

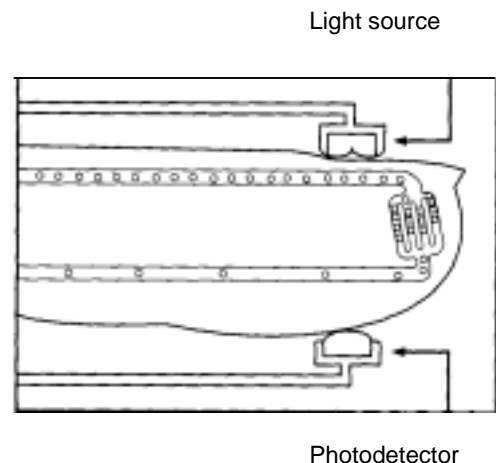
## Oxygen Saturation Monitoring by Pulse Oximetry

**PURPOSE:** Pulse oximetry is a noninvasive monitoring technique used to estimate the measurement of arterial oxygen saturation ( $\text{SaO}_2$ ) of hemoglobin.

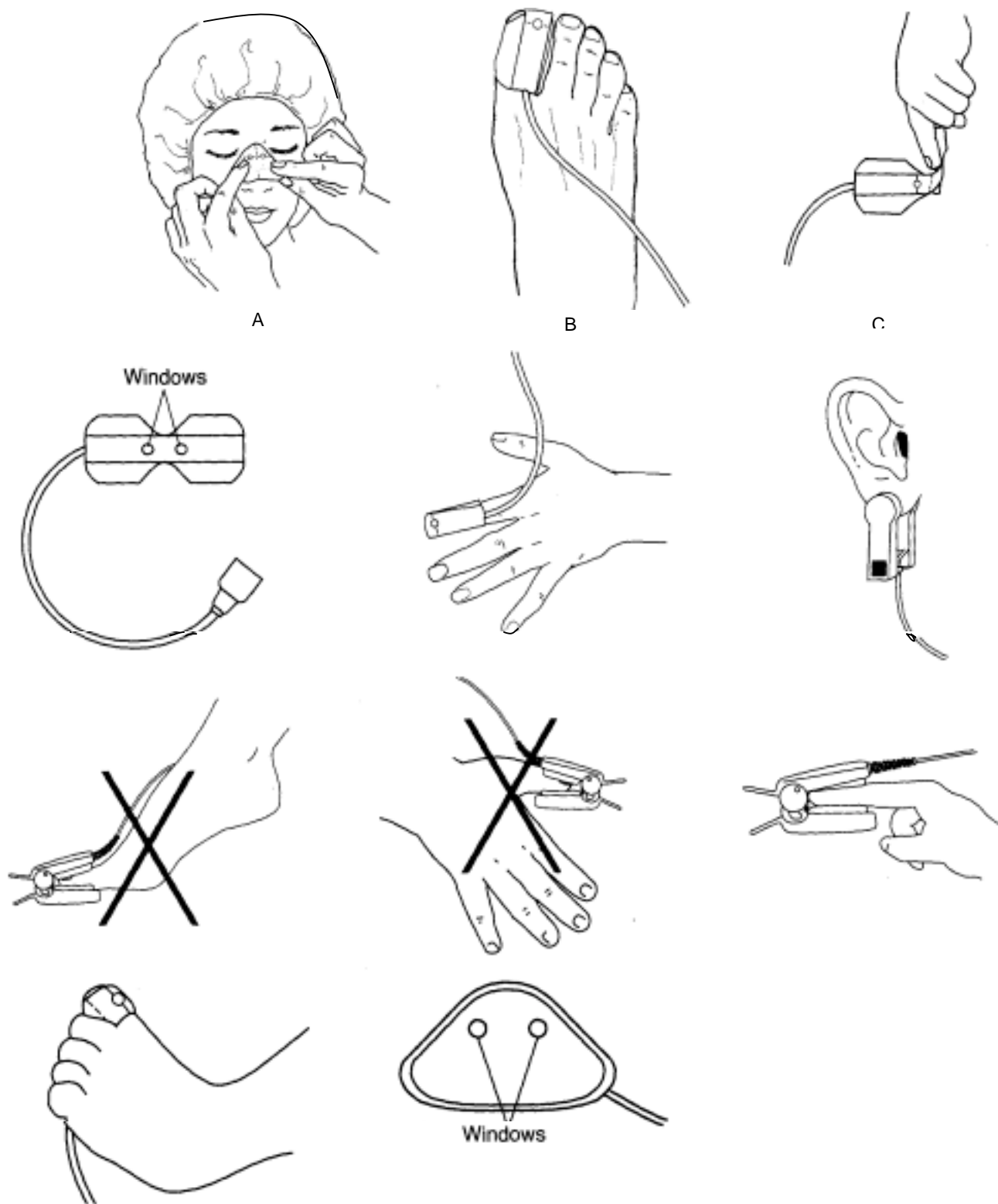
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### PREREQUISITE NURSING KNOWLEDGE

