Use of a Checklist and Clinical Decision Support Tool Reduces Laboratory Use and Improves Cost

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OBJECTIVE: We hypothesized that a daily rounding checklist and a computerized order entry (CPOE) rule that limited the scheduling of complete blood cell counts and chemistry and coagulation panels to a 24-hour interval would reduce laboratory utilization and associated costs.

METHODS: We performed a retrospective analysis of these initiatives in a pediatric cardiovascular ICU (CVICU) that included all patients with congenital or acquired heart disease admitted to the cardiovascular ICU from September 1, 2008, until April 1, 2011. Our primary outcomes were the number of laboratory orders and cost of laboratory orders. Our secondary outcomes were mortality and CVICU and hospital length of stay.

RESULTS: We found a reduction in laboratory utilization frequency in the checklist intervention period and additional reduction in the CPOE intervention period [complete blood count: 31% and 44% (P < .0001); comprehensive chemistry panel: 48% and 72% (P < .0001); coagulation panel: 26% and 55% (P < .0001); point of care blood gas: 43% and 44% (P < .0001)] compared with the preintervention period. Projected yearly cost reduction was $717,538.8. There was no change in adjusted mortality rate (odds ratio 1.1, 95% confidence interval 0.7–1.9, P = .65). CVICU and total length of stay (days) was similar in the pre- and postintervention periods.

CONCLUSIONS: Use of a daily checklist and CPOE rule reduced laboratory resource utilization and cost without adversely affecting adjusted mortality or length of stay. CPOE has the potential to hardwire resource management interventions to augment and sustain the daily checklist.

The cost of health care in the United States ($8,745 annual per capita in 2012) is the highest in the world. Despite a high percentage of the US Gross Domestic Product consumed by health care, as a nation we are not benefiting from improved health. As high-use environments, ICUs contribute significantly to this high cost, with an estimated consumption of 20% to 30% of all health care expenditures. In response, the Institute for Health Care Improvement has conveyed that quality improvement efforts must consider control of health care expenditures. Apart from expensive innovative technologies, an important component of health care spending is the high utilization of low-cost services such as laboratory tests and radiographs. Studies have shown high variability in the intensity of these services provided to similar patients among major US academic medical centers. These practices are not necessarily guided by published practice guidelines.
or expert consensus and are not associated with higher quality of care or improved survival.6–10 Multiple reports suggest that an important percentage of diagnostic studies may be medically unnecessary, redundant, and contribute to potential harm.3,11–16 We recognized that laboratory testing was susceptible to high utilization in our pediatric cardiovascular ICU (CVICU), where testing may be ordered daily or more frequently without strong clinical justification. To address this potential overutilization, we implemented a CVICU-based initiative consisting of a paper-based “daily checklist” and clinical decision support tool embedded within computerized order entry (CPOE). These tools have been shown to align provider ordering with current best practices, promote cost-effectiveness, and ultimately improve patient care quality.17–26

The objective of this report is to describe the impact of this initiative on laboratory resource utilization and the cost of inpatient care as well as to examine possible unintended consequences of this initiative.

METHODS

This quality improvement initiative was implemented in the pediatric CVICU at Lucile Packard Children’s Hospital of Stanford University School of Medicine in Palo Alto, California. This is a 303-bed, freestanding, quaternary care center with a busy 20-bed CVICU that provides comprehensive critical care for pediatric cardiac medical and surgical patients. Lucile Packard Children’s Hospital has a fully electronic system for provider orders and interdisciplinary documentation and has previously leveraged this system for various quality improvement efforts in the ICUs.23,24,27–31 The CVICU implemented CPOE using the platform provided by Cerner Corporation (Kansas City, MO) in October 2010. The daily checklist and CPOE interventions were implemented in September 1, 2009, and October 1, 2010, respectively. Institutional review board approval was obtained from Stanford University for the report of outcomes associated with this initiative.

