Using Quality Improvement to Reduce Continuous Pulse Oximetry Use in Children With Wheezing

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abstract

BACKGROUND AND OBJECTIVES: Clinicians commonly use continuous pulse oximetry (CPOx) for hospitalized children with respiratory illnesses. The Choosing Wisely initiative recommended discontinuing CPOx for children on room air. We used quality improvement methods to reduce time on CPOx in patients with wheezing.

METHODS: Our project took place on 1 unit of a children’s hospital. We developed consensus-based criteria for CPOx discontinuation. Interventions included education, a checklist used during nurse handoff, and discontinuation criteria incorporated into order sets. We collected data on a second unit where we did not actively intervene to assess for secular trends and negative consequences of shorter monitoring. We followed time until medically ready, ICU transfers, hospital revisits, and medical emergency team calls on both units. We tracked the impact of interventions by using run charts and statistical process control charts.

RESULTS: Median time per week on CPOx after meeting goals decreased from 10.7 hours to 3.1 hours on the intervention unit. Median time per week on CPOx on the control unit decreased from 11.5 hours to 6.9 hours. There was no decrease in time until medically ready on either unit. The percentage of patients needing transfer, revisit, or medical emergency team call was similar on both units.

CONCLUSIONS: With interventions focused on clarity and awareness of CPOx discontinuation criteria, we decreased time on CPOx; however, we saw no impact on time until medically ready. We expect that other centers could use analogous methods to standardize and reduce oxygen monitoring to meet Choosing Wisely recommendations.

Overuse of resources is a large source of waste in patient care. Continuous pulse oximetry (CPOx) monitoring of children hospitalized with acute respiratory disease may provide important data for titrating supplemental oxygen, but once the child’s status has improved, CPOx adds little value and may prolong hospital stays. Existing evidence suggests pulse oximetry readings may contribute to higher admission rates and an increase in average length of stay (LOS) in bronchiolitis. In its bronchiolitis guidelines, the American Academy of Pediatrics emphasized the uncertain role for CPOx in the inpatient setting, citing risk of prolonged hospital stay resulting from “perceived need for supplemental oxygen.”

Studies in adults have also highlighted the contribution of CPOx to alarm counts on units, which the Joint Commission has emphasized as a patient safety issue.

Despite evidence highlighting the limitations and lack of value, CPOx

Dr Schondelmeyer conceptualized and designed the study, carried out the analysis, and drafted the initial manuscript; Drs Simmons, Statile, and Brady contributed to design of the quality improvement study and interventions, data interpretation, and drafting of the initial manuscript, and they critically revised the manuscript for important intellectual content; Ms Hofacer, Ms Smith, and Ms Prine contributed to design of the quality improvement study and interventions and critically revised the manuscript for important intellectual content; and all authors approved the final manuscript as submitted.

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remains widely used for hospitalized pediatric patients. Accordingly, the Pediatric Hospital Medicine section of the Society of Hospital Medicine included the use of CPOx for improving patients with respiratory disease as one of the top “five things that patients and physicians should question” in its Choosing Wisely campaign, emphasizing the lack of evidence and waste involved in its widespread use. In 2009, asthma and bronchiolitis accounted for ∼260,000 admissions and $3.2 million in hospital charges.

Interventions aimed at reducing the cost of these admissions, particularly by reducing LOS, have the potential to affect patient care.

To address concerns about overuse of CPOx at our center, we used quality improvement methods with the aim of reducing CPOx overuse and increasing adherence to local guidelines, which recommend use of intermittent pulse oximetry (IPOx) for patients on room air with asthma or bronchiolitis. The specific aim of this quality improvement project was to reduce CPOx overuse after patients were on room air with decreasing need for albuterol treatments. Based on previous studies, we hypothesized that reducing CPOx overuse would result in decreased LOS on our hospital medicine units.

Additionally, we tracked floor-to-ICU transfers, medical emergency team (MET) activations, and hospital revisits as balancing measures to ensure that our interventions were not causing harm.

**METHODS**

**Context**

Cincinnati Children’s Hospital Medical Center (CCHMC) is a large, urban, academic pediatric medical center. General pediatric patients are admitted primarily to 2 24-bed units. These units are staffed by hospital medicine (HM) attending physicians supervising pediatrics residents, who provide direct patient care, and general pediatric nurses (RNs). CCHMC uses local, evidence-based guidelines for the inpatient care of asthma and bronchiolitis. Both guidelines recommend IPOx for patients who do not need supplemental oxygen. All inpatient data, including vital signs and admission and discharge times, are documented in the electronic health record (EHR). Patient physiologic monitors are connected to the EHR and transmit vital sign information directly into the vital sign flow sheets every minute a continuous monitor is in place.

