ABSTRACT

Objectives: We sought to address concerns regarding recurring inpatient laboratory test order practices (daily laboratory tests) through a multifaceted approach to changing ordering patterns.

Methods: We engaged in an interdepartmental collaboration to foster mindful test ordering through clinical policy creation, electronic clinical decision support, and continuous auditing and feedback.

Results: Annualized daily order volumes decreased from approximately 25,000 to 10,000 during a 33-month postintervention review. This represented a significant change from preintervention order volumes (95% confidence interval, 0.61-0.64; \( P < 10^{-16} \)). Total inpatient test volumes were not affected.

Conclusions: Durable changes to inpatient order practices can be achieved through a collaborative approach to utilization management that includes shared responsibility for establishing clinical guidelines and electronic decision support. Our experience suggests auditing and continued feedback are additional crucial components to changing ordering behavior. Curtailing daily orders alone may not be a sufficient strategy to reduce in-laboratory costs.

Misutilization of clinical laboratory testing can lead to suboptimal patient outcomes and increased health care costs. In particular, unneeded testing may add expense, waste resources, lead to excessive phlebotomy, and increase the risk that key diagnostic data get overlooked in a mass of superfluous laboratory results. Unnecessary testing may also generate clinically misleading or falsely abnormal test results with potential downstream consequences, including additional diagnostic workup, needless patient anxiety, and inappropriate therapeutic intervention. Likewise, an incorrect test order or a failure to order a needed test can lead to delayed or incorrect diagnoses and may hinder optimal patient management and clinical outcomes. Unfortunately, suboptimal laboratory test utilization is commonplace, with some estimates placing the percentage of laboratory tests orders that are inappropriate or of questionable indication as high as 30%.

Clinician factors, including lack of experience and insufficient time, incentive, or training to tailor orders to specific diagnostic questions, as well as structural factors, including inadequate cost transparency and limited data-driven guidance on optimal test order practices, may contribute to laboratory test misutilization. One important contributor to improper test utilization may be recurrent test orders, including inpatient orders for daily laboratory tests. Daily laboratory test orders (eg, CBC, basic metabolic panel, and calcium/phosphorous/magnesium every...
Materials and Methods

Clinical Setting

This initiative was conducted at the Massachusetts General Hospital (MGH), a 983-bed tertiary care teaching hospital in Boston, Massachusetts. This project was undertaken as a Quality Improvement Initiative and, as such, was not formally reviewed by the institutional review board per its policies.

Quality Improvement Goals

An ad hoc committee including representation from both pathology and internal medicine was formed to improve clinical practice surrounding the use of inpatient orders for recurrent daily laboratory testing. In particular, while the committee fully acknowledged the clinical need to monitor certain analytes on a daily or more frequent basis under some clinical circumstances, we also agreed that in most cases, optimal clinical practice would include evaluating each patient’s testing needs on a daily basis. Thus, the committee developed a policy that, with limited exceptions, clinicians should not place orders for recurrent daily testing. Exceptions to this policy, whereby use of recurrent daily orders was permitted, are shown in Table 1. These exceptions were derived based on the consensus opinion of the committee. A final policy prohibiting the use of recurrent daily laboratory test orders with the exceptions noted was approved by the MGH Medical Policy Committee. This policy was primarily disseminated through order entry messages and emails as described below. Due to both technical limitations of the inpatient computerized provider order entry system (CPOE system) as well as clinical concerns related to missed testing, we decided initially (and later indefinitely) to not altogether eliminate the ability to order recurrent daily laboratory tests in the CPOE system. Rather, we sought to enforce the daily laboratory ordering policy through educational efforts and decision support initiatives as described below. A parallel initiative was implemented to reduce the presence of recurrent daily laboratory orders appearing on templates (order sets) to only those deemed to be clinically indicated.

Electronic Decision Support

On April 17, 2012, a decision support alert was implemented in the CPOE system indicating that “Daily lab orders are NOT indicated in most cases.” (See Table 1.)