Interventions

This initiative consisted of 2 interventions targeted at facilitating and reinforcing the daily assessment of need for laboratory testing of patients. The first intervention, initiated September 1, 2009, consisted of a multidisciplinary checklist enabling physicians to assess the necessity for laboratory testing of patients on a daily basis. The checklist was designed to be simple, brief, actionable, and integrated into daily clinical rounds. CVICU attending physicians, advanced practice providers, fellows, and nurses received training on the use of the daily checklist before implementation. Several CVICU-based champions were identified to promote and facilitate the reliable use of the checklist. To monitor our performance, use of the checklist and laboratory utilization rates were tracked regularly. The second intervention was initiated in October 1, 2009. It consisted of a clinical decision support tool embedded within our CPOE system with a rule to restrict order entry for certain laboratory tests (including complete blood cell counts, chemistry, and coagulation panels) to a single 24-hour time frame, thus enforcing the daily needs assessment of laboratory utilization. This intervention was deployed as part of a hospital-wide Clinical Resource Management program that included provider education (conferences, newsletters, and screen savers), utilization audits with feedback to practitioners, and CPOE-based restrictions. The methodology describing the CPOE rule at our center has been described previously.24

Study Design

To evaluate the impact of both interventions on laboratory utilization and costs, we conducted an observational retrospective cohort study in the CVICU at Lucile Packard Children’s Hospital. All medical and surgical patients with congenital or acquired heart disease admitted to the CVICU from September 1, 2008, until April 30, 2011, were included. The preintervention period was from September 1, 2008, until August 31, 2009. The postintervention period included the post-checklist period (September 1, 2009–September 30, 2010) and the post-CPOE period (October 1, 2010–April 30, 2011). Data on laboratory utilization including complete blood cell count, chemistry, coagulation, and point-of-care studies completed per day were collected and categorized as preintervention, post-checklist intervention, and post-CPOE intervention.

Measures

Outcome measures included temporal laboratory utilization rates and hospital costs associated with laboratory utilization changes. Laboratory utilization rate 13 months after implementation of the daily checklist and 7 months after implementation of CPOE intervention were compared with baseline values. Cost translates to the actual expense incurred by the center. Estimated cost reduction was based on comparing actual laboratory costs before and after the intervention. The cost to our hospital is ($25) per test for approved American Medical Association laboratory panels and individual laboratory tests performed by the Stanford clinical laboratories. Estimated costs are nominal and were not adjusted for inflation. Balancing measures assessed to evaluate potential unintended consequences of
our interventions included adjusted mortality rate, CVICU length of stay (LOS), and total hospital LOS.

Statistical Analysis

One-way analysis of variance was used to compare patient characteristics, laboratory utilization rates, CVICU and total LOS, and mortality in the preintervention, post-checklist, and post-CPOE intervention periods. Multivariate regression with adjustment for age, gender, weight, medical versus surgical reason for patient encounter, and Risk Adjustment for Congenital Heart Surgery (RACHS-1) categories was then used to further evaluate our outcomes. RACHS-1, a validated and widely used grouping of individual cardiac procedure types with similar risks, was included to account for confounding from variability in case mix.\textsuperscript{3,2} RACHS-1 categories were divided into groups 1, 2, 3, and 4–6 for analysis. Statistical significance was determined a priori as a 2-tailed \( P < .05 \). Statistical analysis was performed with Stata software (version 12, StataCorp, College Station, TX).

RESULTS

Over the study period, we evaluated at total of 1278 patients encounters (15 851 CVICU patient days) and 88 620 laboratory tests. We noted a higher number of CVICU patients per month in the post-checklist period, but no significant difference in the preintervention and post-CPOE periods. There was an overall higher mean number of patients per month during the postintervention compared with the preintervention period (43 vs 37, \( P < .0001 \)), resulting from a higher mean number of both surgical (38.7 vs 36.3, \( P = .03 \)) and medical patients (4.3 vs 0.9, \( P < .0001 \)) during the postintervention compared with the preintervention period. There was a higher number of CVICU patient days per month in both the post-checklist and post-CPOE periods compared with the preintervention period. RACHS-1 categories were similar in all 3 periods (Table 1).

