

# Reducing Electrolyte Testing in Hospitalized Children by Using Quality Improvement Methods

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**BACKGROUND AND OBJECTIVES:** Despite studies indicating a high rate of overuse, electrolyte testing remains common in pediatric inpatient care. Frequently repeated electrolyte tests often return normal results and can lead to patient harm and increased cost. We aimed to reduce electrolyte testing within a hospital medicine service by >25% within 6 months.

**METHODS:** We conducted an improvement project in which we targeted 6 hospital medicine teams at a large academic children's hospital system by using the Model for Improvement. Interventions included standardizing communication about the electrolyte testing plan and education about the costs and risks associated with overuse of electrolyte testing. Our primary outcome measure was the number of electrolyte tests per patient day. Secondary measures included testing charges and usage rates of specific high-charge panels. We tracked medical emergency team calls and readmission rates as balancing measures.

**RESULTS:** The mean baseline rate of electrolyte testing was 2.0 laboratory draws per 10 patient days, and this rate decreased by 35% after 1 month of initial educational interventions to 1.3 electrolyte laboratory draws per 10 patient days. This change has been sustained for 9 months and could save an estimated \$292 000 in patient-level charges over the course of a year. Use of our highest-charge electrolyte panel decreased from 67% to 22% of testing. No change in rates of medical emergency team calls or readmission were found.

**CONCLUSIONS:** Our improvement intervention was associated with significant and rapid reduction in electrolyte testing and has not been associated with unintended adverse events.

Overuse of resources is a growing problem in health care, with up to 47% to 54% of health care spending classified as waste in some estimates.<sup>1,2</sup> In pediatrics, in part as a result of a sharp increase in spending,<sup>3,4</sup> there is a growing recognition of the need to decrease waste in the care of children.<sup>5,6</sup> In addition, there is also increased understanding that unnecessary care has inherent risks

and costs but provides no benefit to patient outcomes.<sup>7-9</sup>

One frequent source of waste and excess spending is diagnostic laboratory testing, for which as much as 20% may be overuse.<sup>10</sup> Overuse can be defined as tests whose results are not expected to change diagnostic, management, or prognostic plans. There is a growing movement to reduce overuse of testing,

## abstract



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Dr Tchou led overall conceptualization and design of the study, acquired data, analyzed and interpreted the data, drafted the initial manuscript, and reviewed and revised the manuscript; Drs Tang Girdwood, Wormser, Poole, Davis-Rodriguez, Caldwell, and Hagedorn and Ms Shannon were members of the primary improvement team who contributed to the design of the quality improvement study and interventions, performed ongoing data interpretation, and critically reviewed the manuscript; Drs Biondi, Simmons, and Anderson contributed to the conceptualization and analysis of the quality improvement study and critically revised the manuscript for important intellectual content; Dr Brady contributed to conceptualization and design of the study, acquired data, analyzed and interpreted the data, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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including several Choosing Wisely guidelines<sup>11–13</sup> and frameworks for high-value testing.<sup>14–16</sup> Routine laboratory tests in the inpatient setting are frequently ordered but often not expected to return abnormal results.<sup>17–22</sup> This excess testing may result in pain from phlebotomy,<sup>23,24</sup> anemia from excess blood loss,<sup>25,26</sup> and poor sleep for patients and caregivers from early-morning laboratory draws.<sup>27–30</sup> In some cases, excessive testing may also lead to a cascade of repeated testing after false-positive results, especially in tests organized as panels, for which the overall chance of a false-positive increases.<sup>31–33</sup> Overuse of testing also increases the workload of staff who obtain blood samples and physicians who review the results. All of these outcomes negatively affect health care value, defined as outcomes achieved per dollar spent.<sup>34</sup>

The overall goal of our quality improvement project was reduction in overuse of inpatient laboratory testing, with a resulting improvement in the value and experience of care. We targeted electrolyte testing because of its frequent use and a body of literature in which researchers indicate it can be frequently repeated even when not clinically indicated.<sup>19,21,32</sup>

Our specific aim for this study was to reduce the number of electrolyte tests ordered per patient day by 25% for children admitted to the hospital medicine service. Our secondary aims were to reduce overall charges related to electrolyte testing and to reduce ordering of the highest-charge electrolyte panel.

