Anesth Prog 39:194–196 1992

Limitations of Pulse Oximetry

George Mardirossian, DMD, and Ronald E. Schneider, DDS
Department of Oral and Maxillofacial Surgery, New Jersey Dental School, Newark, New Jersey

Pulse oximetry is a noninvasive, accurate, and safe method for the measurement of oxygen saturation during intravenous sedation or general anesthesia. Several factors should be considered with its use, since these variables will either alter the accuracy of the readings or may cause harm to the patient. These factors include changes in the strength of the arterial pulse, body movements, dyshemoglobinemias, plasma lipids and bilirubin, color interferences, venous pulsations, and several physical factors. Awareness of these variations will help the clinician become more knowledgeable in the use of the pulse oximeter.

Pulse oximetry has become a useful adjunct for monitoring the arterial oxygen saturation of hemoglobin. This method of continuous monitoring has been shown to detect early hypoxic changes in sedated or anesthetized patients.[1] Spectrophotoelectric oximetry is a noninvasive, accurate, and safe technique for measuring oxygen saturation and has become standard practice for specific clinical situations, such as intravenous conscious sedation, deep sedation, and general anesthesia.[2] The pulse oximeter sensor is usually attached to a patient's digit and monitors early changes in arterial hemoglobin oxygen saturation (SpO_2) in the peripheral tissues.

Many publications have justly lauded the advent of the pulse oximeter.[1–4] However, the literature also reports several conditions when the use of this instrument has either harmed the patient or has given incorrect data.[5–8] In most of these cases, these problems can be circumvented by thoroughly reviewing the medical history and physical findings and by proper application of this device to the patient. The clinician must be aware of the limitations of this technique and understand the conditions that alter its proper function.

BASIS OF PULSE OXIMETRY

The pulse oximeter functions by positioning a pulsating arterial vascular bed between a two-wavelength light-emitting diode and a detector (photodiode). One wavelength is 660 nm (red) and the other is 940 nm (infrared). Oxygenated hemoglobin (O_2Hb) will absorb more of the 940 nm wavelength than reduced hemoglobin (RHb); conversely, RHb will absorb ten times more of the 660 nm wavelength than O_2Hb.[9] The pulse oximeter isolates readings of the pulsatile-dependent portion of the total light absorption, which is presumably arterial in nature. The percent saturation reading results from a ratio of oxygenated hemoglobin to the total hemoglobin content. In most situations, the total hemoglobin is essentially the sum of O_2Hb and RHb (functional Hb Saturation); however, methemoglobin (MetHb) and carboxyhemoglobin (COHb) also absorb these wavelengths and, when increased in concentrations, will interfere with accurate SpO_2 readings. This example is but one of many sources of error.

SOURCES FOR ERROR

Factors that can adversely influence the pulse oximeter reading include changes in the strength of the arterial pulse, body movements, dyshemoglobinemias, plasma lipids and bilirubin, color interferences, venous pulsations, and various physical factors. These factors are summarized in Table 1.

Strength of the Arterial Pulse

The pulse oximeter is designed to measure changes in light absorbance produced during arterial pulsations. In this manner, absorbance changes due to surrounding tissue are eliminated. Any factor that reduces vascular pulsations will reduce the ability of the instrument to detect

Received January 10, 1992; accepted for publication December 28, 1992.

Address correspondence to Dr. George Mardirossian, Department of Oral and Maxillofacial Surgery, New Jersey Dental School, 110 Bergen Street, Newark, NJ 07103–2400.

ISSN 0003-3006/92/$6.00

Table 1. Sources of Errors

Error Source	*Effects on SpO_2*	*Response*
Hypotension	Possible loss of signal	Correct underlying problem (eg, give fluid challenge, lighten anesthesia), vasopressors
Vasoconstriction (Reduction of blood flow to arterial bed)	Possible loss of signal, reduction of SpO_2	Change to more central site
Hypothermia (Reduction of blood flow; seen in Pts. w/Raynaud's disease)	Possible loss of signal, reduction of SpO_2	Keep patient and extremities warm
Shivering/muscle twitching	Changes in pulse size, possible loss of signal	Warm and/or sedate patient
Carboxyhemoglobinemia	Falsely high SpO_2 reading	Increase ventilation, eliminate rebreathing
Methemoglobinemia	Falsely low readings approaching 85%	Administer methylene blue
Venous pulsations	Falsely low SpO_2 readings	Change site
Blood pressure cuff on monitored arm	Loss of signal decreases SpO_2	Change site
Arterial lines on monitored arm	Loss of signal decreases SpO_2	Avoid use of arteries in monitored arm
Intense bright light (eg, fiberoptic fluorescent lights)	Lower SpO_2 readings	Avoid exposure of photodiode to light

and analyze the signal and, therefore, to calculate the arterial oxygen saturation. Hypothermia, hypotension (mean arterial blood pressure under 50 mm Hg), and the use of vasopressors that act to decrease the arterial pulsation in the finger or toe used for pulse oximetry may contribute to inaccurate readings. Most manufacturers warn that the instrument will not register a reading if there is inadequate perfusion. However, the clinician must still be aware that inaccurate reading may result from *decreasing* tissue perfusion.