**Planning the Intervention**

We chose asthma and bronchiolitis as the diagnoses of interest because there is a body of literature supporting the reduction in CPOx use. We included patients with International Classification of Diseases, Ninth Revision codes for asthma (493.xx), bronchiolitis (466.1×), or wheezing (786.07) in the data collection and analysis.

Before interventions, we assembled a multidisciplinary team that included bedside nurses, resident physicians, and HM attending physicians. We developed a concise list of key drivers or themes our improvement team proposed as necessary to achieve our aim (Supplemental Figure 3). Key drivers included clear criteria for timely CPOx discontinuation, staff knowledge of local guidelines and CPOx limitations, clear communication between team members about the monitoring plan, and staff engagement in timely CPOx discontinuation.

**Improvement Activities**

Improvement activities on the intervention unit targeted the 4 key drivers using frequent, small tests of change according to the Plan–Do–Study–Act model.

Certain interventions, such as nursing education and handoff tools, were confined to the intervention unit. Because physicians care for patients on both units, order set changes and resident physician education interventions were not confined to the intervention unit.

**Clear Criteria for Removal of CPOx: Prestudy Survey and Definition of Criteria for CPOx Discontinuation**

Before the start of improvement activities, an online survey was completed by 51% (28/55) of RNs on the intervention unit and 72% (28/39) of HM attending physicians. The primary aim of the survey was to determine a consensus-based goal for timely CPOx discontinuation, because none existed locally. Based on responses, we chose >90% oxygen saturations on room air for 2 hours or weaned to every-2-hour albuterol treatments through our asthma weaning protocol as goals for timely CPOx discontinuation.

**Staff Knowledge of Local Guidelines and Limitations of Pulse Oximetry: Staff Education**

We developed a summary of local guidelines and of the rationale for the improvement project, which emphasized waste reduction, guideline adherence, and patient safety related to alarm fatigue, and disseminated this summary to RNs, pediatric residents, and HM attending physicians during staff meetings and educational conferences.

**Nursing Handoffs**

RNs on the intervention unit participate in group shift handoffs, which are brief gatherings to discuss safety concerns and current quality...
initiatives. Charge RNs were given a brief description of the project to review with nursing staff at shift handoffs, which was kept in a common work area.

Clear Communication Between Team Members About Monitoring Plan: Order Set Changes

Language was initially manually added to the CPOx orders for patients with asthma and bronchiolitis directing the RN to discontinue CPOx and initiate IPOx at a specified time. The new order required a call from the RN to the physician to discuss an alternative monitoring plan if concerns were present (eg, patient had an oxygen desaturation during feeding). These changes were later incorporated into the EHR asthma and bronchiolitis order sets.

Nursing Handoff Tool

An RN signout tool was developed to prompt discussion of patient CPOx and to reinforce education (Fig 1). The signout tool consisted of 3 short questions to determine whether a patient was potentially ready to transition to IPOx. The oncoming RN determined the cause for any failure of timely CPOx discontinuation that occurred on the previous shift.

**Staff Engagement in Reducing CPOx Use:**

**Feedback via Distribution of Updated Run Charts**

Updated run charts for the primary outcome measure were shared with group members for distribution to their teams at biweekly meetings. We updated HM physicians by posting run charts in a common work area and at 2 division-wide meetings. We updated nurses via monthly unit-wide meetings.

**Resident Physician Quality Improvement Contest**

Four separate HM resident teams provide care on both units. Residents were updated weekly of ongoing progress via an e-mail displaying team success percentages side by side along with an updated run chart to promote competition between the teams.

**Study of the Improvement**

Baseline data included a convenience sample of patients from October through December 2012, and patient data were collected in July 2013, before the start of interventions in mid-August. To allow rapid-cycle learning, we chose this time period based on local data for asthma and bronchiolitis admission rates, which are typically highest in the late fall and early winter. Data were collected during the intervention period via daily structured chart review of the inpatient census in the EHR by the principal investigator or a trained research coordinator.

