

Does Ambient Light Affect the Accuracy of Pulse Oximetry?

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OBJECTIVE: Determine whether ambient light affects the accuracy of pulse oximetry readings. **DESIGN:** Prospective, repeated-measures study. **SETTING:** A photographic darkroom. **SUBJECTS:** Forty-five faculty and students at a university, none of whom had pale skin, dark skin, or evidence of cardiopulmonary disease. Any nail polish was removed. **METHODS:** Five light sources were individually tested: incandescent, quartz-halogen, infrared, fluorescent, and bilirubin light. A pulse oximetry probe was placed on the subject's finger, and the finger and probe were placed sideways under each light source, on a predetermined mark. **RESULTS:** The greatest difference in pulse oximetry reading between any of the light sources was 0.5%. Repeated-measures analysis of variance yielded a p value of 0.204. **CONCLUSIONS:** Ambient light has no statistically significant effect on pulse oximetry readings. Even had the differences been statistically significant, the magnitude of the differences was small and thus clinically unimportant. *Key words:* pulse oximetry, monitoring, patient assessment, oxyhemoglobin saturation. [Respir Care 2003;48(7):677–680. © 2003 Daedalus Enterprises]

Introduction

Pulse oximetry is widely used in clinical practice. Prior to the widespread use of pulse oximeters, arterial blood had to be drawn and analyzed with a co-oximeter every time a clinician needed to know the oxygen saturation of arterial blood. Pulse oximetry provides noninvasive, immediate, and continuous arterial oxygen saturation readings (S_{pO_2}) and can be used in various settings.¹ Although easy to perform, pulse oximetry requires clinician training to ensure accurate readings. In one report 87% of nurses claimed that they regularly use pulse oximetry to evaluate their patients, but only 37% thought they had adequate training and knowledge of pulse oximetry.² If pulse oximetry is not properly performed or is performed by persons who are not aware of the limitations and applications of

the device, spurious S_{pO_2} readings could lead to inappropriate treatment.³

Early research showed that pulse oximeters produced clinically acceptable results.⁴ Manufacturers claim a 68% confidence limit (± 1 standard deviation) of 2% for oxygen saturations between 70% and 100% for adults or 3% for neonates or adults with motion.⁵ However, according to the American Association for Respiratory Care's Clinical Practice Guidelines,¹ several internal and external factors can affect the accuracy of pulse oximetry. Readings can be affected by patient motion,⁶ shivering,⁷ abnormal hemoglobins,⁶ intravascular dyes,⁸ low perfusion states,^{9,10} skin pigmentation,¹¹ nail polish,¹² and exposure of the measuring probe to ambient light during measurement.¹³ Many of these potentially confounding influences can be minimized or eliminated, but ambient light is a factor in almost all care environments. Numerous light sources have been reported to interfere with the accuracy of pulse oximetry. These largely anecdotal reports included interference from fluorescent,¹⁴ incandescent,¹⁵ quartz-halogen,¹⁶ and infrared¹⁷ light sources.

There is a rationale for concern about the effects of ambient light on pulse oximetry readings. Pulse oximetry is based on the fact that light of 660 nm wavelength is absorbed roughly 10 times more readily by deoxygenated hemoglobin than by oxygenated hemoglobin, and light of

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920 nm wavelength is absorbed by oxygenated hemoglobin more readily than by deoxygenated hemoglobin. The ratio of those 2 light absorptions is the basis for the algorithm to calculate S_{pO_2} . The photoplethysmography contribution (the "pulse" aspect of pulse oximetry) permits isolation of the pulsatile flow of arterial blood (which can be referred to as the "alternating current" signal) from tissue, venous blood, and nonpulsatile arterial blood (which collectively make up the static or "direct current" signal).⁷ By comparing the ratio of the "alternating current" and "direct current" red light signal (660 nm) to the ratio of that of the infrared light signal (920 nm) the pulse oximeter cancels out the components of the static signal and calculates arterial blood oxygen saturation.⁷

