

The Ear as an Alternative Site for a Pulse Oximeter Finger Clip Sensor

Jeffrey M Haynes RRT RPFT

BACKGROUND: Finger clip pulse oximetry sensors are commonly used to obtain functional oxygen saturation readings (S_{pO_2}), but these sensors may perform poorly if the digit is poorly perfused or there is excessive hand movement. I have increasingly witnessed clinicians obtaining S_{pO_2} readings by placing the finger clip sensor on the patient's ear when an S_{pO_2} reading cannot be obtained from a finger. **OBJECTIVE:** Determine if reliable S_{pO_2} readings can be obtained from a finger clip sensor placed on the ear. **METHODS:** This was a prospective study with patients undergoing pulmonary function testing. The calculated functional oxygen saturation values from arterial blood gas analysis (S_{aO_2}) were compared with S_{pO_2} readings from a finger clip sensor placed on a finger (finger S_{pO_2}) and on the upper portion of an ear (ear S_{pO_2}). S_{pO_2} data were included in the study only if (1) the pulse rate from finger S_{pO_2} and ear S_{pO_2} differed by ≤ 5 beats/min and (2) the photoplethysmographic waveform was stable and acceptable. **RESULTS:** Data were obtained from 30 adult white patients. The number of S_{pO_2} readings that differed from the S_{aO_2} values by $\geq 3\%$ were 1 (3.3%) finger S_{pO_2} reading and 24 (80%, 95% CI 61%–92%) ear S_{pO_2} readings ($p < 0.001$). Bland-Altman analysis showed better agreement between S_{aO_2} and finger S_{pO_2} (mean ± 2 SD limits of agreement -2.35 to 2.35) than between S_{aO_2} and ear S_{pO_2} (limits of agreement -7.24 to -0.08) or finger S_{pO_2} and ear S_{pO_2} (limits of agreement -7.56 to -0.23). **CONCLUSION:** A pulse oximeter finger clip sensor placed on the ear does not provide clinically reliable S_{pO_2} readings. *Key words:* pulse oximetry, blood gas analysis, oxygenation, monitoring. [Respir Care 2007;52(6):727–729. © 2007 Daedalus Enterprises]

Introduction

Pulse oximeters are widely used to assess oxygenation and adjust oxygen therapy. Finger clip pulse oximetry sensors are commonly used to obtain functional oxygen saturation readings (S_{pO_2}) but may perform poorly when the patient has cold, poorly perfused digits¹ or excessive hand movement² (eg, tremor). Though pulse oximeter finger clip sensors are only approved by the U.S. Food and Drug Administration for use on the finger, I have increasingly witnessed clinicians obtaining S_{pO_2} readings by placing a finger sensor on the patient's ear when an S_{pO_2} reading cannot be obtained on a finger. Many of these clinicians assume that these ear measurements are accurate, based solely on pulse-rate correlation. The purpose of this study

was to determine if reliable S_{pO_2} readings can be obtained by using a finger clip sensor on an ear.

Methods

Study Design

Approval for this study was granted by the institutional review board of St Joseph Hospital, Nashua, New Hampshire. Written informed consent was obtained from each patient before testing. Data were sought from 30 patients in a prospective study of patients undergoing pulmonary function testing that included a physician's order for arterial blood gas analysis. Calculated functional oxygen saturation measurements (S_{aO_2}) from arterial blood gas analysis (AVL Omni 6, Roche Diagnostics, Indianapolis, Indiana) were compared with S_{pO_2} (NPB-195, Nellcor Puritan Bennett, Pleasanton, California) values obtained from a finger clip sensor placed on a finger (finger S_{pO_2}) and on the upper portion of the ear (ear S_{pO_2}) (Fig. 1). I chose this ear site because it is the one I have most frequently observed used by other clinicians. S_{pO_2} data were included in the study only if (1) the pulse rate readings from the finger sensor and the ear sensor differed by ≤ 5 beats/min and (2) the photoplethysmographic waveform was stable and acceptable. A

Jeffrey M Haynes RRT RPFT is affiliated with the Department of Respiratory Therapy, St Joseph Hospital, Nashua, New Hampshire.

