Validity of Continuous Pulse Oximetry Orders for Identification of Actual Monitoring Status in Bronchiolitis

Patrick W Brady, MD, MSc1,2,3*, Amanda C Schondelmeyer, MD, MSc1,2,3, Christopher P Landrigan, MD, MPH1,5,6, Rui Xiao, PhD7, Canita Brent, MPH8, Christopher P Bonafide, MD, MSCE9,10,11, for the Pediatric Research in Inpatient Settings (PRIS) Network

1Division of Hospital Medicine, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio; 2James M. Anderson Center for Health Systems Excellence, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio; 3Department of Pediatrics, University of Cincinnati College of Medicine, Cincinnati, Ohio; 4Division of General Pediatrics, Department of Pediatrics, Boston Children’s Hospital, Boston, Massachusetts; 5Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women’s Hospital, Boston, Massachusetts; 6Harvard Medical School, Boston, Massachusetts; 7Department of Biostatistics, Epidemiology, and Informatics, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania; 8Section of Pediatric Hospital Medicine, Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania; 9Department of Biomedical and Health Informatics, Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania; 10Center for Pediatric Clinical Effectiveness, Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania; 11Department of Pediatrics, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania.

The accuracy of pulse oximetry monitor orders for identifying infants with bronchiolitis who are being continuously monitored is unknown. In this 56-hospital repeated cross-sectional study, investigators used direct bedside observation to determine continuous pulse oximetry monitor use and then assessed if an active continuous monitoring order was present in the electronic health record. Investigators completed 3,612 observations of infants aged 8 weeks to 23 months hospitalized with bronchiolitis and on room air.

Most monitored infants did not have an active monitoring order (sensitivity 49% [95% CI, 41-57]). The positive predictive value of a monitoring order was 77% (95% CI, 72-82), and the negative predictive value was 69% (95% CI, 61-77). Teams intending to measure continuous pulse oximetry use should understand the limitations of using electronic health record orders as a stand-alone measure. Journal of Hospital Medicine 2020;15:665-668. © 2020 Society of Hospital Medicine

Understanding the validity of orders for detection of actual use is critical because continuous pulse oximetry monitoring is considered an overused practice in pediatric acute viral bronchiolitis, and national guidelines recommend against its use in low-risk hospitalized children. Continuous monitoring may identify trivial, self-resolving oxygen desaturation and its use is not associated with improved outcomes. When self-resolving desaturations are treated with additional supplemental oxygen, hospital stays may be unnecessarily prolonged. In order to reduce unnecessary continuous pulse oximetry use, measurement of the extent of the overused practice is necessary. In this 56-hospital study, we aimed to determine the validity of using active continuous pulse oximetry orders instead of bedside observation of actual monitor use.

METHODS

Design

In this multicenter, repeated cross-sectional study, investigators used direct bedside observation to determine continuous pulse oximetry monitor use and then assessed whether an active continuous monitoring order was present in the electronic health record. The study took place during one bronchiolitis season, December 1, 2018, through March 31, 2019.

Setting and Patients

Investigators at 56 freestanding children’s hospitals, children’s hospitals within general hospitals, and community hospitals in...
Data Collection
Investigators used the electronic health record to identify eligible infants. Investigators entered patient rooms to confirm the infant was not on supplemental oxygen (hence confirming eligibility for the study) and determine if continuous pulse oximetry was actively in use by examining the monitor display for a pulse oximetry waveform. Investigators then confirmed if active orders for pulse oximetry were present in the patient’s chart. Per study design, site investigators aimed to observe approximately half of eligible infants during the day (10 am to 5 pm) and the other half during the night (11 pm to 7 am).

Analysis
We excluded patients with conditional orders (eg, monitored only when certain conditions exist, such as when asleep) because of the time-varying and wide range of conditions that could be specified. Furthermore, conditional orders would not be useful as proxies to measure oximetry use because investigators would still need additional data (eg, bedside observation) to determine current monitoring status.

We calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of active orders using the reference standard of direct bedside observation, as well as corresponding 95% CIs that accounted for within-hospital clustering. We calculated these test characteristics overall and as stratified across four age groups: 8 weeks to 5 months, 6 months to 11 months, 12 months to 17 months, and 18 months to 23 months. We also calculated the test characteristics for each hospital. We decided a priori that a PPV and NPV of 80% would represent a reasonable threshold to use active orders as a proxy in multicenter research. For hospital-level analyses we included only hospitals with 60 or more total observations and more than 15 observations with active orders for PPV and more than 15 observations without active orders for NPV. We used Stata (StataCorp LLC, College Station, Texas) version 15.1 for analysis.

DISCUSSION
Active continuous pulse oximetry orders did not accurately represent actual monitoring status in this study. Monitoring orders alone frequently misrepresent true monitoring status and, as such, should be interpreted with caution in research or quality improvement activities. If more valid estimates of monitoring use and overuse are needed, potential measurement options include direct observation, as used in our study, as well as the use of more complex data streams such as the output of monitoring devices or pulse oximetry data in the electronic health record. In only two of the hospitals, using active continuous monitoring orders was a reasonable proxy for detecting actual monitor use. Monitoring orders could potentially be validly used for deimplementation efforts at those centers; other hospitals could consider targeted improvement efforts (eg, morning huddles examining the discordance between monitoring orders and monitoring status) to improve the accuracy of using continuous pulse oximetry orders.

