Improving Patient Safety by Increasing Staff Knowledge of **Evidence-Based Pulse Oximetry Practices**

Danielle Hlavin, BSN, RN, CCRN, CMC
Maureen Varty, PhD, RN

BACKGROUND Pulse oximetry is commonly used in critical care settings to monitor oxygenation status and assist with decision-making regarding oxygen therapy. Although it is imperative that nurses follow manufacturer guidelines, off-label use is common and could affect patient safety.
OBJECTIVE To increase staff members' knowledge and reduce the frequency of off-label pulse oximeter placement in the critical care setting.
METHODS A preintervention audit was completed to assess the frequency of off-label use, and a preintervention survey was given to staff. Health care staff in the critical care units received an educational intervention. A postintervention survey for health care staff and a postintervention audit were completed to assess outcomes. With the support of hospital management, 90 ear probes were purchased for critical care settings to address supply barriers to the use of appropriate pulse oximetry sensors.
RESULTS In the preintervention audit (508 observations), a finger probe was used off label on the ear in 77 patients (15.2%). In the postintervention audit (365 observations), a finger probe was used on the ear in only 3 patients (0.8%).
CONCLUSION Providing a brief educational session and making ear pulse oximeter probes readily available in the critical care setting increased compliance with manufacturer guidelines and helped ensure safe pulse oximetry monitoring. (*Critical Care Nurse*. 2022;42[6]:e1-e6)

CE 1.0 hour, CERP A

This article has been designated for CE contact hour(s). The evaluation tests your knowledge of the following objectives:
1. Identify 2 factors that may limit nurses' ability to obtain accurate oxygen saturation readings from pulse oximeters.
2. Describe the potential impact of using off-label pulse oximetry placement on measurement of oxygen saturation.
3. Identify 1 direct measurement and 1 indirect measurement of blood oxygen saturation.

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 doi:https://doi.org/10.4037/ccn2022998

Pulse oximetry is a commonly used monitoring technology that provides an indirect and accurate method of measuring a patient's oxygen saturation. Pulse oximetry sensors measure oxygen saturation by projecting 2 different light wavelengths from one side of the sensor through tissues to the photodetector on the opposite side of the sensor. When pulsatile arterial blood passes through the tissues near the sensor, the levels of oxygenated and deoxygenated blood are measured by assessing the absorption of 660-nm (red) light and 940-nm (infrared) light, respectively.[1,2] A ratio of the absorption of these 2 light wavelengths is calculated to provide the indirect oxygen saturation. This measurement can be compared with the arterial blood oxygen saturation, which is a direct and invasive measurement of a patient's oxygenation status. Pulse oximetry sensors provide a waveform on a screen, allowing the health care provider to assess whether the pulse oximetry measurements are accurate or artifact.[2,3] Factors such as patient movement, poor perfusion, skin pigmentation, nail polish, dysrhythmias, and dyshemoglobins can decrease the ability to collect a valid and reliable pulse oximetry measurement.[4-7]

The purpose of this project was to reduce off-label placement of pulse oximetry sensors and increase health care staff members' knowledge regarding the optimal use of pulse oximetry.

Knowledge of pulse oximetry limitations is important for health care staff because decisions regarding oxygen treatment are often made using pulse oximetry measurements. Overestimation or underestimation of oxygenation status from pulse oximetry sensors could cause health care staff to offer inappropriate oxygen therapy to their patients. Prior research has demonstrated that within the critical care setting, nurses lack essential knowledge regarding these limitations, highlighting the need to ensure proper education for those using this technology.[8] Understanding limitations is critical because health care staff members need to be able to recognize situations in which pulse oximetry measurements may be inaccurate.[9] In addition to knowing the limitations of pulse oximetry, staff members should assess other factors, such as manufacturer guidelines for specific pulse oximetry sensors, to ensure that pulse oximetry is used appropriately for oxygen saturation measurement.