The author reports no conflicts of interest related to the content of this paper.

Correspondence: Jeffrey M Haynes RRT RPFT, Department of Respiratory Therapy, St Joseph Hospital, 172 Kinsley Street, Nashua NH 03060. E-mail: jhaynes@sjh-nh.org.



Fig. 1. The placement of a pulse oximeter finger clip sensor on the upper portion of the ear.

piece of cardboard was used to cover the S_{pO_2} display until the pulse rate and photoplethysmographic waveform were deemed acceptable, then the cardboard was lifted to obtain the S_{pO_2} reading. S_{pO_2} data were collected first, followed by arterial blood gas analysis. The order of S_{pO_2} readings was randomized with statistics software. If a patient was wearing fingernail polish, the finger clip sensor was turned 90 degrees, as described by Chan et al.³

Statistical Analysis

Statistical computations were done with commercially available software (Prism 4, GraphPad Software, San Diego, California). Differences in categorical data were analyzed with Fisher's exact test. Bland-Altman⁴ analysis was performed to evaluate the agreement between the methods.

Results

Thirty-one patients agreed to participate in the study, but one patient had to be excluded because an ear S_{pO_2} reading could not be obtained. The number of S_{pO_2} readings that differed from S_{aO_2} by $\geq 3\%$ were 1 (3.3%) finger S_{pO_2} , and 24 (80%, 95% CI 61%–92%) ear S_{pO_2} ($p < 0.001$). Bland-Altman analysis showed better agreement between S_{aO_2} and finger S_{pO_2} (mean ± 2 SD limits of agreement -2.35 to $+2.35$) (Figure 2) than between S_{aO_2} and ear S_{pO_2} (limits of agreement -7.24 to -0.08) (Fig. 3), or finger S_{pO_2} and ear S_{pO_2} (limits of agreement -7.56 to -0.23) (Fig. 4).

Discussion

The ear S_{pO_2} values did not agree with the S_{aO_2} or finger S_{pO_2} values. By design, this was true even with pulse-rate

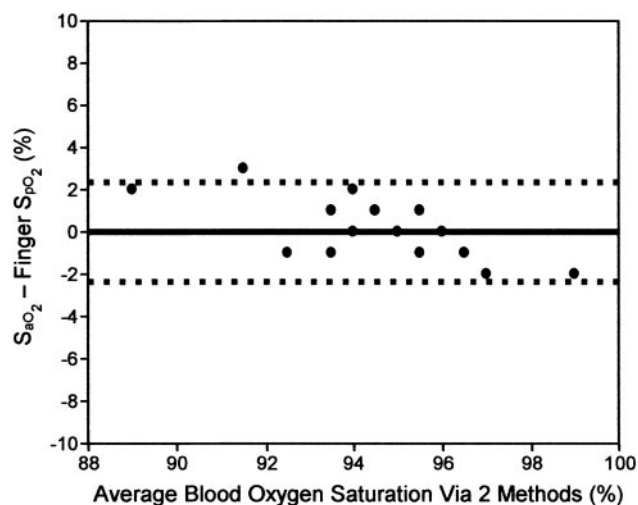


Fig. 2. Bland-Altman analysis of the agreement between oxygen saturation measurements on arterial blood (S_{aO_2}) and oxygen saturation readings (finger S_{pO_2}) from a pulse oximetry sensor placed on a finger (the anatomical site for which the sensor was designed). The solid line represents the mean bias. The dashed lines represent the limits of agreement (± 2 standard deviations).