Table 1

Appropriateness Categories for Daily Orders

<table>
<thead>
<tr>
<th>Test</th>
<th>Acceptability Criteria</th>
<th>Automated Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTT</td>
<td>Patient taking heparin</td>
<td>Indication field contains the word heparin or warfarin. (This is one of the checkboxes available on the order entry screen.)</td>
</tr>
<tr>
<td>PT</td>
<td>Patient taking warfarin</td>
<td>Indication field contains the word warfarin. (This is one of the checkboxes available on the order entry screen.)</td>
</tr>
<tr>
<td>Tacrolimus</td>
<td>Any order</td>
<td></td>
</tr>
<tr>
<td>Any laboratory test</td>
<td>Chemotherapy patient</td>
<td>Indication contains the phrase <em>chemo</em> where * is the wildcard.</td>
</tr>
<tr>
<td>Any laboratory test</td>
<td>Ordered using an approved template</td>
<td>Template used is automatically reflected in the order. Orders reflecting a template were deemed “appropriate.”</td>
</tr>
</tbody>
</table>

PT, prothrombin time; PTT, partial thromboplastin time.
Supplemental Figure 1 for screenshots of the CPOE system and alerts; all supplemental materials can be found at American Journal of Clinical Pathology online.) This alert appeared in the electronic ordering system each time an order with frequency greater than one occurrence was selected. There had previously been an alert related to daily laboratory test orders, although this was only displayed when the clinician selected three or more occurrences for an order. The justification for the order was also captured by the CPOE system, as providers were required to select one of three approved indications for the daily laboratory test (patient taking warfarin, patient taking heparin, chemotherapy regimen) or manually enter another indication. Inpatient CPOE orders, including clinician-entered indications, were stored in a Structured Query Language server-based database (datamart) that was established previously to support quality improvement and utilization management initiatives.

Email Reminders for Inappropriate Daily Laboratory Tests

On November 5, 2012, we implemented a system of weekly email reminders to clinicians who had placed four or more daily orders in the prior week (each for four or more collections or “until discontinued”) without an apparently approved indication as shown in Table 1. In addition to the indications shown in Table 1, recurrent daily orders entered using templates (order sets) were considered to have an approved indication as the management of order sets was institutionally reviewed for clinical appropriateness. Of note, ordering templates provided an “additional laboratory tests” feature, allowing laboratory tests not built into the template (and thus not specifically institutionally reviewed) to be ordered during the template order entry process. Because these additional laboratory tests were also tagged as template orders in our data set, we counted these as appropriate in both our email generation process and analysis in this article, representing a possible limitation in our approach. Finally, although the clinical appropriateness of daily orders in the intensive care unit (ICU) setting was internally debated, given the clinical considerations and complexities of care in this setting, ICU orders were also deemed to be appropriate in the context of this project. Inpatient locations were classified as ICU vs non-ICU locations using a manually maintained table; while we made efforts to ensure the accuracy of this table and keep it up to date, as well as generally classified ICU locations correctly, for parts of our study period, the table led to an overly restrictive definition of ICU locations.

We generated the reminder emails using a semi-automated process. This process used a script (run as a Microsoft Access [Microsoft, Redmond, WA] macro) that we ran each Monday. This script queried the laboratory datamart for daily orders occurring during the prior week (Monday through Sunday) and classified each order as having or not having an approved indication using the heuristics defined in Table 1. The script then generated a list of MGH user names for clinicians who placed four or more orders without an approved indication. This list of usernames was pasted into the Bcc line of a form email that was then sent. Prior to sending the emails, a pathologist (J.M.B. or A.S.D.) also reviewed a list of all daily orders placed during the prior week by clinicians flagged to receive the email. The pathologist occasionally removed the clinician from the email list at his discretion based on the nature of the orders and the indications provided. The process of order review and email generation required less than 30 minutes of pathologist time most weeks. In addition, although daily ICU orders were not considered permitted, ICU orders were not counted toward email criteria. The verbiage of the email is shown in Supplemental Figure 2. The email was designed as a nonpunitive reminder. This procedure was followed according to protocol most weeks; on infrequent occasions, weeks were missed or emails were sent on days other than Monday (eg, when investigators were out of town).