Lack of knowledge regarding topics such as the proper location for sensors should be assessed because the accuracy of off-label locations not included in manufacturer guidelines has not been thoroughly studied.[10] Furthermore, the limited literature that exists suggests that off-label placement, such as placement of a finger- or toe-designated sensor on an earlobe, may lead to overestimation of a patient's oxygenation status.[10,11] Although 3 studies have assessed this specific practice, only 2 studies compared off-label sensor placement with the reference standard, arterial blood gas measurement.[10-12] These studies have limitations; neither reported using power analysis and both relied upon small sample sizes.[10,11] In addition, one of the previously published studies used finger clip pulse oximetry sensors, which are not commonly used in the clinical setting for continuous pulse oximetry monitoring.[10] Without high-quality evidence to support the practice of off-label placement, accepted practice should include only on-label placement because potential overestimation of a patient's oxygen saturation could lead to reduced detection of hypoxemia and underuse of appropriate oxygen therapy. Because of this concerning outcome, ensuring that health care staff members have the appropriate knowledge regarding managing pulse oximetry is essential. When off-label use is identified, education should be provided to discourage this practice.

Although off-label placement is not evidence based, some clinical situations might lead nurses to use this practice. Many common situations can result in a health care staff member placing a pulse oximetry sensor in an off-label location. Motion such as that caused by hands being used for activities of daily living or a confused patient pulling at the sensor can cause the sensor to either misread or be unable to detect blood oxygen saturation. In these scenarios, staff members who do not have adequate knowledge of pulse oximetry placement may use

Authors

Danielle Hlavin is a charge nurse at UCHealth Memorial Hospital Central in Colorado Springs, Colorado.

Maureen Varty is a research nurse scientist at UCHealth University of Colorado Hospital and an assistant professor at University of Colorado College of Nursing, Aurora, Colorado.

Corresponding author: Maureen Varty, PhD, RN, UCHealth University of Colorado Hospital, Professional Development, 12401 E 17th Ave, MailStop 901, Leprino 6-024, Aurora, CO 80045 (email: maureen.varty@uchealth.org).

Table Results from pre- and postintervention surveys that assessed staff members' knowledge about pulse oximetry practices

Survey item	Acceptable responses[a]	No. (%) of acceptable responses	
		Before the intervention (N = 185)	After the intervention (N = 140)
It is safe to use a finger pulse oximeter probe on the ear to get an Spo_2 measurement.	Strongly disagree or disagree	72 (38.9)	119 (85.0)
I know the difference between Spo_2, Sao_2, and Pao_2.	Agree or strongly agree	151 (81.6)	114 (81.4)
I know factors that may affect Spo_2 accuracy.	Agree or strongly agree	170 (91.9)	128 (91.4)
I feel confident troubleshooting pulse oximeters to obtain optimal accuracy.	Agree or strongly agree	167 (90.3)	132 (94.3)
I know when to ask for an ABG.	Agree or strongly agree	158 (85.4)	117 (83.6)

Abbreviations: ABG, arterial blood gas; Sao_2, arterial oxygen saturation; Spo_2, oxygen saturation measured by pulse oximetry.

[a] Survey response options were "strongly disagree," "disagree," "neutral," "agree," and "strongly agree."

off-label placement to reduce the impact of the motion on oxygen saturation measurement. Another scenario that may lead to off-label placement is difficulty getting pulse oximetry measurements because of perfusion issues in distal tissues such as fingers or toes. If a patient is hypotensive, hypothermic, or receiving vasopressors causing vasoconstriction, the sensors may not be able to obtain a measurement. In this situation, health care staff may try different sites, including off-label sites, until they are able to obtain a pulse oximetry measurement.

After noticing that off-label placement was being used in the critical care setting at our organization, we decided that further investigation of this practice should be completed because it could affect patient safety and proper administration of oxygen therapy. The purpose of this quality improvement project was to reduce off-label placement of pulse oximetry sensors and increase health care staff members' knowledge regarding the optimal use of pulse oximetry.