Laboratory Utilization Rates

Over the study period, there were significant reductions in laboratory utilization in both the post-checklist and post-CPOE intervention periods when compared with the preintervention period. Specifically, there was a 44\% reduction in complete blood cell counts, 72\% reduction in comprehensive chemistry panels, 55\% reduction in coagulation panels, and 44\% reduction in point of care blood gases after the implementation of both interventions (Table 2). Adjusted laboratory utilization remained significantly lower in the postintervention period: mean complete blood cell count per patient day was 1.5 (95\% CI 1.4–1.6) in the preintervention period and 1.0 (95\% CI 0.8–1.2) in the postintervention period, \( P < .0001 \); mean comprehensive chemistry panel count per patient day was 1.5 (95\% CI 1.3–1.6) in the preintervention period and 0.6 (95\% CI 0.4–0.8) in the postintervention period, \( P < .0001 \); mean coagulation panel per patient day was 0.7 (95\% CI 0.5–0.7) in the preintervention period and 0.4 (95\% CI 0.3–1.0) in the postintervention period, \( P < .0001 \); and mean point of care blood gases per patient day was 7.5 (95\% CI 7.1–7.9) in the preintervention period and 4.7 (95\% CI 3.8–5.6) in the postintervention period, \( P < .0001 \). We observed the greatest reduction in point of care blood gases, reflecting concern that point-of-care testing is particularly vulnerable to inappropriate and overutilization.\textsuperscript{23} An adjusted subgroup analysis of laboratory utilization within the various RACHS-1 categories demonstrated a decrease in laboratory utilization across all subgroups (Table 3).

Cost Comparison

We evaluated the average daily cost in the preintervention period and after the adoption of both interventions. These data demonstrated a daily cost reduction of $1028.11 after the interventions were implemented. The highest cost reduction occurred for point-of-care blood gases, which accounted for $731.58 in daily cost reduction. Assuming this daily cost reduction, this projects an estimated total direct cost reduction of $375 260 per year based on variable direct costs.

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**TABLE 1** Patient Characteristics in the Preintervention and Postintervention Periods

<table>
<thead>
<tr>
<th></th>
<th>Preintervention(^a)</th>
<th>Post-Checklist(^b)</th>
<th>Post-CPOE(^c)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVICU total patients/mo, mean (SD)</td>
<td>38.09 (8.97)</td>
<td>45.25 (7.92)</td>
<td>59.74 (4.74)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Medical, mean (SD)</td>
<td>1.05 (1.24)</td>
<td>5.19 (2.67)</td>
<td>3.56 (2.06)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Surgical, mean (SD)</td>
<td>37.14 (8.14)</td>
<td>40.06 (6.08)</td>
<td>36.18 (4.13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CVICU patient d/mo, mean (SD)</td>
<td>425.31 (135.80)</td>
<td>566.29 (103.63)</td>
<td>526.89 (90.37)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age (mo), median (range)</td>
<td>13.26 (0–514.80)</td>
<td>16.62 (0–762.24)</td>
<td>11.10 (0–606.96)</td>
<td>.03</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>221 (51.15)</td>
<td>308 (53.85)</td>
<td>147 (53.65)</td>
<td>.72</td>
</tr>
<tr>
<td>Wt (kg), mean (SD)</td>
<td>16.92 (20.24)</td>
<td>20.51 (24.13)</td>
<td>19.10 (25.41)</td>
<td>.05</td>
</tr>
<tr>
<td>RACHS-1 1</td>
<td>25 (5.79)</td>
<td>27 (4.72)</td>
<td>9 (3.28)</td>
<td>.21</td>
</tr>
<tr>
<td>2</td>
<td>85 (21.99)</td>
<td>80 (14.00)</td>
<td>50 (18.25)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>150 (34.72)</td>
<td>188 (32.87)</td>
<td>106 (38.69)</td>
<td></td>
</tr>
<tr>
<td>4–6</td>
<td>56 (12.96)</td>
<td>66 (11.54)</td>
<td>28 (10.22)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Preintervention period was between September 1, 2008, and August 31, 2009.

\(^b\) Post-checklist period was between September 1, 2009, to September 30, 2010.

\(^c\) Post-CPOE period was between October 1, 2010, to April 30, 2011.
Balancing Measures

A comparison of patient outcomes in the preintervention and postintervention periods is shown in Table 4. There was no significant association in adjusted mortality rate associated with laboratory utilization changes (odds ratio 1.1, 95% CI 0.7–1.9, P = .65) in the overall population and across RACHS-1 subgroups (Table 5). Overall adjusted CVICU LOS was similar in the pre- and postintervention periods: preintervention mean CVICU LOS was 13.6 days (95% CI 10.5–16.8) compared with 14.1 days (95% CI 8.8–19.3) in the postintervention period, P = .69. Subgroup analysis demonstrated higher CVICU LOS in RACHS-1 category 1, similar CVICU LOS in RACHS-1 categories 2 and 3, and lower CVICU LOS in RACHS-1 categories 4–6.