Metric Definitions

The basic unit of analysis we used to develop our metrics was the “ordering event,” which we define as all laboratory tests ordered on a single patient during a single date-time (to the minute) combination. A single ordering event routinely included more than one laboratory test. When describing metrics, we subsequently use the term order to mean “ordering event.” We focused our analysis on recurrent daily orders for four or more collections (or “until discontinued” daily orders), and as used in subsequent descriptions, we define daily order to mean a recurrent daily order placed for four or more collections or placed “until discontinued.” We consider daily orders “appropriate” if they meet the automated appropriateness heuristics defined above for use in sending reminder emails, including appropriateness criteria shown in Table 1, orders originating from templates, and ICU orders. Otherwise, we consider them “without an apparent approved indication.”

Of note, for the purposes of the analyses reported in this article, we used the ICU location classification table as it was at the conclusion of the study period, rather than any of the various earlier versions of the classification table used to generate emails earlier in the study period.
We used location within the hospital as a surrogate for the primary medical or surgical service caring for the patient. This may occasionally misattribute a patient to an ordering service due to table limitations or in the case of “boarders.” Order locations for which 10 or more daily orders were issued during 2014 were included. Two ordering locations accounting for 204 total orders in 2014 (1.6% of daily orders for 2014) could not be attributed to a service and were excluded from the analysis regarding services. We used laboratory results data as a surrogate for “hospital admissions.” In particular, each unique patient, admit-date, hospital location combination was counted as an admission to the corresponding location (and hence corresponding medical or surgical service). While most hospital admissions were attributed to just a single service, a patient who is admitted to an ICU setting and then transferred to a general medicine unit prior to discharge would be counted as two admissions (one for the ICU and one for the general medicine floor).

Data Analysis

We monitored the impact of the initiative using orders data and test results data queried from our institutional datamart. The orders data presented in this article are based on orders placed between January 2, 2012, and August 3, 2015. Analysis was performed in Microsoft Access 2007 (Microsoft), and figures were generated with the python scripting language as implemented in the Anaconda software package (Python 3.5.1 in Anaconda 2.4.1 [32-bit]; Continuum Analytics, Austin, TX).

We computed confidence intervals for rates of daily laboratory test ordering and P values denoting the statistical significance of observed differences in daily ordering rates before and after the interventions using the Poisson exact test as implemented in the R statistical program (R Core Team, Vienna, Austria). We evaluated the trend in the rate of daily laboratory test ordering during the postintervention period using a Poisson generalized linear model as implemented in R to evaluate the monthly rate of daily laboratory test orders as a function of calendar months postintervention.

Results

Our data set included 61,664 daily laboratory test orders, and 48.5% (29,940/61,664) of ordering events met automated appropriateness heuristics as outlined in Table 1.

The frequency of orders by ordering service for 2014 is presented in Figure 1. Here services may represent multiple order locations (different wards) that are then aggregated by medical service. Medical services represent the most common origination location of daily orders in comparison to surgical and pediatric services, as shown in Figure 1A. Daily order volumes normalized to admission volumes are presented in Figure 1B. For this analysis, we defined an admission event as a unique patient, admit-date, location combination from which a laboratory order was received. Comparing daily order volumes to admissions reveals that the rates of daily orders are higher in the ICU settings than in the non-ICU settings.

Indications

The most commonly ordered tests (those ordered as daily orders more than 500 times over the review period from January 2, 2012, to August 3, 2015) are presented in Figure 2A. This includes both commonly ordered individual tests such as magnesium as well as panels such as electrolytes. The top 10 most commonly ordered tests as daily orders account for 89% of the total daily order test volume.