**Measures**

The primary outcome measure was defined as the median time per week that patients were on CPOx after reaching consensus-derived definition of timely discontinuation. We defined continuous monitoring as >30 consecutive minutes on CPOx and CPOx discontinuation time as the end of the final episode of continuous monitoring. Supplemental oxygen status and albuterol treatment frequency were obtained from RN documentation flow sheets. Operational definitions are detailed in Table 1.

We followed median time to medically ready per week, defined as the time in hours between arrival to the unit from which the patient was discharged and the time the patient was medically ready for discharge as a proxy for LOS.24 We chose this time because it indicates when our patients are considered medically safe for discharge (80% of our patients are discharged within 2 hours of meeting medically ready criteria)24 and is not influenced by system issues such as pharmacy delays or lack of transportation. We also followed the percentage of patients per week with CPOx discontinued by goal. We followed balancing measures of 7-day revisits (emergency department or inpatient), MET calls, and floor-to-ICU transfers.

Patient characteristics, including primary diagnosis, history of chronic medical problems, and ICU admissions were collected to allow comparison of the cohort before and after our interventions began and between the intervention and control units.

**Analysis**

We used a run chart for analysis of our primary measure, median time per week on CPOx after meeting goals, and our secondary outcome measure of median time to medically ready per week. The chart is available in the online version of this article.
ready per week. We used a statistical process control p-chart for our process measure. We used established rules for identifying special cause for run charts and control charts: 8 consecutive points above or below the centerline to prompt a midline shift, which would occur <0.4% of the time by chance.25–28 Fisher’s exact test, or Cochran–Armitage trend tests were used as appropriate to compare study populations, revisits, MET calls, and floor-to-ICU transfers between the intervention and control units.

RESULTS

Patient-level descriptors are presented before and after our intervention and on our intervention and control units in Table 2. The most common medical comorbidity on both the intervention and control units was a history of prematurity. The intervention unit overall had a younger patient population ($P = .002$) and a higher proportion of patients with bronchiolitis ($P = .02$) when compared with the control unit.

On the intervention unit, median time per week on pulse oximetry after meeting goals decreased from 11.5 hours at baseline to 6.9 hours by 3 months after initiation of improvement activities (Fig 2A). The largest reduction was seen shortly after the start of our education intervention. The proportion of patients with CPoX discontinued within goal time increased from 25% to 46% (Fig 2C) within 3 months of initiation of improvement activities on the intervention unit. This improvement remained stable over a 3-month follow-up period.

On the control unit, median time per week on pulse oximetry after meeting goals decreased from 11.5 hours at baseline to 6.9 hours by 3 months after initiation of improvement activities (Fig 2A). Proportion of patients with CPoX discontinued appropriately on control unit remained unchanged at 23% (Fig 2C).

Using established run chart rules, we did not identify special cause variation in time until medically ready on either unit. The percentage of patients who experienced a MET was higher on subsequent 3 months (Fig 2A).

### TABLE 1 Description of Measures

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary outcome measure</td>
<td>Median time on CPoX after meeting goals</td>
<td>Calculated as the time on CPoX (h) after patient weans to every-2-h albuterol treatments or is weaned to room air. Monitors are also linked to the EHR with the capability to directly transmit vital signs from the patient monitors every minute if a monitor is in place, allowing precise determination of monitor discontinuation.</td>
</tr>
<tr>
<td>Secondary outcome measure</td>
<td>Median time until medically ready</td>
<td>Calculated as the time between when the patient arrived on the unit and when the patient was medically ready for discharge.</td>
</tr>
<tr>
<td>Process measure</td>
<td>Percentage of patients with CPoX discontinuation within goal time frame</td>
<td>Calculated as the percentage of patients who were changed to IPOX monitoring at the time of weaning to every-2-h albuterol treatments or &gt;90% oxygen saturation for 2 h on room air.</td>
</tr>
<tr>
<td>Balancing measure</td>
<td>7-day revisits</td>
<td>Calculated as the percentage of patients who needed a visit to the emergency department or admission within 7 days of discharge. Seven days was chosen because, clinically, revisits &gt;7 days after discharge are probably unrelated to premature discharge and more likely to be related to a separate illness.</td>
</tr>
<tr>
<td>Balancing measure</td>
<td>Medical emergency team calls</td>
<td>Calculated as the percentage of patients for whom a medical emergency team response was called.</td>
</tr>
<tr>
<td>Balancing measure</td>
<td>Floor-to-ICU transfers</td>
<td>Calculated as the percentage of patients who needed transfer to the ICU after spending time on the HM floor.</td>
</tr>
</tbody>
</table>