## METHODS

### Context

Cincinnati Children's Hospital Medical Center (CCHMC) is a large, quaternary care pediatric health system with >700 hospital beds. The

CCHMC hospital medicine service has 6 clinical teams at 2 locations (the main hospital and a satellite location) who care for >7000 admissions per year. The hospital medicine team most commonly admits patients with general pediatric issues, such as bronchiolitis, pneumonia, and asthma, but also cares for patients with complex chronic conditions. Each team is staffed by an attending physician and 1 to 5 residents and may also have a hospital medicine fellow or nurse practitioner. Within the hospital system, bedside nurses typically perform phlebotomy for laboratory tests, and there are no scheduled phlebotomists. A residency-wide high-value care curriculum including a series of lectures and case conferences began concurrently with our project.

### Planning the Intervention

We assembled a multidisciplinary improvement team of faculty, fellows, residents, nurse practitioners, and an administrative resident. We also engaged key stakeholders, including bedside and vascular access nurses, family and patient councils, as well as attending physicians, fellows, residents, and nurse practitioners who rotate on the hospital medicine service.

Initial interviews and surveys among hospital medicine providers and residents indicated a consensus that our teams order more electrolyte testing than necessary. Because of the challenges of determining overuse on a case-by-case basis, the improvement team decided to use overall rates of testing as a primary measure and established a goal for reduction of testing on the basis of review of similar improvement projects<sup>35,36</sup> and our observed local rates of testing in specific low-value categories (eg, daily repeated testing). On the basis of these results and further process observations, our improvement team developed key drivers of overuse (Supplemental

Fig 4), created a process map, and completed a failure modes and effects analysis of electrolyte test ordering (Supplemental Fig 5). Key drivers of reducing test overuse included discussion of the necessity of laboratory orders within the primary and consulting teams, awareness of recurring laboratory orders, developing best-practice guidelines for electrolyte testing, electronic medical record (EMR) order design, knowledge of the cost of testing, and staff engagement.

We performed a quality improvement study to determine the effect of our intervention on the rate of electrolyte testing. This study was reviewed and designated as exempt by the CCHMC Institutional Review Board.

### Improvement Activities

We present our improvement activities as organized around the 6 key drivers. Each activity was tested and implemented on all hospital medicine teams unless otherwise noted.

#### *Electrolyte Value Education*

At the launch of our improvement efforts, presentations in which the rationale for the project and interventions were detailed were made to residents at their main educational conference and to the hospital medicine division. Further education occurred at monthly 30-minute resident orientation sessions. Ongoing e-mail reminders were sent to attending physicians weekly and to residents monthly, coinciding with the first day of their rotation.

#### *Individual Feedback on Ordering Behavior*

During the initial stages of our improvement project, direct observations of rounds occurred with follow-up discussion with residents on the value and impacts of testing. Residents were asked if any changes to management occurred

**TABLE 1** Electrolyte Panels Included in Primary Measure and Corresponding Results and Charges

Test Name	Included Results										Total No. Results	Relative Charge <sup>a</sup>
	Na	K	Cl	Co <sub>2</sub>	BUN	Cr	Glucose	Ca	Ph	Alb		
Renal panel	X	X	X	X	X	X	X	X	X	X	10	\$\$\$\$
BMP	X	X	X	X	X	X	X	X	X		8	\$\$\$
CMP <sup>b</sup>	X	X	X	X	X	X	X	X		X	9	\$\$\$\$
Electrolyte panel	X	X	X	X							4	\$\$
Individual test	X	X	X	X	X	X	X	X	X	X	1	\$

Alb, albumin; BMP, basic metabolic panel; Ca, calcium; Cl, chloride; CMP, complete metabolic panel; Co<sub>2</sub>, bicarbonate; Cr, creatinine; K, potassium; Na, sodium; Ph, phosphate; SUN, serum urea nitrogen.