- Oxygen saturation is an indicator of the percentage of hemoglobin saturated with oxygen at the time of the measurement. The reading, obtained through pulse oximetry, uses a light sensor containing two sources of light (red and infrared) that are absorbed by hemoglobin and transmitted through tissues to a photodetector. The amount of light transmitted through the tissue is then converted to a digital value representing the percentage of hemoglobin saturated with oxygen (Fig. 14-1).
  - Oxygen saturation values obtained from pulse oximetry ( $\text{SpO}_2$ ) are one part of a complete assessment of the patient's oxygenation status and are not a substitute for measurement of arterial partial pressure of oxygen ( $\text{PaO}_2$ ) or of ventilation.
  - The accuracy of  $\text{SpO}_2$  measurements requires consideration of a number of physiologic variables. Such patient variables include the following:
    - ❖ Hemoglobin level
    - ❖ Arterial blood flow to the vascular bed
    - ❖ Temperature of the digit or the area where the oximetry sensor is located
    - ❖ Patient's oxygenation ability
    - ❖ Percentage of inspired oxygen
    - ❖ Evidence of ventilation-perfusion mismatch
    - ❖ Amount of ambient light seen by the sensor
    - ❖ Venous return at the probe location
  - A complete assessment of oxygenation includes evaluation of oxygen content and delivery, which includes the following parameters:  $\text{PaO}_2$ ,  $\text{SpO}_2$ , hemoglobin, cardiac output, and, when available, mixed venous oxygen saturation ( $\text{S}\bar{\text{v}}\text{O}_2$ .)
  - Normal oxygen saturation values are 97% to 99% in the healthy individual. An oxygen saturation value of 95% is clinically accepted in a patient with a normal hemoglobin level. Using the oxyhemoglobin dissociation curve, an oxygen saturation value of 90% is generally equated with a  $\text{PaO}_2$  of 60 mm Hg.
  - Tissue oxygenation is not reflected by oxygen saturation. The affinity of hemoglobin to oxygen may impair or enhance oxygen release at the tissue level.
- ❖ Decreased oxygen affinity-Oxygen is more readily released to the tissues when pH is decreased, body temperature is increased, arterial partial pressure of carbon dioxide ( $\text{PaCO}_2$ ) is increased, and 2,3-DPG levels (a byproduct of glucose metabolism also found in stored blood products) are increased.
  - ❖ Increased oxygen affinity-When the hemoglobin has greater affinity for oxygen, less is available to the tissues. Conditions such as increased pH, decreased temperature, decreased  $\text{PaCO}_2$ , and decreased 2,3-DPG will increase oxygen binding to the hemoglobin and limit its release to the tissue.
- Oxygen saturation values may vary with the amount of oxygen utilization by the tissues. For example, in some patients, there is a difference in  $\text{SpO}_2$  values at rest compared with those during activity, such as ambulation or positioning.
  - Oxygen saturation does not reflect the patient's ability to ventilate. Utilization of  $\text{SpO}_2$  in a patient with obstructive pulmonary disease may be very misleading. As the de-



■ • **FIGURE 14-1.** A sensor device that contains a light source and a photodetector is placed around a pulsating arteriolar bed, such as the finger, great toe, nose, or earlobe. Red and infrared wavelengths of light are used to determine arterial oxygen saturation. (Reprinted by permission of Mallinckrodt Inc., Pleasanton, California.)