We acknowledge several limitations of this study. Site investigators employed a convenience sampling approach, so it is possible that some investigators observed sicker or less sick infants. Although the PRIS network includes a geographically diverse group of North American hospitals, community hospitals were underrepresented in this study. Our results hence generalize more precisely to freestanding children’s hospitals than to community hospitals. We did not observe infants currently on supplemental oxygen, so we do not know to what degree using orders is valid in that context. We did not collect data on why actual monitoring status differed from monitoring orders and hence cannot quantify to what extent different factors (eg, nurse belief that monitors are a safety net or infants inadvertently left on monitors after a spot check pulse oximetry reading) contributed to this discordance. Finally, our study only examined one electronic health record variable—the presence of an active order that could be used as a proxy in multicenter research.
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An Official Publication of the Society of Hospital Medicine

Journal of Hospital Medicine

Vol 15 | No 11 | November 2020

order. It may be that other variables in the health record (eg, minute-by-minute pulse oximetry values in a vital sign flowsheet) are much better proxies of actual continuous monitor use.

CONCLUSION

Using an active order for continuous pulse oximetry has poor sensitivity, PPV, and NPV for detecting true monitoring status at the bedside. Teams intending to measure the actual use of pulse oximetry should be aware of the limitations of using active orders alone as an accurate measure of pulse oximetry monitoring.

Acknowledgments

We thank the NHLBI scientists who contributed to this project as part of the U01 Cooperative Agreement funding mechanism: Lora Reineck, MD, MS, Karen Bienstock, MS, and Cheryl Boyce, PhD.

We thank the Executive Council of the PRIS Network for their contributions to the early scientific development of this project. We thank the PRIS site investigators for their major contributions to the Eliminating Monitor Overuse (EMO) Study data collection. Each listed collaborator is a group author for the PRIS Network in this manuscript. Their names can be found in the online supplemental information.

Disclosures: The authors have no financial or other conflicts of interest to disclose.

Previous presentation of the information reported in the manuscript: Presented at the Pediatric Hospital Annual Meeting in Seattle, Washington, on July 26, 2019.

Funding: This study was funded by a Cooperative Agreement from the National Heart, Lung, and Blood Institute of the National Institutes of Health (SU01HL143475) awarded to Dr Bonafide. Dr Brady’s contribution to this manuscript was supported by the Agency for Healthcare Research and Quality under Award Number K08HS23827. Dr Schondelmeyer’s contribution to this manuscript was supported by the Agency for Healthcare Research and Quality under Award Number K08HS026763. Dr Bonafide’s contribution to this manuscript was

### TABLE. Test Characteristics of the Relationship Between Active Orders and Actual Pulse Oximetry Monitoring, Both Overall and as Stratified by Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Patient monitored</th>
<th>Patient unmonitored</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active order present</td>
<td>639</td>
<td>192</td>
<td>PPV: 77% (95% CI, 72%-82%)</td>
<td></td>
</tr>
<tr>
<td>Active order absent</td>
<td>670</td>
<td>1,480</td>
<td>NPV: 69% (95% CI, 61%-77%)</td>
<td></td>
</tr>
<tr>
<td>8 wk – 5 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active order present</td>
<td>339</td>
<td>76</td>
<td>PPV: 82% (95% CI, 76%-88%)</td>
<td></td>
</tr>
<tr>
<td>Active order absent</td>
<td>330</td>
<td>695</td>
<td>NPV: 68% (95% CI, 60%-76%)</td>
<td></td>
</tr>
<tr>
<td>6 mo – 11 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active order present</td>
<td>172</td>
<td>62</td>
<td>PPV: 74% (95% CI, 67%-80%)</td>
<td></td>
</tr>
<tr>
<td>Active order absent</td>
<td>182</td>
<td>406</td>
<td>NPV: 69% (95% CI, 60%-78%)</td>
<td></td>
</tr>
<tr>
<td>12 mo – 17 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active order present</td>
<td>80</td>
<td>35</td>
<td>PPV: 70% (95% CI, 60%-79%)</td>
<td></td>
</tr>
<tr>
<td>Active order absent</td>
<td>104</td>
<td>247</td>
<td>NPV: 70% (95% CI, 62%-78%)</td>
<td></td>
</tr>
<tr>
<td>18 mo – 23 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active order present</td>
<td>48</td>
<td>19</td>
<td>PPV: 72% (95% CI, 58%-85%)</td>
<td></td>
</tr>
<tr>
<td>Active order absent</td>
<td>54</td>
<td>132</td>
<td>NPV: 71% (95% CI, 61%-81%)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: mo, months; NPV, negative predictive value; PPV, positive predictive value; wk, weeks.
supported in part by the National Heart, Lung, and Blood Institute under award number K23HL116427. The funding organizations had no role in the design and conduct of the study, collection, management, analysis, and interpretation of the data, preparation, review, or approval of the manuscript, and decision to submit the manuscript for publication.

References