Order indications for the same period (January 2, 2012, to August 3, 2015) were grouped for the top 500 occurring indications. This aggregated summary is presented...
in Figure 2B. Commonly listed indications included patients taking warfarin, those undergoing chemotherapy, or patients deemed to be critically ill. Less common indications included the test being needed for a study protocol or because a particular team recommended the test.

Impact of Intervention

During a 90-day preintervention baseline period (January 2, 2012, through March 31, 2012), 6,463 orders for recurrent daily laboratory tests (more than three collections, without an apparent approved indication) were placed for a mean daily rate of 71.8 orders per day (95% confidence interval [CI], 70.1-73.6). During the 1,003-day postintervention period (consisting of the 33 full calendar months immediately succeeding the implementation of weekly emails), 44,900 orders for recurrent daily laboratory tests (more than three collections, without an apparent approved indication) were placed for a mean daily rate of 44.8 orders per day (95% CI, 44.4-45.2), representing a highly significant decrease in...
daily laboratory test ordering (rate ratio, 0.62; 95% CI, 0.61-0.64; \( P < 10^{-16} \)). Furthermore, during the 33-month postintervention period, there was an overall downward trend in the monthly rate of daily laboratory test ordering (\( P < 10^{-16} \)), averaging a 2.5% monthly decrease. The rate of daily laboratory test ordering during the 5 full calendar months between the CPOE intervention and the start of the email intervention was 73.4 daily laboratory test orders per day (95% CI, 72.0-74.8; based on 11,230 daily orders over 153 days), which was not significantly different from the rate during the 90-day baseline period (\( P = .16 \)).

The effect of the initiative over time is shown in Figure 3. Daily order volume was reduced by approximately 60% during the observation period (annualized order volume decreasing from 25,000 to 10,000), while hemoglobin result volume, a test that we use as a benchmark for our total result volume, remained roughly unchanged during this same period (Figure 3A). Inpatient admission volumes increased slightly during the period (~47,000 in fiscal year 2011 to ~50,000 in fiscal year 2015). Changes in order and result volume for specific analytes are presented in Figure 3B. Total orders and total results for specific analytes were not significantly different over the observation period (Figures 3C and 3D).

### Discussion

Our initiative to curtail use of routine daily test orders resulted in a long-term shift in ordering practice, with an eventual reduction in daily order use by approximately 60%. Typically, laboratory utilization initiatives lead to immediate changes in test utilization.\(^\text{20,21}\) In contrast, the immediate impact of this daily laboratory test ordering initiative was modest (note the trend in Figure 3A), with the effects manifesting as a slow but steady downward trend in daily laboratory test utilization over the course of several years. Based in part on discussions with residents, we speculate that this slow but steady shift represents a change in physician test ordering culture. In particular, few residents immediately changed their daily test ordering behavior as a result of our initiatives. However, over time, the continued alerts, emails, and other discussions around this issue led to shifts in laboratory test ordering.
practices that we suspect may represent a change in cultural attitudes. Other authors have noted similar related effects, documenting test reduction “spillover” to the order practices of other assays than the intended utilization targets, suggesting the possibility of cultural shifts in ordering practices.4,19

A related consideration is that in many cases, the “interns” (eg, first-year residents) were the ones placing orders and receiving alerts and email notifications. The intern cohort includes physicians training in a wide spectrum of disciplines, including internal medicine, surgical specialties, and others. It has been previously published that trainees, especially interns, are largely responsible for test ordering practices and significantly contribute to observed variation in test utilization.22 Nonetheless, many ordering decisions and “unwritten” standard test ordering practices may be driven by more senior residents. We postulate that in many cases, the electronic alerts and email messages had an educational impact on the interns that was not in turn translated to practice until the following years when these physicians who received this education as interns became more senior members of the team with greater decision-making authority.