### TABLE 2 Description of Study Population

<table>
<thead>
<tr>
<th></th>
<th>Before Intervention, $n = 36, n (%)</th>
<th>After Intervention, $n = 455, n (%)</th>
<th>Intervention Unit, $n = 192, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>14 (39)</td>
<td>186 (41)</td>
<td>61 (38)</td>
</tr>
<tr>
<td>ICU stay</td>
<td>10 (28)</td>
<td>79 (17)</td>
<td>31 (19)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;6 mo</td>
<td>9 (25)</td>
<td>116 (20)</td>
<td>33 (20)</td>
</tr>
<tr>
<td>6–&lt;12 mo</td>
<td>4 (11)</td>
<td>63 (11)</td>
<td>15 (9)</td>
</tr>
<tr>
<td>12 mo–&lt;2 y</td>
<td>8 (22)</td>
<td>88 (15)</td>
<td>23 (14)</td>
</tr>
<tr>
<td>2–&lt;5 y</td>
<td>9 (25)</td>
<td>83 (14)</td>
<td>31 (19)</td>
</tr>
<tr>
<td>5–18 y</td>
<td>6 (17)</td>
<td>105 (18)</td>
<td>60 (37)</td>
</tr>
<tr>
<td>Primary diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>18 (50)</td>
<td>170 (37)</td>
<td>81 (50)</td>
</tr>
<tr>
<td>Bronchiolitis</td>
<td>18 (50)</td>
<td>225 (49)</td>
<td>58 (36)</td>
</tr>
<tr>
<td>Wheezing</td>
<td>0</td>
<td>60 (13)</td>
<td>25 (14)</td>
</tr>
<tr>
<td>Medical comorbidities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic neurologic disease</td>
<td>2 (6)</td>
<td>3 (1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>0</td>
<td>9 (2)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>0</td>
<td>7 (2)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Genetic syndrome</td>
<td>0</td>
<td>4 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Oncologic disorder</td>
<td>0</td>
<td>1 (0)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Prematurity</td>
<td>7 (19)</td>
<td>65 (14)</td>
<td>17 (11)</td>
</tr>
</tbody>
</table>
the control unit ($P = .04$), but there was no significant difference between the units for percentage of patients with floor-to-ICU transfer. Percentage of patients with revisit within 7 days was not statistically different between the 2 units (Table 3). There were no deaths.

**FIGURE 2**
Run charts for intervention and control units for (A) primary outcome measure, (B) secondary outcome measure, and (C) statistical process control p-chart for process measure. Brackets indicate shared baseline data from 2012. Vertical dashed lines indicate end of baseline period. *After on >90% oxygen saturation room air or weaned to every-2-hour albuterol treatments.
We successfully reduced the overuse of CPOx by >70% on a single unit within 3 months. Previous work in reducing the negative impact of CPOx overuse has focused on changing response times and alarm limits; we are not aware of any successful reductions of CPOx overuse previously described in the literature. Our work is also, to our knowledge, the first published improvement project targeting the Pediatric Hospital Medicine Choosing Wisely recommendations.

Despite reduction in time spent on CPOx, there was no change in time until medically ready. Although an earlier study suggested CPOx prolonged LOS, our findings are consistent with preliminary results of a randomized trial comparing IPOx and CPOx, which did not show reduced LOS. The previous study suggesting decreased LOS noted lack of a standard oxygen saturation for initiating supplemental oxygen in the earlier study, leading to prolonged LOS; we use 90% as a cutoff for initiating supplemental oxygen at our center. Although multiple studies have demonstrated that oxygen saturation influences admission rates, other factors such as poor oral intake and need for aggressive suctioning may be important drivers of LOS. Studies have described an association between decreased oral intake and nasal suctioning with LOS in infants with bronchiolitis, and our interventions did not have any impact on suctioning practices or improving oral intake for patients. The median time to medically ready in our study was also <25 hours on our intervention unit; it is possible that reducing LOS further may be challenging. Finally, both bronchiolitis and asthma have significant seasonal variations, and LOS may naturally vary during seasonal surges of disease. We are unable to determine this impact from our data.