Methods

Per organization policies, this quality improvement project was deemed exempt from institutional review board oversight. We conducted a literature review to assess the accuracy of off-label pulse oximetry placement after noticing frequent off-label use within the critical care units at the primary author's (D.H.) hospital. The limited literature available suggested that off-label placement could potentially give erroneous readings and negatively impact decisions about managing oxygen therapy.[10,11] No evidence supported the use of off-label placement. To evaluate the scope of the local problem, we assessed resources, the frequency of off-label use, and health care staff members' knowledge.

First, an audit form was developed to assess the number of finger probes used on off-label sites such as patients' ears across all the critical care units. Audits were conducted by entering each occupied room and noting finger probes found on off-label sites. The preintervention audits were conducted from August 2020 through October 2020. Sixteen separate observation periods were conducted during these months. A total of 508 observations were documented.

Second, a preintervention survey using a Likert scale was developed to assess health care staff members' knowledge of and confidence in pulse oximetry use and appropriate placement (see Table). Critical care nurses, patient care technicians, advanced care partners, and respiratory therapists were asked to complete the preintervention survey via multiple means including email communication, staff huddles, flyers placed around the unit, and one-on-one interactions. The survey contained 5 questions and took approximately 2 minutes to complete.

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In addition, the first author assessed pulse oximetry supplies. The purpose was to evaluate availability of supplies, type of supplies, and any barriers to obtaining this equipment that might increase health care staff members'

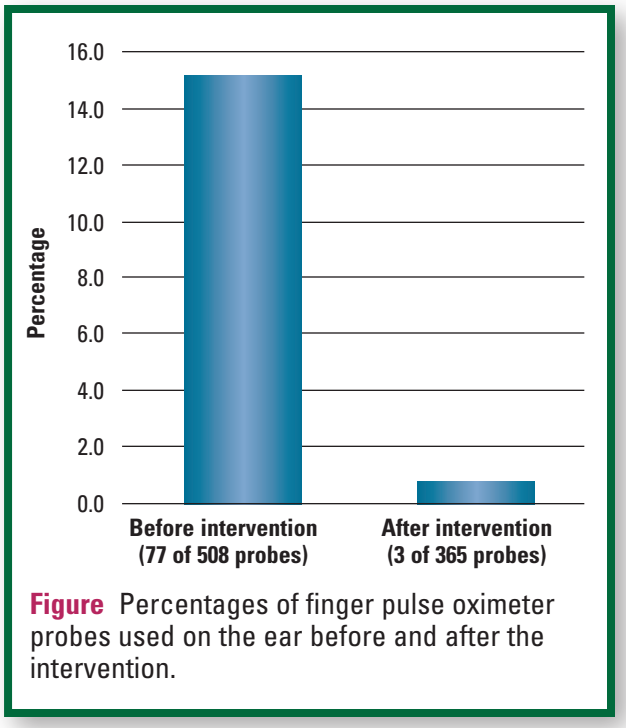

Figure Percentages of finger pulse oximeter probes used on the ear before and after the intervention.

off-label placement of pulse oximetry sensors. This examination found anecdotal evidence that staff members had difficulty finding ear probes for their patients. When finger pulse oximetry sensors were not able to detect a good signal on the finger or the ear, the staff would sometimes turn to off-label placement rather than trying to find the few ear probes that were available for use. Information gathered during this investigation was used to justify purchasing additional pulse oximetry ear probes so that each room in the critical care setting would have a dedicated ear probe.

Using the knowledge gained from the audits and preintervention surveys, we presented the findings and solutions for reducing these barriers to hospital leaders. The interventions agreed upon for implementation were to increase the number of reusable ear pulse oximeter probes for situations in which oxygen saturation could not be obtained via finger pulse oximetry sensors and to educate health care staff members who participated in direct patient care in critical care areas. For the first intervention, coordination with numerous stakeholders was imperative to facilitate the purchase of 90 ear pulse oximeter probes by contacting supply chain representatives. After the ear pulse oximeter probes were purchased, they were labeled "ICU" and affixed to the pulse oximeter cable in each intensive care unit patient room for easy access.