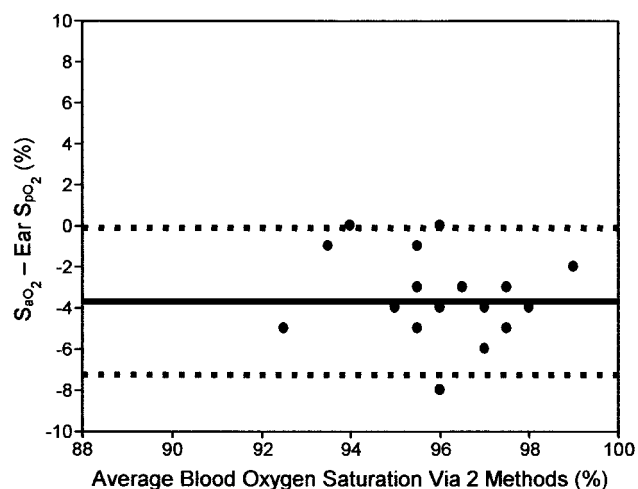


Fig. 3. Bland-Altman analysis of the agreement between oxygen saturation measurements on arterial blood (S_{aO_2}) and oxygen saturation readings (ear S_{pO_2}) from a pulse oximetry sensor placed on an ear (the sensor was designed to be placed on a finger). The solid line represents the mean bias. The dashed lines represent the limits of agreement (± 2 standard deviations).

correlation and acceptable photoplethysmographic waveforms. In 80% of the patients the ear S_{pO_2} overestimated S_{aO_2} by $\geq 3\%$, and in one patient by 8%. Ear S_{pO_2} never underestimated S_{aO_2} . The basic mechanism of this phenomenon is simple: the absorption of red light (approximate wavelength 660 nm) and infrared light (approximate wavelength 940 nm) measured by a finger clip sensor is different when the light passes through an earlobe than when it passes through a finger. Therefore, one cannot assume that using a sensor on anatomical structures other than the intended site will yield reliable results. Another

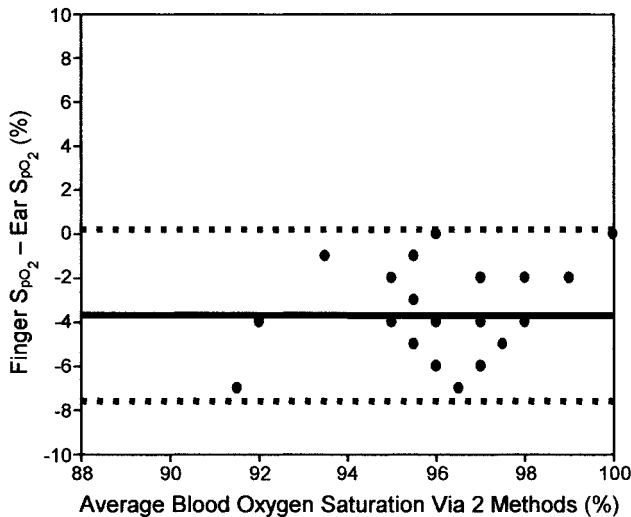


Fig. 4. Bland-Altman analysis of the agreement between pulse oximetry oxygen saturation readings from a pulse oximetry sensor placed on a finger (finger S_{pO_2}) versus on an ear (ear S_{pO_2}). The solid line represents the mean bias. The dashed lines represent the limits of agreement (± 2 standard deviations).

plausible explanation is that affixing an ill-fitting finger clip sensor to a patient's ear may result in optical shunting (light passing from the light-emitting diodes to the photodetector without passing through tissue). Indeed, Barker et al⁵ found that intentional sensor malpositioning resulted in both overestimation and underestimation of S_{aO_2} , depending on the oximeter manufacturer, model, and actual S_{aO_2} . In patients with small ears, the light-emitting diode and photodetector of a finger clip sensor may not extend far enough to pass over tissue. However, in post hoc experimentation, I could not produce spuriously high S_{pO_2} values when I purposefully created optical shunts with the pulse oximeter and probe used in this study.

