommendations for follow-up action and result interpretation for inclusion in the patient result letter. The rules engine will then place the result and relevant decision support parameters onto the results queue, which is indexed by recipients of results. When the user invokes RM user interface, the results queue is queried so that all results intended for the user will be displayed in the RM front screen. RM also records all actions performed on items on the results queue.

7. Current status

We have recently completed the pilot of RM in two clinics in our healthcare system and the application is actively being used by over 20 physicians and nurse practitioners in these two clinics. Prior to the pilot phases, we gave 1-h tutorials during the practice meetings. During the pilot phase, team members sat with users to observe their interaction with RM. Elements of the user interface that users found to be confusing were modified. We also used questions that users commonly asked during the training and observation sessions to refine the content of our training sessions.

### Table 2
Current classification scheme for the degree of abnormality in results

<table>
<thead>
<tr>
<th>Critical results</th>
<th>Sub-critical results</th>
<th>Abnormal results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemistry</strong></td>
<td>Sodium &lt;140</td>
<td>Cholesterol:</td>
</tr>
<tr>
<td></td>
<td>Potassium &gt;5.4 or &lt;3.0</td>
<td>• LDL &gt;100 in patients with</td>
</tr>
<tr>
<td></td>
<td>Glucose &gt;400</td>
<td>coronary heart disease or</td>
</tr>
<tr>
<td></td>
<td>Creatinine &gt;2.5</td>
<td>diabetes on problem list</td>
</tr>
<tr>
<td></td>
<td>BUN &gt;50</td>
<td>• LDL &gt;130 in patients with</td>
</tr>
<tr>
<td></td>
<td>Calcium &gt;12 of &lt;8</td>
<td>2 or more cardiac risk factors</td>
</tr>
<tr>
<td></td>
<td>Magnesium &lt;1.7</td>
<td>defined on problem list</td>
</tr>
<tr>
<td></td>
<td>Creatinine kinase &gt;300</td>
<td>• High triglycerides</td>
</tr>
<tr>
<td></td>
<td>AST/SGOT &gt;300</td>
<td>• Low amylase/lipase</td>
</tr>
<tr>
<td></td>
<td>ALT/SGPT &gt;300</td>
<td>• Low creatinine</td>
</tr>
<tr>
<td></td>
<td>Alk Phos &gt;300</td>
<td>• Low AST/SGOT, ALT/SGPT</td>
</tr>
<tr>
<td></td>
<td>Total bilirubin &gt;4</td>
<td>• Low Alk Phos</td>
</tr>
<tr>
<td></td>
<td>Direct bilirubin &gt;3</td>
<td>• Low total or direct bilirubin</td>
</tr>
<tr>
<td></td>
<td>Amylase &gt;120</td>
<td>• Low cholesterol, HDL</td>
</tr>
<tr>
<td></td>
<td>TSH &gt;20 or &lt;0.1</td>
<td>• Low triglycerides</td>
</tr>
<tr>
<td></td>
<td>Digoxin &gt;2</td>
<td>• Low amylase/lipase</td>
</tr>
<tr>
<td><strong>Hematology</strong></td>
<td>WBC &gt;15,000 or &lt;2000</td>
<td>HbA1c &gt;8.0 in patients with</td>
</tr>
<tr>
<td></td>
<td>Hematocrit &lt;30</td>
<td>diabetes on problem list</td>
</tr>
<tr>
<td></td>
<td>Platelets &lt;100,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ESR &gt;50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INR: &lt;1.6 or &gt;4.0 in patients</td>
<td></td>
</tr>
<tr>
<td></td>
<td>on warfarin</td>
<td></td>
</tr>
<tr>
<td><strong>Pap smears</strong></td>
<td>None</td>
<td>Any results suggestive of dysplasia or malignancy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mammograms</strong></td>
<td>None</td>
<td>Any results suggestive of malignancy</td>
</tr>
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</tbody>
</table>
As part of our formal evaluation plans, we are conducting a randomized controlled trial across our 24 primary care clinics to determine whether RM can improve the safety, reliability and efficiency of abnormal test result follow-up. Domains of study will include abnormal pap smears, mammograms, cholesterol and hemoglobin A1c. We will also survey clinicians’ satisfaction with their result management system and patients’ satisfaction with the way test results are communicated to them before and after the deployment of RM.

8. Methodological challenges

We describe here three challenges in the design and maintenance of RM and our approach in tackling these issues. The first issue concerns the identification of the recipients for test results when computerized order entry is not in place. The second issue concerns the ongoing management of the medical knowledge embedded within the application. The third issue concerns the completeness of clinical data supported by RM.

8.1. Association of patient results with providers and clinic visits

In order for any result management application to function, results must be assigned to the correct recipients. When orders for each test are recorded electronically through an ambulatory computerized physician order entry (ACPOE) application, this association can reliably be made by querying the order database to determine which order the test result at hand fulfills and which clinician placed the order. However, since ACPOE is still forthcoming in many organizations including ours, alternative approaches were needed.
One alternative would be to utilize pre-defined patient panels and associate an incoming result for a patient with all the physicians who have placed that patient on their panels (personal communication, Dr. Jim Jirgis, Vanderbilt University Medical Center). While this approach has many merits, our outpatient clinicians were concerned that they would be inundated with results for tests ordered by physicians of other specialties and during patients' hospital stays. Moreover, physicians in our institution do not have robust and efficient ways to define their panel of patients. Therefore, we adopted another approach.