We note that despite the very substantial reduction in daily laboratory test ordering, overall utilization of inpatient routine laboratory testing did not appreciably decline. We propose several explanations for this finding. Since routine test volumes vary according to numerous factors, the impact of our daily laboratory test initiative may have been obscured by confounding factors and statistical noise, including an increase in admission volume during the study period (4.5%). Likewise, although we were not able to directly calculate the proportion of test results originating as daily orders, we estimate that daily orders account for a minority of total test results. Thus, we would expect a percentage change in daily test orders to represent a smaller percentage change in overall volumes. This effect may have been partially offset, however, by the fact that daily orders likely have an outsized influence on overall utilization stemming from their recurrent nature.

Moreover, the goal of this initiative was to promote thoughtful, clinical “hypothesis-driven” test ordering decisions, not to reduce utilization per se. This is in contrast to similar initiatives where the a priori stated goal was volume reduction.4,23 We anticipate that some physicians may not have reduced their overall testing but instead redirected testing to patients and circumstances where it was most needed. Nonetheless, it should be noted that curtailing daily orders alone may not be a sufficient strategy to reduce in-laboratory costs.

While effective at reducing test utilization during a defined intervention period, some prior studies have been limited by short postintervention observation periods and a strong reliance on one-time or short-term provider education.1,18 The effects of education initiatives have previously been reported to be variable and transient.2,5,8 Continuous auditing and feedback are crucial to the success of such large utilization initiatives.1,6,9,24 A recent systematic review of interventions to reduce laboratory testing concluded that multifaceted approaches involving a combination of education, system changes, incentives or penalties, and auditing and feedback are able to achieve the largest reductions in test use.24 Examples of multi-intervention utilization initiatives are being increasingly tried and available in the literature.3,4,22,23 Due to the multiple concurrent facets of our intervention, we are not able to tease apart the specific impact of any particular component. However, based on the research in this area and our experience, we suspect the elements of this intervention acted synergistically to achieve the sustained decrease in daily order requests.

Our study is subject to several limitations. First, our analysis is based on a before-and-after comparison and, as such, lacks a formal control group. Thus, we cannot definitively exclude the possibility that some of the observed changes in test ordering patterns may be due to confounding by factors coinciding with but unrelated to the interventions. However, we are not aware of any internal or external influences unrelated to our utilization management efforts that would have affected the use of recurrent daily orders and thus believe that the observed change was in all likelihood primarily due to our interventions.

A second limitation of our initiative relates to the targeting of our decision support alert. As is common in many academic medical centers, patient care in most cases at our hospital is driven by a team, including medical students, residents, fellows, and attending physicians, rather than by a single physician. However, responsibility for entering laboratory orders often falls to the more junior member of the team, and accordingly, only the junior members of the team may directly interact with the decision support. Nonetheless, decisions about test selection and frequency would generally include input from the entire team, particularly some of the more senior members, and thus our decision support measures may not reach some of the predominant decision makers.

A third limitation to our approach and analysis is that providers could use workarounds to place daily orders, entering the orders in a manner that would not trigger our audits. For example, placing staggered sets of orders to occur every other day or writing in daily orders on templates could have circumvented our auditing process and accounting of daily testing for this analysis.
However, informal data reviews did not suggest that such workarounds were present. In addition, an analysis of template order volumes did not suggest any substantive changes in the use of template daily orders. Moreover, given the nonpunitive nature of our intervention, there would have been little incentive for physicians to pursue such workarounds.

Despite these noted limitations, we believe our experience demonstrates that meaningful and sustained reductions in the frequency of recurring laboratory orders can be made through decision support and targeted utilization management. Successful implementation of such an initiative requires support from the many stakeholders, the employment of a multimodal decision support solution, and, most important, time. While such an initiative is unlikely to generate significant cost-savings, there are presumed benefits to patient experience (decreased phlebotomy) and possible improved outcomes (decreased risk for false-positive test results and subsequent interventions), although these effects are difficult to capture and require further study.

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References