This study has several limitations. Only one model of pulse oximeter and finger clip sensor were used, and other models might produce different results. Data collection was performed solely by me. Since S_{pO_2} values may fluctuate slightly, even during resting conditions, the selection of the reported S_{pO_2} value was subject to the bias of the sole investigator. This type of interpretive bias also applies to the determination of what constitutes an acceptable photoplethysmographic waveform. To decrease the risk of this bias, the cardboard that covered the S_{pO_2} display was lifted only when the pulse rate and photoplethysmographic waveform were deemed acceptable.

In addition, the same pulse oximeter and sensor were used for both finger S_{pO_2} and ear S_{pO_2} measurements, so that differences in pulse oximeter and sensor function^{1,6} would not be a factor; however, this was done at the cost of the measurements being made at different points in time. While the time difference between measurements

was minimal, variations in the patient's breathing pattern (eg, sighs) could have affected the S_{pO_2} values.

Lastly, all of the patients had an $S_{pO_2} \geq 90\%$, and pulse oximeters may perform differently under conditions of moderate-to-severe hypoxemia.⁷ In addition, the clinical impact of S_{aO_2} overestimation by ear S_{pO_2} may have been greater if patients with $S_{aO_2} \leq 88\%$ (ie, patients who qualify for long-term oxygen therapy) had been included in the study. Clearly, overestimation of S_{aO_2} in hypoxemic patients poses both immediate and long-term risks from non-treatment and misinterpretation of clinical events.

Scientific investigation of the accuracy of pulse oximetry sensors needs to be ongoing, because new technologies are frequently introduced to the market. Despite some internal safeguards (eg, signal-quality indicators), the quality control of pulse oximetry depends on the end-user's ability to use the device and correctly interpret the validity of S_{pO_2} readings. Since pulse oximetry is poorly understood by many,⁸ finding ways to improve end-user knowledge is critical.

Conclusions

These data support the recommendation in the American Association for Respiratory Care clinical practice guideline for pulse oximetry, that a pulse oximeter probe should be attached only to the intended site.⁹ Placing a pulse oximeter finger clip sensor on an ear does not provide clinically reliable S_{pO_2} readings.

ACKNOWLEDGMENTS

Thanks to William C Stephan MD, Pulmonary Associates, Nashua, New Hampshire, for his advice and review of this manuscript.

REFERENCES

- Gehring H, Hornberger C, Matz H, Konecny E, Schmucker P. The effects of motion artifact and low perfusion on the performance of a new generation of pulse oximeters in volunteers undergoing hypoxemia. *Respir Care* 2002;47(1):48-60.
- Barker SJ, Shah NK. The effects of motion on the performance of pulse oximeters in volunteers (revised publication). *Anesthesiology* 1997;86(1):101-108.
- Chan MM, Chan MM, Chan ED. What is the effect of fingernail polish on pulse oximetry? (letter) *Chest* 2003;123(6):2163-2164.
- Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1(8476):307-310.
- Barker SJ, Hyatt J, Shah NK, Kao YJ. The effect of sensor malpositioning on pulse oximeter accuracy during hypoxemia. *Anesthesiology* 1993;79(2):248-254.
- van Oostrom JH, Melker RJ. Comparative testing of pulse oximeter probes. *Anesth Analg* 2004;98(5):1354-1358.
- Chiappini F, Fuso L, Pistelli R. Accuracy of a pulse oximeter in the measurement of the oxyhaemoglobin saturation. *Eur Respir J* 1998; 11(3):716-719.
- Stoneham MD, Saville GM, Wilson IH. Knowledge about pulse oximetry among medical and nursing staff. *Lancet* 1994;344(8933): 1339-1342.
- American Association for Respiratory Care. AARC Clinical Practice Guideline: Pulse oximetry. *Respir Care* 1991;36(12):1406-1409.