The 2 wavelengths sensed by the oximeter probe (660 nm and 920 nm) can be generated (in various proportions) by several ambient light sources commonly used in clinical settings. For example, the spectrum of energy produced by both quartz-halogen and incandescent bulbs begins in the visible range, at 650 nm, and peaks around 1,000 nm. An infrared heat lamp, with spectral output beginning at approximately 700 nm, generates little energy in the visible (red) range. In contrast, bilirubin and fluorescent light sources emit more energy at shorter wavelengths and minimal energy in the infrared range. Bilirubin light peaks around 200–400 nm. Fluorescent light produces most of its energy in the visible range: 405–579 nm.

Since pulse oximetry depends on accurate measurement of the 660–920 nm range and quartz-halogen, incandescent, infrared, fluorescent, and bilirubin bulbs produce wavelengths in that range, those light sources could, theoretically, affect pulse oximetry readings. While practitioners and manufacturers commonly believe that those light sources do affect pulse oximetry readings,⁵ there have been no randomized, prospective, controlled studies addressing this topic.¹⁶ Therefore, the purpose of this study was to determine whether the ambient light sources commonly used in clinical settings affect S_{pO_2} readings. Our hypothesis was that ambient light does affect S_{pO_2} readings.

Methods

Approval was obtained from the Upstate Medical University's Institutional Review Board for the Protection of Human Subjects. We recruited 45 Upstate Medical University faculty and student volunteers between the ages of 20 and 59. Subjects gave written informed consent. A brief medical history was obtained from each subject, to exclude individuals with cardiopulmonary disease. A visual inspection was done to exclude individuals with peripheral edema. Subjects who were extremely pale or had dark skin pigmentation were also excluded. Any nail polish was removed.

Prior to the acquisition of data we measured the relative output from each of the 5 light sources, using narrow band pass filters at the 2 wavelengths used by pulse oximeters. The light sources included a 23-watt fluorescent lamp, a 100-watt incandescent lamp, 125-watt infrared heat lamp, a 10-watt quartz-halogen lamp, and portable infant bilirubin lamp. The light intensity at each of the wavelengths was measured with a photometer (Graseby S370, UDT Instruments, Baltimore, Maryland). Measurements were taken using 2 interference band pass filters (Edmund Industrial Optics, Barrington, New Jersey): one with a peak at 660 nm, the other at 905 nm (a band pass filter specifically for 920 nm was not available). The filters have a full half width maximum of 12.8 nm, which means that transmission through the filter falls to 50% of peak value at \pm 6.4 nm. The measurements were done in a photographic darkroom to exclude other sources of ambient light. Table 1 lists the ratio of the intensity at 660 nm to the intensity at 905 nm from each light source.

Quartz-halogen, infrared, and incandescent bulbs have fairly similar energy output ratios, and those ratios are close to 1. Because these ratios are < 1 , the energy intensity is slightly higher around 905 nm.

The fluorescent and bilirubin bulbs have similar energy output ratios (about 112 and 132), and because those ratios are > 100 , their intensity is higher around 660 nm.

The environmental conditions of our study were controlled. The subjects participated one at a time, and the tests were conducted in complete darkness in a photographic darkroom that excluded all ambient light. Each light source was applied at the same intensity, which was confirmed with the photometer, in the spectral range of 200–1,000 nm; the distance of the light source from the subject's finger was adjusted so that the overall intensity was the same. The probe was placed on the subject's right index finger, and the finger was positioned sideways under each light source to maximize the potential for interference from the ambient light being tested. The subject's finger was placed on the same predetermined mark under each light source. Once the reading was stable, S_{pO_2} was recorded from a pulse oximeter (Nellcor N-200, Nellcor Puritan Bennett, Pleasanton, California). The pulse oxim-