• • **FIGURE 14-2.** Sensor types and sensor sites for pulse oximetry monitoring. Use "wrap" style sensors on the fingers (including thumb), great toe, and nose. The windows for the light source and photodetector must be placed directly opposite each other on each side of the arteriolar bed to ensure accuracy of SpO<sub>2</sub> measurements. Choosing the correct size of the sensor will help decrease the incidence of excess ambient light interferences and optical shunting. "Clip" style sensors are appropriate for fingers (except the thumb) and the earlobe. Ensuring that the arteriolar bed is well within the clip with the windows directly opposite each other will decrease the possibility of excess ambient light interference and optical shunting. (Reprinted by permission of Mallinckrodt Inc., Pleasanton, California.)

gree of lung disease increases, the patient's drive to breathe may shift from an increased carbon dioxide stimulus to a hypoxic stimulus. Therefore, enhancing the patient's SpO<sub>2</sub> may limit his or her ability to ventilate. The baseline SpO<sub>2</sub> for a patient with known severe restrictive disease needs to be considered.

- Any discoloration of the nail bed can affect the transmission of light through the digit. Dark nail polish and bruising under the nail can severely limit the transmission of light and result in an artificially decreased SpO<sub>2</sub> value.
- Pulse oximeters are unable to differentiate between oxygen and carbon monoxide bound to hemoglobin. Readings in the presence of carbon monoxide will be falsely elevated. Pulse oximetry should never be used in suspected cases of carbon monoxide exposure. An arterial blood gas reading should always be obtained.
- A pulse oximeter should never be used in a cardiac arrest situation because of the extreme limitations of blood flow.

**EQUIPMENT**

- Oxygen saturation meter and sensor
- Oxygen saturation cable and monitor

**PATIENT AND FAMILY EDUCATION**

- Explain the need for determination of oxygen saturation with a pulse oximeter. *-Rationale:* Informs patient of the purpose of monitoring, enhances patient cooperation, and decreases patient anxiety.
- Explain that the values displayed may vary by patient movement, amount of environmental light, patient level of consciousness (awake or asleep), and position of the sensor. *Rationale:* Decreases patient and family anxiety over the constant variability of the values.
- Explain that the use of pulse oximetry is part of a much larger assessment of oxygenation status. *-Rationale:* Prepares patient and family for other possible diagnostic tests of oxygenation, such as an arterial blood gas test.
- Explain the equipment to the patient. *-Rationale:* Facilitates patient cooperation in maintaining sensor placement.
- Explain the need for an audible alarm system for determination of oxygen saturation values below a set acceptable limit.

Demonstrate the alarm system, alerting the patient and family to the possibility of alarms, including causes of false alarms.

*Rationale:* Providing an understanding of the use of an alarm system and its importance in the overall management of the patient, as well as of circumstances in which a false alarm may occur, assists in patient understanding of the values seen while at the bedside.

**PATIENT ASSESSMENT AND PREPARATION**

**Patient Assessment**

- Signs and symptoms of decreased ability to ventilate are as follows:
  - ❖ Cyanosis
  - ❖ Dyspnea
  - ❖ Tachypnea
  - ❖ Decreased level of consciousness
  - ❖ Increased work of breathing
  - ❖ Loss of protective airway (patients undergoing conscious sedation)

*Rationale:* Patient assessment will determine the need for continuous pulse oximetry monitoring. Anticipation of conditions in which hypoxia could be present allows earlier intervention before unfavorable outcomes occur.

- Conditions of the extremity (digit) or area where the sensor will be placed include the following:
  - ❖ Decreased peripheral pulses
  - ❖ Peripheral cyanosis
  - ❖ Decreased body temperature
  - ❖ Decreased blood pressure
  - ❖ Exposure to excessive environmental light sources (such as examination lights)
  - ❖ Excessive movement or tremor in the digit, presence of dark nail polish, or bruising under the nail

*Rationale:* Assessment of factors that may inhibit accuracy of the measurement of oxygenation before attempting to obtain an SpO<sub>2</sub> value will enhance the validity of the measurement.

**Patient Preparation**

- Ensure that patient understands preprocedural teaching. Answer questions as they arise, and reinforce information as needed. *-Rationale:* Evaluates and reinforces understanding of previously taught information.

<b>Procedure for Oxygen Saturation Monitoring by Pulse Oximetry</b>		
<b>Steps</b>	<b>Rationale</b>	<b>Special Considerations</b>
1. Wash hands, and use personal protective equipment.	Reduces transmission of microorganisms and body secretions; standard precautions.	
2. Select the appropriate pulse oximeter sensor for the area with the best pulsatile vascular bed to be sampled (Fig. 14-2). Use of finger probes has been found to produce the best results over other sites.	The correct sensor optimizes signal capture and minimizes artifact-related difficulties.	Several different types of sensors are available. These include disposable and nondisposable sensors that may be applied over a variety of vascular beds.