<sup>a</sup> \$\$\$\$\$ = highest charge, \$ = lowest charge.

<sup>b</sup> CMP also includes liver function test results, which are not included in the "Total No. Results" column.

as a result of the laboratory test result, if the patient had intravenous fluids stopped or was discharged soon after testing, if the test had a previously normal result within the last day, if the patient had multiple phlebotomies in the same day, and if the resident thought the test was necessary in hindsight. After an initial 3-week trial, we transitioned to discussing testing decisions with senior residents after rounds. We later transitioned to bimonthly check-ins with the entire resident team as the project progressed.

#### High-Value Tip and Control Chart Display

To provide overall feedback on the intervention, the most recent control chart and a high-value tip was displayed at resident conferences and distributed in a resident newsletter weekly.

#### Cost Reference Cards

Through discussion with the hospital finance team and use of hospital finance software, the team acquired the average charge and estimated cost for common hospital medicine laboratory tests, including 4 different electrolyte panels and individual electrolyte tests. Cost reference cards (Supplemental Fig 6) were created from this information and attached to mobile rounding workstations and above desktop workstations. During orientation sessions, residents were instructed on the content and use of the cards, and later they were asked for feedback.

#### Targeting of Highest-Charge Panel for Reduction

As a means to reduce overuse of the renal panel (Table 1), our highest-charge electrolyte panel, educational e-mails and orientation sessions for both attending physicians and residents were changed to include a clear statement to avoid using the highest-charge panel except in instances where it would be beneficial for patient care.

#### Standardized Laboratory Plan Template in Patient Notes

Providers were not always aware of the current laboratory plan, so a standard laboratory plan was added to all history, physical, and progress notes. This standard template detailed the current laboratory orders, frequency, and rationale for testing and was updated daily by the note writer and reviewed by attending physicians when cosigning the notes (Supplemental Fig 7). After initial rollout of this intervention, the improvement team tracked how often the template was used and accurately represented the laboratory plan, with feedback given to individual providers and teams weekly.

#### Structured Round Discussions

To encourage the discussion of testing necessity, a structured laboratory plan discussion was incorporated on rounds, during which residents would discuss the necessity of any ongoing or newly ordered laboratory tests. Commonly,

residents used their progress notes to guide their presentations and were encouraged to use their laboratory plan template as a prompt for this discussion.

#### Eliminating AM Laboratory Tests

A review of the timing of laboratory draws indicated that >60% were drawn during the overnight nursing shift, between 12 AM and 8 AM. The improvement team observed that frequently these tests became unnecessary after discussion later on rounds. On 2 hospital medicine teams, we implemented an intervention to eliminate most laboratory tests drawn before rounds. The intervention was discontinued after 2 weeks when it was discovered that shifting the laboratory draw burden from overnight to day-shift nursing presented significant workflow challenges.

#### Discouraging Use of Daily Laboratory Ordering

It was observed that residents ordering laboratory tests for a frequency listed as "AM Rounds" (1 of 3 default choices) did not realize that this frequency was a daily repeating order. We worked with information services to remove this option from the default options that appeared when providers ordered laboratory tests.

#### Study of the Interventions

Baseline electrolyte testing results data from January 1, 2015, to

August 1, 2016, were collected retrospectively via a real-time decision support tool (Vigilanz, VigiLanz Corp, Chicago, IL) linked to the EMR. To understand the impact of our improvement interventions and allow for rapid-cycle learning, testing results were retrieved on a weekly basis throughout the intervention period. A census of hospital medicine inpatients was derived from divisional billing data for both the baseline and intervention time periods. Charge and cost data for tests were obtained through an institutional financial system (MicroStrategy Enterprise, MicroStrategy Inc., Tyson's Corner, VA) linked to hospital charges and cost estimates.