A short formal educational intervention was developed using articles from the literature review, feedback from stakeholders, and manufacturer guidelines. The 12-minute education covered the basic mechanics of pulse oximeters, proper placement and assessment, pulse oximetry limitations, manufacturer guidelines highlighting that finger pulse oximeters should not be used on the ear, and ways to troubleshoot pulse oximeters and find solutions when readings are difficult to obtain. With minor changes to adjust the education to the scope of health care staff members' practice (eg, nurses' scope versus patient care technicians' scope), similar education was provided to all critical care nurses, respiratory therapists, patient care technicians, and advanced care partners. The educational intervention was provided to nurses in October 2020 during staff skill laboratories. Respiratory therapists, patient care technicians, and advanced care partners received education during their staff meetings in December 2020 and January 2021 to allow for proper social distancing during the winter surge of patients with COVID-19.

To assess the impact of the purchase of more supplies and the educational intervention, we conducted observational audits in March and April 2021 and gave a postintervention survey to critical care nurses, patient care technicians, advanced care partners, and respiratory therapists. The same methods for auditing and the same survey were used. We collected additional data on ear probes in use and any off-label use of ear probes.

Results

Five hundred eight observations were completed during the preintervention audits. During these audits, finger pulse oximeter probes were found on the earlobe (an off-label use) in 77 patients (15.2%). Three hundred sixty-five observations were completed during the postintervention audits after more ear probes were obtained and the educational intervention was provided. Of these observations, 61 (16.7%) showed proper use of the new ear probes provided during the quality improvement project. Only 6 postintervention observations (1.6%) revealed off-label placement of pulse oximetry sensors and probes. Three of the off-label placements (0.8%) were finger sensors placed on the ear, and 3 (0.8%) were ear probes placed on the nose, which was not discussed in the education (see Figure).

A total of 175 critical care nurses, 37 respiratory therapists, and 21 patient care technicians and advanced care

partners received education from October 2020 through January 2021. Of these 233 health care staff members, 185 completed preintervention surveys. Only 72 respondents (38.9%) knew that finger pulse oximeters should not be placed on the ear, although 170 respondents (91.9%) reported on the survey that they had confidence with the statement "I know factors that may affect oxygen saturation accuracy" (see Table).

One hundred forty staff members completed postintervention surveys. The critical care units experienced significant staff turnover during the postintervention survey time period because of the COVID-19 pandemic, so a response rate could not be accurately calculated. After the intervention, 85.0% of respondents reported understanding that finger pulse oximeters should not be placed on the ear, which demonstrated a 46.1% improvement in staff knowledge regarding evidence-based placement. The level of staff confidence with pulse oximetry did not substantially change; 91.4% of respondents reported that they either agreed or strongly agreed with the statement "I know factors that may affect oxygen saturation accuracy" (see Table).

Discussion

Measuring oxygen saturation is not only a vital part of critical care but is also essential in many inpatient clinical areas. The familiarity and simplicity of pulse oximetry technology may easily lead staff members to overlook best clinical practice. The off-label practice of placing finger pulse oximeters on the ear was frequently used within our organization despite no evidence or policies supporting the practice. Before the intervention, finger pulse oximeters were used on the ear in an off-label fashion in 15.2% of patients, and only 38.9% of bedside staff members knew not to use finger probes on the ear. After the intervention, finger pulse oximeters were used on the ear in only 0.8% of patients, and 85.0% of respondents knew not to use finger probes on the ear. Because of the success of this brief educational intervention, this project should be implemented across our whole organization because all critical care and non–critical care health care staff members who use pulse oximeters could benefit from the education. According to anecdotal evidence, off-label use is not only a critical care problem and is likely common across all inpatient care settings within our organization.