*(Level VI: Clinical studies in a variety of patient populations and situations)*

*Procedure continued on following page*

<b>Procedure for Oxygen Saturation Monitoring by Pulse Oximetry <i>Continued</i></b>		
<b>Steps</b>	<b>Rationale</b>	<b>Special Considerations</b>
3. Select desired sensor site. If using the digits, assess for warmth and capillary refill. Confirm the presence of an arterial blood flow to the area monitored.	Adequate arterial pulse strength is necessary for obtaining accurate SpO <sub>2</sub> measurements.	Avoid sites distal to indwelling arterial catheters, blood pressure cuffs, military antishock trousers (MAST), or venous engorgement (eg, arteriovenous fistulas, blood transfusions).
4. Plug oximeter into grounded wall outlet if the unit is not portable. If the unit is portable, ensure sufficient battery charge by turning it on before using. Plug patient cable into monitor.	When using electrical outlets, grounded outlets decrease the occurrence of electrical interference.	Portable systems have rechargeable batteries and are dependent on sufficient time plugged into an electrical outlet to maintain proper level of battery charge. When system is used in the portable mode, always check battery capacity.
5. Apply the sensor in a manner that allows the light source (light-emitting diodes) to be:	To properly determine a pulse oximetry value, the light sensors must be in opposing positions directly over the area of the sample. <sup>1, 5-7</sup>	
A. Directly opposite the light detector (photodetector) <i>(Level IV: Limited clinical studies to support recommendations)</i>		
B. Shielded from excessive environmental light <i>(Level V: Clinical studies in more than one patient population and situation)</i>	Light from sources such as examination lights or overhead lights can cause elevated oximetry values. <sup>5-7</sup>	If the oximeter sensor fails to detect a pulse when perfusion seems adequate, excessive environmental light (overhead examination lights, phototherapy lights, infrared warmers) may be binding the light sensor. Troubleshoot by reapplying the sensor or shielding the sensor with a towel or blanket.
C. All sensor-emitted light comes in contact with perfused tissue beds and is not seen on the other side of the sensor without coming in contact with the area to be read.	If the light is seen directly from the sensor without coming in contact with the vascular bed, too much light can be seen by the sensor, resulting in either a falsely high reading or no reading.	Known as optical shunting, the light bypasses the vascular bed. Shielding the sensor will not eliminate this if the sensor is too large or not properly positioned.
D. The sensor does not cause restriction to arterial flow or venous return. <i>(Level IV: Limited clinical studies to support recommendations)</i>	The pulse oximeter is unable to distinguish between true arterial pulsations and fluid waves or fluid accumulation. <sup>1-2, 8</sup>	Restriction of arterial blood flow can cause a falsely low value as well as lead to vascular compromise, causing potential loss of viable tissues. Edema from restriction of venous return can cause venous pulsation. Elevating the site above the level of the heart will reduce the possibility of venous pulsations. Moving the sensor to another site on a routine schedule will also reduce tissue compromise.
1 Plug sensor into oximeter patient cable.	Connects the sensor to the oximeter, allowing SpO <sub>2</sub> measurement and analysis of waveforms	
1 Turn instrument on with the power switch.		Allow 30 seconds for self-testing procedures and for detection and analysis of waveforms before values are displayed.

**Procedure for Oxygen Saturation Monitoring by Pulse Oximetry *Continued***

Steps	Rationale	Special Considerations
1. Determine accuracy of detected waveform by comparing the numeric heart rate value to that of a monitored heart rate or an apical heart rate or both.	If there is insufficient arterial blood flow through the sensor, the heart rate values will vary significantly. If the pulse rate detected by oximeter does not correlate with the patient's heart rate, the oximeter is not detecting sufficient arterial blood flow for accurate values.	Consider moving the sensor to another area site, such as the earlobe or the nose. This problem occurs particularly with the use of the fingers and the toes in conditions of low blood flow.
9. Set appropriate alarm limits.	Alarm limits should be set appropriate to the patient's condition.	Oxygen saturation limits should be 5% less than patient acceptable baseline. Heart rate alarms should be consistent with the cardiac monitoring limits (if monitored).
10. Wash hands.	Reduces transmission of microorganisms to other patients.	