## Measures

We defined our primary measure as the weekly number of electrolyte laboratory draws per 10 patient days on all hospital medicine teams. Electrolyte laboratory draws were defined as the total number of instances in a patient's stay when an electrolyte test (or tests) were drawn. If multiple electrolyte tests were obtained at the exact same time, and thus only required 1 blood sample, they were counted as 1 laboratory draw to most accurately capture the patient's experience and staff workflow impacts of testing. All panels that contained at least 1 electrolyte test and individual electrolyte tests were included in this measure (Table 1). We also included nonelectrolyte tests that are commonly found on most electrolyte panels, such as creatinine or blood urea nitrogen. Electrolyte laboratory draws were then divided by the weekly number of patient days to account for high seasonal variation in the hospital population and hence variable patient days in which patients could potentially have testing. We chose 10 patient days as the denominator to create a resulting measure that was generally >1. We

also measured the rate of use of our highest-charge panel, the renal panel.

To measure the total number of individual results clinicians reviewed, we also followed the weekly volume of electrolyte results that were generated from testing orders. This rate was expressed as weekly laboratory test results per 10 patient days. In this measure, an order for a single sodium test would contribute 1 result, whereas an order for a basic metabolic panel would contribute 8 results (Table 1). To measure the financial impact of testing on patient-level billing, we also measured charges for electrolyte testing, expressed as weekly charges per patient day. This measure was calculated by using hospital pricing software to calculate the average charge for each individual test. Total weekly rates of charges for each individual test were then calculated and summed to produce an aggregated weekly charge per patient day.

To monitor whether decreasing usage of electrolyte testing led to adverse clinical effects, such as hyponatremic seizures or electrolyte-related arrhythmias, we also followed balancing measures of medical emergency team (MET) (also called a rapid response team) use and readmissions within 7 days of discharge.

## Analysis

Measures were evaluated by using both run and statistical process-control charts,<sup>37,38</sup> and established rules for determining special cause variation were employed. Our primary measure of electrolyte tests per 10 patient days was evaluated on a statistical process-control u-chart. Secondary measures and balancing measures were also evaluated with control charts. Highly variable data such as charges were evaluated by using an XMR control chart.<sup>39</sup>

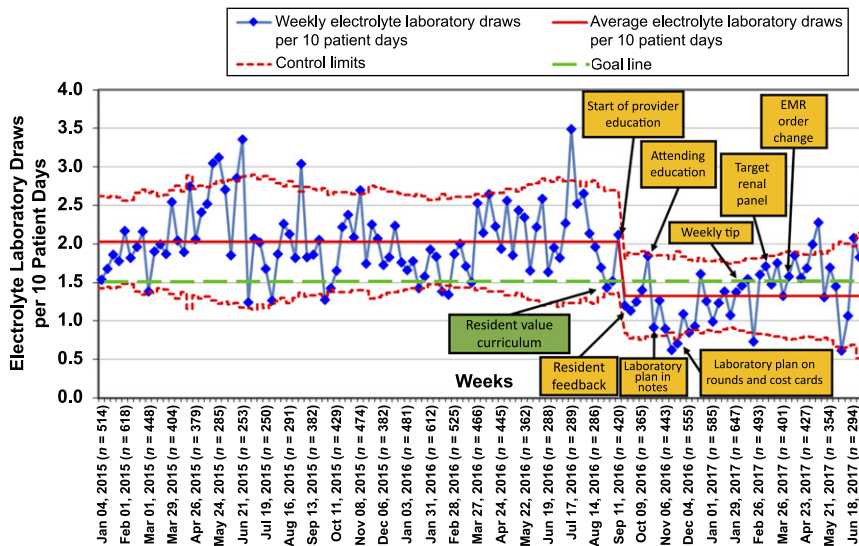
## RESULTS

Baseline rates of electrolyte laboratory draws demonstrated significant variability (Fig 1, Table 2), with a mean of 2.0 laboratory draws per 10 patient days. Within 2 months of the initiation of improvement interventions, there was a 35% decrease in electrolyte laboratory draws, with a new centerline of 1.3 laboratory draws per 10 patient days. There remained substantial variation in the postintervention data. The observed reduction in laboratory draws occurred shortly after the initiation of our educational interventions and individual feedback, and our lowest series of points coincided with the introduction of our cost reference cards, standardized laboratory plan template in patient notes, and structured rounds discussions. This reduction was sustained throughout the rest of the intervention period during our other interventions.