Table 1. Energy Output Ratios

Light Source	Energy Output Ratio*
Quartz-halogen	0.70
Infrared	0.55
Incandescent	0.81
Fluorescent	112.10
Bilirubin light	132.08

*Ratio of the intensity at 660 nm in mw to the intensity at 905 nm in mw

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Table 2. Pulse Oximetry Readings Under 5 Light Sources and Control

	Control	Quartz-Halogen	Infrared	Incandescent	Fluorescent	Bilirubin
Mean S_{PO_2}	98	97.5	97.6	97.7	97.6	97.8
SEM	0.182	0.158	0.150	0.165	0.160	0.163
Difference	NA	-0.467	-0.311	-0.289	-0.356	-0.200
SEM	NA	0.133	0.130	0.141	0.128	0.137

S_{PO_2} = pulse oximetry reading

SEM = standard error of the mean

NA = not applicable

etry probe was cleaned with an alcohol pad between subjects. The light sources were applied in a random order determined by the Latin square design.

The fluorescent light source was allowed to warm up for 3 min, to ensure that it was providing a stable intensity output. Each individual's S_{PO_2} was also measured in complete darkness, to serve as a control reading.

Statistical Analysis

Statistical analysis was performed with statistics software (Minitab, State College, Pennsylvania). All values are expressed as mean \pm standard error of the mean. Differences were considered statistically significant when $p < 0.05$ (2-sided). A one-way analysis of variance, with repeated measures, was used to analyze the effects of the 5 sources on S_{PO_2} readings.

Results

A sample of convenience included 45 subjects (29 women, 16 men). The mean age of the women was 35.5 ± 2.1 years, and that of the men was 35.4 ± 2.9 years. All the subjects had good cardiopulmonary function.

The S_{PO_2} for each light source for each subject was subtracted from the control value for that subject. The differences were then averaged for all subjects for each light source. Table 2 shows the results. No difference $> 0.5\%$ was measured between any light source and the control. Measurements were all higher than the control, with little variability among measurements.

Discussion

Our findings suggest that ambient light has no statistically significant effect on S_{PO_2} readings and that ambient light's effect on S_{PO_2} is clinically unimportant. We believe the results would be similar in the clinical setting.

In the clinical setting patients are often exposed to several light sources simultaneously, rather than individually as in our experimental design. However, different ambient

light sources would not be expected to interfere with each other.

Our results do not support the belief that ambient light affects pulse oximetry readings. Ambient light is listed as an interfering factor in the American Association for Respiratory Care's Clinical Practice Guidelines for Pulse Oximetry,¹ and several published reports suggest that ambient light causes interference. Brooks et al¹⁷ found that an infrared heat lamp caused false low S_{PO_2} readings. Block¹⁶ found that a quartz-halogen light placed next to the pulse oximetry probe on the subject's finger caused false low readings. Amar and Neidzwski¹⁴ reported that fluorescent light caused a pulse oximeter to give a reading when it was not attached to a patient. However, those reports were anecdotal, not prospective, randomized, controlled studies.

Our results may be explained by considering the principle of photoplethysmography. A pulse oximeter uses photoplethysmography to detect arterial pulsations and measure the saturation of arterial blood. Therefore, both the volume of arterial blood in tissue and the light absorption of blood change during the pulsatile phase. The photodetector, sampling the light at 480 times per second, is also measuring ambient light during both static and pulsatile phases. Therefore, the pulse oximeter nulls not only tissue and venous blood but also incident energy from any ambient energy source.¹

We used only healthy white subjects, to minimize confounding variables. Future research should include testing subjects with darker skin and subjects whose oxygen saturation is below normal ($< 95\%$).

Conclusions

Pulse oximeter readings are not significantly affected by 5 light sources commonly found in the clinical setting. Therefore, our data suggest that ambient light in the clinical setting has no clinically important effect on pulse oximetry readings.

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Catalogue of Standard Surgeons Instruments and Apparatus.
Klomo Instrument Co, Washington, DC, 1926.
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