In the absence of reduced LOS, the potential for reducing alarm frequency by reducing CPOx overuse remains clinically relevant given evidence supporting alarm fatigue as a risk to patient safety. Pulse oximetry is limited by frequent alarms caused by false readings in active young children. Frequent alarms from CPOx may contribute to alarm fatigue, which has been linked to serious safety events. The Joint Commission issued a warning in 2013, which named alarm fatigue as “the most common contributing factor” to alarm-related sentinel events. The largest reduction in median time on CPOx during our interventions was seen after the introduction of our education intervention, with additional decrease seen after asthma and bronchiolitis order changes and the introduction of the RN signout tool. Although we are unable to determine causality, these may be important interventions contributing to the observed improvement and could be implemented at other institutions that have a customizable order sets. Despite broadening the order set changes to all admissions, including those admitted to the control unit, we did not see the degree of reduced time on CPOx compared with the intervention unit. We hypothesize that time spent on CPOx is largely a nursing-driven process, and the difference between the 2 units was related to education and empowerment of nurses on the intervention unit.

DISCUSSION

There is no clear evidence indicating when CPOx should be discontinued as patients improve, so our goals were based on consensus. We improved our primary outcome with no significant difference in ICU admissions or revisits compared with the control unit, which suggest our criteria and goals were reasonable. The reason for a higher percentage of MET calls on the control unit is unclear, but it is not consistent with our systematic interventions leading to patient harm on the intervention unit. If the reduction in CPOx use resulted in premature discharge or unsafe monitoring, we would have expected a rise in 7-day revisits or ICU admissions. In contrast, based on the mounting body of evidence about the dangers of alarm fatigue, if shorter pulse oximetry monitoring resulted in fewer alarms, it could result in safer conditions for patient care.

<table>
<thead>
<tr>
<th></th>
<th>Intervention Unit, n = 455, n (%)</th>
<th>Control Unit, n = 160, n (%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-day revisits</td>
<td>20 (4)</td>
<td>5 (3)</td>
<td>.47</td>
</tr>
<tr>
<td>Medical emergency team call</td>
<td>55 (12)</td>
<td>30 (19)</td>
<td>.04</td>
</tr>
<tr>
<td>Floor-to-ICU transfer</td>
<td>34 (7)</td>
<td>20 (12)</td>
<td>.06</td>
</tr>
</tbody>
</table>

TABLE 3 Balancing Measures

**Limitations**

A significant limitation of our study was the unintended spread of our EHR and physician interventions. Physicians provide care for patients on both the units. Similarly, the asthma and bronchiolitis order sets are used for admitting patients to both units. However, we did not see the same degree of improvement on the control unit as on the intervention unit. Although the new order sets were used on both units, we saw a greater improvement in our intervention unit. This suggests order sets are an important intervention but are not sufficient to effect change without education and handoff tools.

The patient populations on the 2 units were not identical, which may have influenced our results. The weekly patient volume on the control unit was smaller, which probably contributed to the greater variability on the run charts. The balancing measures we followed, ICU transfers, revisits, and deaths, are rare. We were not powered to show a difference between our intervention and control units with regards to these types of
events. Additionally, the patient populations on the 2 units were not identical, which may have influenced the results we saw. However, we are not aware of any literature that suggests an older patient population on the control unit would have made longer CPOx monitoring more likely or medically necessary. We were unable to directly observe when patients were on CPOx and may have not included some patients who were only briefly on CPOx.

This project was conducted at a single institution with a strong foundation of implementing evidence-based care, including inpatient care guidelines that drive treatment decisions. Therefore, it may be challenging to implement these changes in an institution where practitioners are less accustomed to rapidly changing practice. Finally, it is possible that physicians who cared for patients on the control unit and had participated in our education session were less likely to respond to brief, mild desaturations on monitored patients. This difference may have contributed to a reduction in LOS on both units and biased us toward the null hypothesis for our LOS outcome.

Next Steps

Having demonstrated the success of our interventions, we plan to sustain our change and spread our interventions to the control unit and our satellite HM unit in a separate facility. We are investigating the impact of our improvement work on overall alarm count on our intervention unit.

CONCLUSIONS

We reduced the median time on CPOx by >70% by using simple interventions, which included education about local guidelines, standard goals for timely discontinuation, and changes to the EHR. The study findings are relevant for clinicians caring for patients with asthma and bronchiolitis in the non-ICU inpatient setting who aim to reduce waste in patient care. This study adds to the body of evidence supporting a more judicious approach to CPOx, by demonstrating likely safety of early CPOx removal and questioning the impact of supplemental oxygen on LOS.

ACKNOWLEDGMENTS

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