Similarly, the number of laboratory test results decreased from 18.4 to 13.5 test results per 10 patient days after initial improvement activities. A second reduction to 9.5 test results per 10 patient days occurred after rollout of the cost reference cards, the laboratory plan template in patient notes, and structured rounds discussion. This 48% reduction in test results was sustained throughout the intervention period (Fig 2A).

Patient charges for electrolyte testing were reduced by 29% from a mean \$53.81 per patient day to \$38.22 per patient day, corresponding to a >\$292 000 reduction in charges over the 9-month intervention period (Fig 2B).

The use of our highest-charge panel, the renal panel, initially decreased from 67% to 48% of all electrolyte testing, coinciding with initial educational interventions, with a



**FIGURE 1** Electrolyte laboratory draw rate statistical process-control u-chart in which the primary outcome measure of electrolyte laboratory draws per 10 patient days is displayed and annotated with improvement interventions. Data are from January 2015 to June 2017.

**TABLE 2** Description and Timing of Interventions

Intervention Description	Intervention Start Date
Start provider education: introductory lectures and meetings for providers	September 12, 2016
Resident feedback: postrounds feedback for residents about laboratory ordering and value	October 3, 2016
Attending education: specific education targeting attending providers	October 15, 2016
Laboratory plan in patient notes: adding a laboratory plan to all provider daily notes and note templates	October 22, 2016
Laboratory plan in rounds: formalized process to include a discussion of the laboratory testing plan on rounds	November 14, 2016
Cost cards: reference cards at resident workspaces detailing both cost and charge for commonly ordered tests	November 14, 2016
Weekly tip: a high-value tip displayed at resident conferences with current control chart	February 1, 2017
Target renal panel: specific education about reducing use of highest-charge panel	March 3, 2017
EMR order change: limiting availability of recurrent daily laboratory order options in the EMR	April 4, 2017

subsequent shift after initiation of the high-value tip and a third shift down to 22% after targeted education on renal panel use (Fig 2C).

During our intervention period, we saw no special cause variation in MET or readmission rates (Fig 3).