Adjusted total LOS was also similar in both periods: preintervention mean total LOS was 24.5 days (95% CI 20.3–28.7) compared with 23.9 days (95% CI 16.9–31.0) in the postintervention period, P = .71. Subgroup analysis demonstrated lower total hospital LOS in RACHS-1 categories 1 and 4–6 and similar total LOS in RACHS-1 categories 2 and 3.

**TABLE 2** Laboratory Utilization in the Preintervention and Postintervention Periods

<table>
<thead>
<tr>
<th></th>
<th>Preintervention</th>
<th>Post-Checklist</th>
<th>Post CPOE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete blood count</td>
<td>1.65 (0.72)</td>
<td>1.14 (0.69)</td>
<td>0.93 (0.53)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1.55 (0.77)</td>
<td>0.84 (0.70)</td>
<td>0.46 (0.46)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coagulation</td>
<td>0.72 (0.59)</td>
<td>0.58 (0.62)</td>
<td>0.35 (0.41)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Blood gas</td>
<td>7.09 (2.90)</td>
<td>4.51 (2.40)</td>
<td>4.18 (1.87)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Preintervention</th>
<th>Post-Checklist</th>
<th>Post CPOE</th>
<th>P</th>
</tr>
</thead>
</table>
| Preintervention period was between September 1, 2008, and August 31, 2009.  
Post-checklist period was between September 1, 2009, to September 30, 2010.  
Post-CPOE period was between October 1, 2010, to April 30, 2011.  
Values are means ± SDs per CVICU patient day.

**DISCUSSION**

Previous reports have highlighted that high laboratory utilization is linked to high medical costs and does not improve patient outcomes. Variability in practice, fear of litigation, and unchecked standing orders are described as the leading reasons for excessive utilization of healthcare resources. Although there are reports of quality initiatives with the purpose of targeting laboratory overutilization, the data on the impact these initiatives have on health care cost is scarce. We present a quality initiative in our center that resulted in decreased laboratory utilization for several routine tests. This translated into a significant reduction of inpatient-related costs. We evaluated mortality and LOS as balancing measures to ensure that the initiative to improve resource utilization did not adversely affect patient outcome and found that reduction in laboratory utilization was not associated with overall increased mortality or LOS.

Subgroup analysis across RACHS-1 categories confirmed no significant difference in mortality across all risk groups and no significant difference in CVICU and total hospital LOS among

Patients in RACHS-1 categories 2 and 3, representing the majority of our total population. We noted a
slightly longer duration in the CVICU, albeit without a longer total hospital duration, in the lowest complexity group after the interventions, which suggests that laboratory testing plays an important role in determining discharge eligibility from the CVICU. More important, we found there was a significant decrease in both CVICU and total LOS for the more complex operations (RACHS-1 categories 4–6). This suggests that decreasing unnecessary testing may have important consequences on avoidable LOS (for example, by averting additional tests and procedures that are based on laboratory findings with questionable clinical relevance in high-complexity patients).

Our findings have significant implications for ICUs across the country, which strive to provide outstanding yet cost-efficient patient care. There are several potential reasons that we were able to improve our laboratory utilization.

By implementing a simple daily laboratory-necessity checklist and enforcing this evaluation in real-time during the ordering process with the use of CPOE, we were able to standardize care and reduce potentially unnecessary laboratory tests. We found that the combined impact of the checklist and computerized clinical decision support tool was associated to a substantial and sustained reduction of laboratory resource utilization and cost to our hospital. The daily checklist provided a practical, inexpensive tool to promote thoughtful assessment of laboratory needs and foster resource stewardship each day at clinical rounds. Clinical decision support through our CPOE rule provided just-in-time advice to reinforce this daily needs assessment precisely at the time of decision-making.\(^{35}\) CPOE interventions designed to improve clinical decision-making have shown varying results in part associated to tool design.\(^{36,37}\) It is likely that our use of interruptive alerts, which require provider acknowledgment and action, contributed to the amplified reduction in laboratory utilization rates observed.\(^{36,37}\)