We discovered during the design of RM that third-party payers do not reimburse for tests unless an ordering physician is identified. As a result, various mechanisms exist in our institution to ensure that out-patient test requisition forms are marked with an ordering provider. For this reason, we are able to identify the ordering provider for a large proportion of tests, including all chemistry and hematology tests performed in our institution. RM takes advantage of this information to identify the recipient for most results. However, since certain source systems within our institution do not maintain the ordering provider field using the standard enterprise-wide provider dictionary, the identity of the ordering provider may not always be available as RM processes each result. Currently, this is the case for pathology and radiology tests results. When this issue arises, we examine the appointments the patient has had within a pre-defined time frame of the test result and assign that result to the provider whose appointment with the patient falls temporally closest to the result. We also provide mechanisms to allow physicians to declare an explicit interest in a particular patient—a physician can place particular patients on a ‘watchlist’ for a period of time and all results that become available during that time window on those patients are sent to that physician, regardless of who ordered the test. A physician who has set a test-tickler for a particular test on a patient will also receive a copy of the result even if the physician is not the ordering provider. Users are educated on these two ways to express interest in patients’ results during training sessions for the application.

In summary, we learned in tackling this methodological challenge that ACPOE, while highly desirable, is not an absolute pre-requisite for the development of a results management application. When mechanisms exist to leverage the ordering provider information that is usually present for billing purposes, results can be streamed to their correct recipients. In this context, the ordering provider field for test results has significant value in terms of workflow efficiency and patient safety. This provides additional support for the creation, maintenance and use of a master provider index within a healthcare organization.

8.2. Management of medical knowledge

During the design phase of RM, we relied on feedback obtained during focus groups to guide our development of the medical knowledge base for RM. As far as possible, we also made use of well-established national guidelines that are well accepted by the local medical community. However, guidelines on many clinical issues, including how quickly abnormal test results should be acted on, remain to be fully developed. As national guidelines and practice patterns evolve over time, we recognize that the medical knowledge embedded in RM will have to be updated. We anticipate the use of several mechanisms to accomplish this task. First, we will rely on direct user feedback and our implementation experiences to help us refine the knowledge base. Second, we will conduct periodic review with physician leaders in the user base to update the knowledge base. Third, we will use automated tools to detect any broken weblinks embedded within the clinical decision support material.

We also plan to expand the scope of decision support that helps clinicians manage abnormal test results. Areas where we feel clinicians will benefit from further decision support include the management of abnormal liver function tests, thyroid function tests, prostate-specific antigen, and drug–laboratory interactions. Furthermore, as RM is rolled out to other specialty clinics, we will also need to adopt the decision support rules to their patient populations. For example, the rules for anemia and leukopenia for medical oncology patients should be different from those for primary care patients. To facilitate the refinement of existing rules and creation of new rules in the RM knowledge base, we are currently designing a ‘Rules Editor.’ This should diminish the time needed to translate knowledge established by new medical research into practice for physicians in our community.

8.3. Completeness of clinical data

RM leverages clinical data that are captured by the enterprise-wide clinical data repository (CDR). While this enables RM to display a large majority of test results used in the outpatient clinical setting, certain data types that are not yet captured by the CDR, including microbiology and neurophysiology data, cannot be displayed. As clinicians shifts their workflow from paper to electronic, they begin to ignore paper and there is a risk of missing important results. This underscores the importance of building complete enterprise-wide databases. As the CDR expands its data types, results manager will begin to support them. Our current plans call for the inclusion of microbiology within the next 6 months.

Another issue we have encountered is that not all test results are coded. Since RM is unable to interpret un-coded test results, important findings, such as nodules
on a chest radiograph, cannot be labeled on the user interface as results that require prompt attention. Our short-term approach is to label test results RM cannot fully interpret as ‘unable to categorize,’ and display these test results after the ‘sub-critical’ results but ahead of ‘abnormal’ results on users’ queue. In the long run, we will work with our ancillary testing staff to ensure that, to the extent possible, coded information is passed into the CDR. Natural language processing techniques [29] can also be explored to translate free-text clinical information into coded form.

9. Future directions

The software architecture created for the RM project can also serve as part of the information technology infrastructure for our healthcare organization. Data stored in the RM results queue can be queried by other applications currently in development. For example, our planned ambulatory order entry module [30] will be able to query it to determine if orders placed by clinicians for tests have been fulfilled. The results queue may also communicate with our secure patient website application to allow patients to review test result letters and/or test results.

10. Conclusion

Results management is an important activity for outpatient clinicians and we have built RM to facilitate this process. The strength of RM lies in its ability to comprehensively address the workflow for test result follow-up in the outpatient setting: it classifies the degree of abnormality for outpatient test results, provides context-sensitive templates for physicians to generate result letters to patients, presents guidelines for managing abnormal results, suggests reminders for repeat testing in the future and allows clinicians to electronically acknowledge the result. By providing these features in RM, we have satisfied the requirements initially laid out by our user-base. We have also employed iterative design methods to design a user-interface that fits into the clinicians’ workflow and we believe our application will reduce the time required for managing test results. In addition, by improving the reliability and efficiency of the test results management process and ensuring that important abnormal test results do not get lost, we believe RM will improve patient safety. Future studies are planned to quantify the impact of RM on safety outcomes.

References


[23] Poon EG, Haas JS, Puopolo AL, Gandhi TK, Burdick E, Bates DW, Brennan TA. Communication factors involved in the follow-up of abnormal test results: an analysis of women with marginally abnormal mammograms [submitted].