Expected Outcomes	Unexpected Outcomes
<ul style="list-style-type: none"> <li>• All changes in oxygen saturation are detected.</li> <li>• The number of oxygen desaturation events is reduced.</li> <li>• The need for invasive techniques for monitoring oxygenation is reduced.</li> <li>• False-positive pulse oximeter alarms are reduced.</li> </ul>	<ul style="list-style-type: none"> <li>• Accurate pulse oximetry is not obtainable because of movement artifact.</li> <li>• Low perfusion states or excessive edema prevents accurate pulse oximetry measurements.</li> <li>• Disagreements occur in SaO<sub>2</sub>, and oximeter SpO<sub>2</sub>.</li> </ul>

**Patient Monitoring and Care**

Patient Monitoring and Care	Rationale	Reportable Conditions
		<i>These conditions should be reported if they persist despite nursing interventions.</i>
1. Evaluate the physical assessment, the laboratory data, and the patient.	SpO <sub>2</sub> values are one segment of a complete evaluation of oxygenation and supplemental oxygen therapy. Data should be integrated into a complete assessment to determine the overall status of the patient.	<ul style="list-style-type: none"> <li>• Inability to maintain oxygen saturation levels as desired</li> </ul>
2. Evaluate sensor site every 8 hours (if a disposable sensor is used) or every 4 hours (if a ridged encased nondisposable sensor is used).	Assessment of the skin and tissues under the sensor identifies skin breakdown or loss of vascular flow, allowing appropriate interventions to be initiated.	<ul style="list-style-type: none"> <li>• Change in skin color</li> <li>• Loss of warmth of the tissue unrelated to vasoconstriction</li> <li>• Loss of blood flow to the digit</li> </ul>
3. Monitor the site for excessive movement.	Excessive movement of the sampled site may result in unreliable saturation values. Moving the sensor to a less physically active site will reduce motion artifact. Using a lightweight sensor will also help. If the digits are used, ask the patient to rest the hand on a flat or secure surface.	
4. Compare and monitor the actual heart rate with the pulse rate value from the oximeter to determine accuracy of values.	The two numeric heart rate values should correlate closely. A difference in heart rate values may indicate excessive movement or a loss of pulsatile flow detection.	<ul style="list-style-type: none"> <li>• Inability to correlate actual heart rate and pulse rate from oximeter</li> </ul>

## Documentation

Documentation should include the following:

- |  |  |
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| • Patient and family education   | • Sensor site                                      |
| • Indications for use of pulse oximetry  | • Simultaneous arterial blood gases (if available) |
| • Patient's pulse with SpO <sub>2</sub> measurements   | • Recent hemoglobin measurement (if available)     |
| • Fraction of inspired oxygen (Fio <sub>2</sub> ) delivered (if patient is receiving oxygen) | • Skin assessment at sensor site                   |
| • Patient clinical assessment at the time of the saturation measurement                      | • Oximeter alarm settings                          |
|  | • Events precipitating acute desaturation          |
|  | • Unexpected outcomes                              |
|  | • Nursing interventions                            |

## References

1. Grap MJ. Pulse oximetry. In: *AACN Protocols for Practice: Technology Series*. Aliso Viejo, Ca: American Association of Critical-Care Nurses; 1996.
2. Grap MJ. Pulse oximetry. *Crit Care Nurse*. 1998;18:94-99.
3. Rutherford KA. Principles and application of pulse oximetry. *Crit Care Nurs Clin Am*. 1989;1:649-657.
4. Robertson RE, Kaplan RE. Another site for the pulse oximeter probe. *Anesthesiology*. 1991;74:198.
5. Siegel MN, Garvenstein N. Preventing ambient light from affecting pulse oximetry. *Anesthesiology*. 1987;67:280.
6. Zablocki AD, Rasch DK. A simple method to prevent interference with pulse oximetry by infrared heating lamps. *Anesth Analg*. 1987;66:915.
7. Hanowell L, Eisele JH, Downs D. Ambient light affects pulse oximeters. *Anesthesiology*. 1987;67:864-865.
8. Szarlarski NL, Cohen NH. Use of pulse oximetry in critically ill adults. *Heart Lung*. 1989;18:444-453.

## Additional Readings

- Carroll P. Using pulse oximetry in the home. *Home Healthc Nurse*. 1997;15:88-97.
- Tittle M, Flynn MB. Correlation of pulse oximetry and co-oximetry. *Dimens Crit Care Nurs*. 1997;16:88-95.
- Wahr JA, Tremper KK, Dlab M. Pulse oximetry. *Respir Care Clin N Am*. 1995;1:77-105.