We found that the reduction of low-cost but frequently used services is an important source of improving health care expenditures. Although the unit cost of laboratory testing is seemingly miniscule compared with other expensive health care products and services, the routine and daily nature of laboratory testing can be a pernicious source of healthcare waste. The estimated reduction in cost from laboratory materials is significant, but associated cost such as avoidable unneeded medical testing, invasive procedures, and patient distress,\(^{38–40}\) along with the potential benefits by minimizing iatrogenic anemia,\(^{15,16}\) have far-reaching implications in the mission to improve value in health care delivery.

A number of limitations to our study deserve discussion. First, the results from our observational retrospective study design are vulnerable to secular changes. For example, it is possible that differences in laboratory testing might be associated with differences in patient population or other factors. Although we used multivariate analysis to control for confounding from patient characteristics and case mix, there remains the possibility of unmeasured confounders that may have affected laboratory utilization. Second, because of concurrent quality improvement interventions that may have influenced laboratory utilization, it is challenging to distinguish the impact of these interventions alone. Third, we were limited to the metrics of mortality and LOS as indicators of patient care quality. Although important, these metrics are crude evaluations of quality and thus limited our ability to determine the comprehensive impact of decreased laboratory testing on other more granular quality metrics such as infection rates or pain satisfaction scores, which should be included in the tracking and evaluation of similar initiatives. Finally, this is an experience from a single institution and may not be generalizable to other institutions, although previous CPOE-enabled interventions at our institution have been effectively implemented elsewhere.\(^{41}\) Institutions that do not use trainees or advanced practice practitioners may find overall different laboratory utilization rates.

**Table 5** Subgroup Analysis of Patient Outcomes in the Preintervention and Postintervention Periods by RACHS-1 Category

<table>
<thead>
<tr>
<th>RACHS-1</th>
<th>RACHS-1 2</th>
<th>RACHS-1 3</th>
<th>RACHS-1 4–6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality, OR (CI)</td>
<td>NA (no deaths)</td>
<td>1.00 (0.96–5.15)</td>
<td>1.48 (1.49–4.54)</td>
</tr>
<tr>
<td>(P)</td>
<td>.02</td>
<td>.24</td>
<td>.07</td>
</tr>
<tr>
<td>CVICU LOS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preintervention, mean (CI)</td>
<td>13.70 (7.27–20.13)</td>
<td>6.36 (4.86–7.86)</td>
<td>12.98 (10.49–15.47)</td>
</tr>
<tr>
<td>Postintervention, mean (CI)</td>
<td>15.41 (2.39–30.43)</td>
<td>5.29 (4.13–4.99)</td>
<td>12.46 (8.21–15.47)</td>
</tr>
<tr>
<td>(P)</td>
<td>.02</td>
<td>.24</td>
<td>.07</td>
</tr>
<tr>
<td>Total hospital LOS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postintervention, mean (CI)</td>
<td>22.00 (6.57–42.41)</td>
<td>12.92 (6.57–15.62)</td>
<td>20.57 (13.39–23.20)</td>
</tr>
<tr>
<td>(P)</td>
<td>.04</td>
<td>.55</td>
<td>.007</td>
</tr>
</tbody>
</table>

Preintervention period was between September 1, 2008, and August 31, 2009, and postintervention period was between September 1, 2009, and April 30, 2011. OR, odds ratio.

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CONCLUSIONS
We observed a reduction in laboratory utilization rates after the institution of a daily checklist. We achieved an even greater reduction when this daily needs assessment was integrated into CPOE. This translated to a significant reduction in health care cost without adversely affecting quality of care. As growing health care expenditures continue to be a significant generational issue, we emphasize the importance of quality initiatives, especially those that hardwire evidence-based practices, to optimize health care resource conservation and promote value-based health care.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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ABBREVIATIONS
CI: confidence interval
CPOE: computer order entry
CVICU: cardiovascular intensive care unit
LOS: length of stay
RACHS-1: Risk Adjustment for Congenital Heart Surgery


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