Multiple lessons were learned in this quality improvement project. Simultaneously providing education about pulse oximetry and facilitating the purchase of ear pulse oximeters was imperative to promote on-label practice to ensure the most accurate oxygen saturation measurements. It was not enough for staff members to have adequate knowledge of evidence-based practice; the ear probes were also essential to changing health care staff members' practice. As demonstrated by the postintervention audits, 16.7% of postintervention placements used the new ear probes. By taking the time to understand the barriers to practice, we identified long-term solutions, and now every critical care room has dedicated ear probes to ensure ease of access. After the purchase of ear pulse oximeters, a few postintervention observations showed that staff members began to place these probes on the nose, a practice that was not supported by the manufacturer or the literature. Staff members were reminded of best practice during weekly huddles and one-on-one discussions to curb this new, unexpected practice.

Although ear probes may help overcome the barriers of using finger or toe sensors, like finger and toe sensors they carry a risk for causing pressure injuries.

Another lesson learned during this study was the need to provide further education on the risks of using ear probes. Although ear probes may help overcome the barriers of using finger or toe sensors, like finger and toe sensors they carry a risk for causing pressure injuries. We found that staff needed further education regarding this risk. During the quality improvement project, 3 pressure injuries were associated with ear probes. Spot education was provided in real time to staff members to mitigate this risk and ensure that best practices were followed. The risk for pressure injuries was also conveyed in staff huddles and in unit-wide emails.

Because this quality improvement project focused on changing the culture of pulse oximetry use, it was essential for the education to reach all disciplines that could impact outcomes (eg, by reducing off-label use). By having support from stakeholders and leaders across disciplines from the beginning, the project rollout, including education development and implementation, could be quickly adjusted for barriers posed by the COVID-19 pandemic. If education had been delivered at different times, health care staff members may have been operating with different knowledge levels and the project might not have resulted in as great of a decrease in off-label use.

Implications

Educators and those involved in assessing health care staff members' practices should evaluate whether pulse oximetry sensors are being used in an evidence-based way that aligns with manufacturer guidelines. Health care systems have had increased staff turnover as a result of the COVID-19 pandemic, and this has greatly impacted critical care areas. This turnover can lead to increased hiring of travel or agency nurses, which means less continuity of education regarding best practices or hospital-specific policies. Staff turnover makes this education and intervention even more important because the new health care staff members who replace those who leave may not have the knowledge necessary to ensure safe pulse oximetry use. Although it is a basic practice, placement of pulse oximeters could greatly impact decision-making and interventions for patients; thus, it is a practice worth assessing.

Limitations

This quality improvement project had some limitations. The tool used to measure knowledge was designed for this project, so its validity and reliability are unknown. In addition, staff turnover was increased during this time period, which impacted the postintervention survey response rate. Furthermore, knowledge retained after the intervention may have been affected by stress induced by the COVID-19 pandemic. This quality improvement project began right at the beginning of the winter 2020 COVID-19 case surge. The COVID-19 pandemic has greatly contributed to stress and burnout in critical care areas.[13] This could have affected the short- and long-term impact of the educational intervention. The team conducting this project will continue to assess the efficacy of the intervention and the potential need for reeducation, especially considering the increase in staff turnover, increased use of travel nurses, and health care staffing issues associated with the pandemic.

Conclusion

A review of the literature found that pulse oximetry accuracy is optimized when pulse oximeters are used according to manufacturer guidelines. It is imperative for patient safety and outcomes that these guidelines are followed. However, there may be gaps in staff knowledge and resources. Providing education about pulse oximetry and ensuring that appropriate resources such as ear pulse oximeter probes are available to staff increase compliance with best practice. More research regarding on-label versus off-label use of pulse oximeters is necessary to inform bedside practice. CCN

Acknowledgments
The authors thank Nicki Seyller, DNP, RN, APN, ACCNS-AG, CCRN-K, SCRN, and Lisa Simmons, BSN, RN, CCRN, for their support with this project.

Financial Disclosures
None reported.

See also

To learn more about oxygen therapy in the critical care setting, read "High-Flow Oxygen Therapy to Speed Weaning From Mechanical Ventilation: A Prospective Randomized Study" by Liu et al in the *American Journal of Critical Care,* 2019;28(5):370-376. https://doi.org/10.4037/ajcc2019130. Available at **www.ajcconline.org**.

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