## DISCUSSION

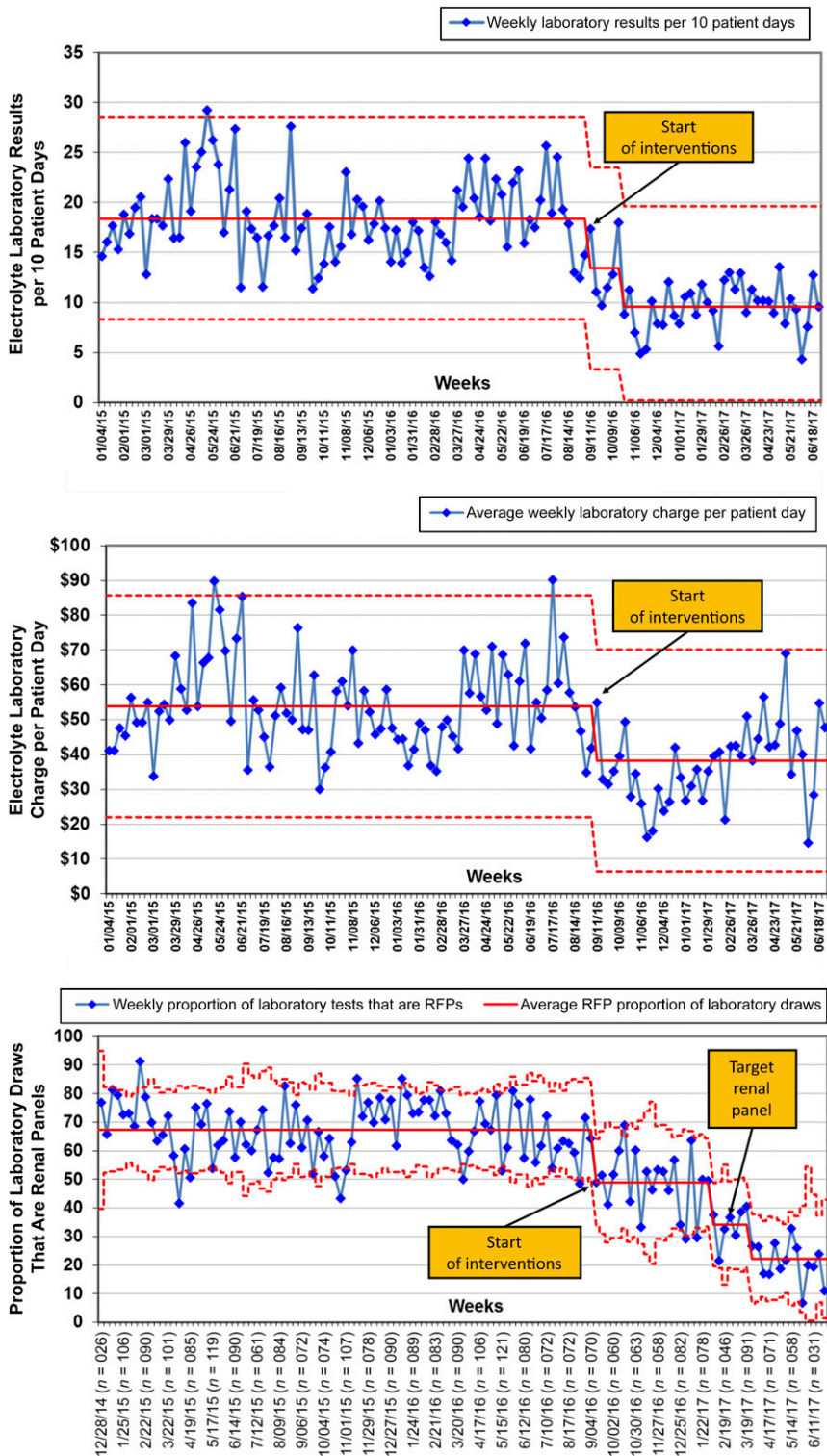
Using improvement science methods, we successfully reduced the use of electrolyte testing by 35% and decreased the overall volume of electrolyte test results

by nearly 50%, indicating a shift to less frequent and more focused electrolyte test ordering. We also saw an overall decrease in the proportion and rate of high-charge test usage, with no change in rates of MET calls or readmissions. Although researchers in previous studies have demonstrated reductions of 8% to 31% in the adult inpatient population,<sup>35,40</sup> efforts to reduce testing in the pediatric population have generally focused on specific diagnoses<sup>41,42</sup> and specific testing situations.<sup>36</sup> With our study we

have expanded on this by applying interventions targeted at improving value to an entire category of testing across all diagnoses.

Researchers in previous studies have identified many types of interventions to target reduced testing.<sup>35,36,40,41,43</sup> Providers often have poor awareness of the cost and benefit of testing,<sup>44–46</sup> so improved cost awareness has been targeted in several studies.<sup>47,48</sup> We also know that provider practice habits are often set during training,<sup>44,45,49</sup> so engaging residents and creating resident-level interventions were focuses of researchers in several other improvement studies.<sup>35,36,43,50</sup> Finally, clinicians can be supported at the point of care through interventions in which the EMR is directly used to guide decisions,<sup>41,51,52</sup> and other decision-support tools such as checklists have been used both within and outside of the EMR.<sup>40,41</sup> One important point from these studies is that multifaceted approaches that create a culture of value may lead to greater impact on outcomes.<sup>40,53</sup> Our study's success may in part be traced to the breadth of interventions that encouraged discussions of necessity and value in testing and reduced overuse of testing. Interventions that focused on residents and integrated easily into their workflow, such as the templates in their notes and easily accessible cost reference cards, were key in encouraging frequent, reliable discussions about test necessity and value. In addition, there may have been a synergistic effect from the concurrent high-value care curriculum in which discussions of value were encouraged. Single interventions in isolation, such as a cost display without relevant education about overuse and value, may not lead to the desired behavior change.<sup>54</sup>