Body Movements

Since pulse oximeters rely on the pulsatile stage of arterial blood flow to determine SpO_2, any extraneous movements that cause intermittent changes in absorbance can affect the reading. Shivering and muscle twitching may influence both the pulse rate display and saturation reading. Most instruments can tolerate small amounts of movement, but exaggerated movements have been shown to effect the accuracy of this method of monitoring.

Dyshemoglobinemias

Dyshemoglobinemias due to methemoglobin, carboxyhemoglobin, and sulfhemoglobin may lead to inaccurate pulse oximeter readings due to absorbance of one or both wavelengths. Carboxyhemoglobin may absorb as much of the 660-nm wavelength as O_2Hb. Methemoglobin will absorb as much of the 660-nm light as RHb, but absorbs the 940-nm light to even a greater degree. This effect will push the saturation reading toward 85%, which will be falsely low at high SpO_2 states and falsely high at SpO_2 states below 85%. Methylene blue, which is used to treat methemoglobinemia will in itself cause a drop in SpO_2 to 65% for several minutes.[9] Careful review of the medical history and physical examination will help to identify these patients.

Lipids and Bilirubin

High blood lipid concentrations, hyperalimentation, and hyperbilirubinemia can interfere with pulse oximeter readings. Increased concentrations of bilirubin tend to overestimate the measured oxygen saturation. The Lambert-Beer Law states that the concentration of solute in suspension is inversely related to the intensity of light transmitted through the solution.[10] Although the pulse oximeter is designed to measure two specific wavelengths, it is apparent that other elements of the blood can interfere with the overall transmission of light, including these two wavelengths.

Color Interferences

Skin color is not a limiting factor in pulse oximetry, since the measurements use the arterial pulsatile component of blood flow, and the surround tissue is basically factored out by the microcomputer. In general, the instrument will accommodate a wide range of tissue thickness and skin pigmentation. However, artificial nails or opaque nail finishes may interfere with the transmission of the light

source. Intravenous dyes, such as methylene blue, indigocarmine, and indocyanine green cause varying changes in pulse oximetry readings.

Venous Pulsations

Arteriovenous anastamoses and glomuses are unusual features of the cutaneous circulation, particularly in the fingers and toes. Arterial blood is shunted into a vein, which also becomes pulsatile, causing falsely low readings.[8]

Physical Factors

Many physical factors should be considered when using the pulse oximeter. The following are common-sense precautions. The clinician should avoid using the grounding pad of the electrocautery near the pulse oximeter sensor. The blood pressure cuff should not be placed on the arm that is being used for the sensor. Arterial lines or sticks should not be placed or performed on extremities used for oximetry. The pulse oximeter should not be plugged into the same power source as the electrocautery unit. In addition, the clinician should avoid interference of the sensor with high intensity light sources such as fiberoptic units. Finally, it must be made sure that the light-emitting diode is facing the nail bed and the photodiode is securely positioned on the opposite side of the digit.

MORBIDITY

Although the pulse oximeter is noninvasive and considered safe, morbidity has been associated with its use. Finger ischemia and necrosis have been reported with use of nondisposable sensors. The duration of application of the pulse oximeter sensor, the amount of pressure exerted (which may depend on the size of the digit), and the amount of hypotension or vasoconstriction during the procedure have been implicated in this type of injury.[5]

Thermal injuries also have been reported due to faulty sensors. Manufacturers warn that these instruments are not designed to be used with explosive anesthetic gases.[11,12]

CONCLUSION

The pulse oximeter has proven efficacy in clinical practice. A vigilant and knowledgeable clinician, however, must be aware of its proper use and limitations. Only then can it be considered a useful adjunct to the care of the patient.

ACKNOWLEDGMENT

We wish to acknowledge the expertise contributed by Karen Taylor in the preparation of this review.

REFERENCES

1. Hovagim AR, Vitkum SA, Manecke GR, Reiner R: Arterial desaturation in adults receiving conscious sedation. J Oral Maxillofac Surg 1989;47:936–939.

2. Yelderman M, New W: Evaluation of pulse oximetry. Anesthesiology 1983;59:349–352.

3. Lopert H: The pulse oximeter in dental surgery. Anesth Prog 1989;36:146–147.

4. Anderson JA, Lambert DM, Kater ER, Dolan P: Pulse oximetry: evaluation of accuracy during outpatient general anesthesia for oral surgery. Anesth Prog 1988;35:53–60.

5. Chemello PD, Nelson SR, Wolford LM: Finger injury from pulse oximeter probe during orthognathic surgery. Oral Surg Oral Med Oral Pathol 1990;69:161–163.

6. Brunel W, Cohen NH: Evaluation of the accuracy of pulse oximetry in critically ill patients. Crit Care Med 1988;16:432.

7. Swedlow DB, Runnin V, Feaster S: In reply to: Ambient light affects pulse oximeters. Anesthesiology 1987;67:865.

8. Kim JM, Mathewson HS: Venous congestion affects arterial hemoglobin saturation measured by a pulse oximeter. Anesthesiology 1985;63:A174.

9. Tremper KK, Barker SJ: Pulse oximetry. Anesthesiology 1989;70:98–108.

10. Barash P, Cullen BF, Stoelting RK: Clinical Anesthesia. Philadelphia, JB Lippincott Co., 1989;116–121.

11. Nellcor Inc: Product Information. Hayward, CA, Nellcor Inc.

12. Novametrix Co: Product Information. Wallingford, CT, Novametrix Medical Systems.