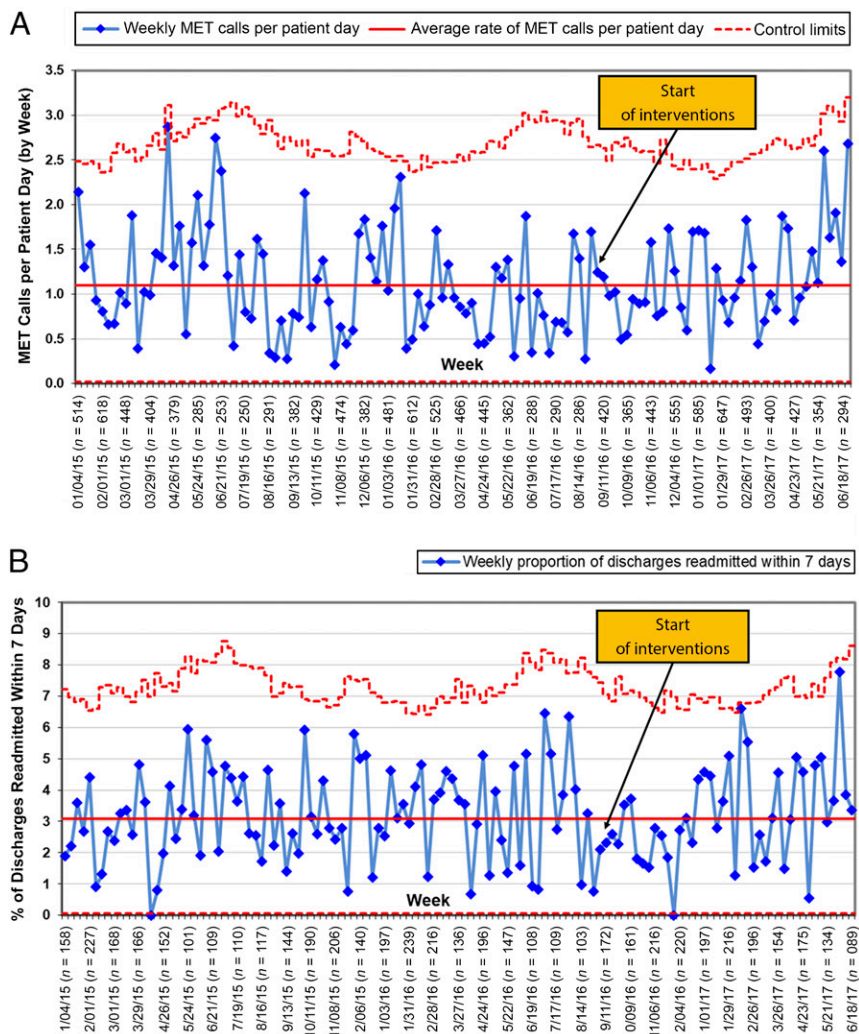
As health care continues to focus on reducing costs, an important



**FIGURE 2** Secondary measures: laboratory results, charges, and high-charge panel usage statistical process-control charts for (A) laboratory test results per 10 patient days (XMR chart), (B) electrolyte testing charges per patient day (XMR chart), and (C) renal panel ordering as the proportion of all electrolyte tests (p-chart). For (A), an explanation of how many test results are present on specific laboratory panels can be found in Table 1. Data are from January 2015 to June 2017. RFP, renal function panel.

consideration will be which interventions or combinations of interventions produce the most efficient reduction in overuse. Because of the relatively close timing of our interventions, it is difficult to ascertain the relative impact of each intervention compared with others. Further comparative studies or factorial designs could better elucidate the specific impacts of individual interventions. In addition, although the cost for materials for our described interventions was minimal, the major cost for our interventions was the salary and time of improvement leaders. The use of multiple interventions to reduce overuse carries an increased cost burden that may outweigh cost savings in certain circumstances.

The immediate and long-term success of improvement interventions can be modified significantly by local factors and context.<sup>55</sup> For our project, resident and attending consensus and enthusiasm for reducing testing was high. By reducing overuse the number of test results that needed to be reviewed decreased by almost half. This potentially provides increased time for other tasks. For frontline nursing and phlebotomy staff, there are similar incentives to avoid unnecessary laboratory tests and create time for other value-added work. However, nursing workflow can be complex. One study revealed that nurses view routine laboratory tests as more beneficial,<sup>56</sup> potentially because they can be scheduled when nursing workload is light. In our environment, nursing workflow and the lack of a dedicated phlebotomy team made afternoon laboratory tests difficult to obtain in a timely, reliable manner, so efforts to reduce early-morning laboratory tests ultimately were



**FIGURE 3** MET use and readmission rate statistical process-control charts for (A) MET use (shown with a u-chart) and (B) 7-day readmission rates (shown with a p-chart). Labels indicate the beginning of the intervention period. Data are from January 2015 to June 2017.

abandoned. In addition, one of the challenges of addressing overuse in an entire category of testing is the inherent variation in a study population that contains many different diagnoses. It is likely that testing rates within 1 diagnosis, such as gastroenteritis, are significantly different from those of another, such as bronchiolitis, and combining this within-group variation and between-group variation can make it difficult to know the specific impact of the work.<sup>39</sup> Finally, most of our interventions are based on

increasing education and awareness as drivers of behavior. Our most reliable intervention, the removal of a specific daily order frequency, did not have a clear impact on order rates but may have helped hardwire some of the education. Although we have demonstrated that education and awareness alone can drive substantial change in this arena, it is likely that more reliable interventions over time may be necessary to continue and sustain the reduction in testing we have initially seen.

## Limitations

Our study had several important limitations. The interventions took place at a quaternary care children’s hospital with a history of multiple successful quality improvement interventions, which may limit the generalizability of the work. Our data have a high degree of variability, leading to challenges in interpreting wide swings in testing rates at certain points in our baseline or intervention periods. We used charges to measure financial impact; however, it is difficult to know the true patient-level financial impact of this work because insurance plans vary greatly and insurance companies negotiate rates with hospitals. Because available cost estimates did not include nonlaboratory costs (ie, supplies, nursing and physician workload related to laboratory testing), actual hospital-level financial impact is difficult to calculate. More accurate measures of cost and methods to quantify true cost will be critical for better understanding value-based improvement work.

## Next Steps

After demonstrating initial improvement, our next improvement steps will be focused on maintaining and expanding the progress made thus far. Potential targets include improved EMR decision support, interventions in which specific diagnoses are targeted, and developing interventions related to nursing workflow that help reduce laboratory testing.

With our project we have also identified the need for further clinical research into diagnoses and other factors that affect electrolyte testing rates and value. Accurate data in this arena could help target benchmarking and more focused interventions in the future.

## CONCLUSIONS

We reduced rates of electrolyte testing by 35% and charges by 29% through the use of interventions that increased awareness of cost and value and encouraged discussion of test necessity. These reductions were achieved without increasing adverse effects,

which adds to evidence that frequent testing of electrolytes may be reduced safely in inpatient pediatric care.

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## ABBREVIATIONS

CCHMC: Cincinnati Children's Hospital Medical Center  
EMR: electronic medical record  
MET: medical emergency team

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