PROCEDURE

18 Oxygen Saturation Monitoring with Pulse Oximetry

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PURPOSE: Pulse oximetry is a noninvasive monitoring technique used to estimate the measurement of arterial oxygen saturation of hemoglobin. Pulse oximetry is indicated in patients at risk for hypoxemia, such as during conscious sedation procedures, transport, and adjustment of fraction of inspired oxygen ($Fi0_2$).

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 with standard pulse oximetry, uses a light sensor that contains two sources of light (red and infrared) absorbed by hemoglobin and transmitted through tissues to a photodetector. The infrared light is absorbed by the oxyhemoglobin, and the red light is absorbed by the reduced hemoglobin. The amount and type of light transmitted through the tissue is converted to a digital value that represents the percentage of hemoglobin saturated with oxygen (Fig. 18-1).
- Oxygen saturation values obtained with pulse oximetry (Spo_2) represent one part of a complete assessment of a patient's oxygenation status and are not a substitute for measurement of arterial saturation of oxygen (Sao_2) or of ventilation (as measured with arterial partial pressure of carbon dioxide [$Paco_2$]).
- A complete assessment of oxygenation includes evaluation of oxygen content and delivery, which includes the following parameters: arterial partial pressure of oxygen (Pao_2), Sao_2 hemoglobin, cardiac output, and, when available, mixed venous oxygen saturation.
- Normal oxygen saturation values are approximately 97% to 99% in a healthy individual breathing room air. An oxygen saturation value of 95% is clinically accepted in a patient with a normal hemoglobin level. With a normal blood pH and body temperature, an oxygen saturation value of 90% is generally equated with a Pao_2 of 60 mm Hg.
- Tissue oxygenation is not reflected by arterial or oxygen saturation obtained with pulse oximetry.
- The affinity of hemoglobin with oxygen may impair or enhance oxygen release at the tissue level.
  - Oxygen is more readily released to the tissues when pH is decreased (acidosis), body temperature is increased, $Paco_2$ is increased, and 2,3-diphosphoglycerate levels (a byproduct of glucose metabolism that facilitates the dissociation of oxygen from the hemoglobin molecule to tissue) are increased (decreased oxygen affinity).
  - When hemoglobin has greater affinity for oxygen, less is available to the tissues (increased oxygen affinity). Conditions such as increased pH (alkalosis), decreased temperature, decreased $Paco_2$, and decreased 2,3-diphosphoglycerate (as found in stored blood products) increase oxygen binding to the hemoglobin and limit its release to the tissue.
- Anemic patients will have normal oxygen saturation levels but may be hypoxic because the total oxygen content of the arterial blood is decreased.
- Oxygen saturation values may vary with the amount of oxygen usage or uptake by the tissues. In some patients, a difference is seen in Spo_2 values at rest compared with values during activity, such as ambulation, motion, or positioning.[19]
- Oxygen saturation does not directly reflect the patient's ability to ventilate. The true measure of ventilation is determination of the $Paco_2$ in arterial blood. Use of Spo_2 in a patient with obstructive pulmonary disease may result in erroneous clinical assessments of a condition. As the degree of lung disease increases, the patient's drive to breathe may shift from an increased carbon dioxide stimulus to a hypoxic stimulus. Enhancing the patient's oxygenation and increasing the Spo_2 may limit the ability to ventilate. The normal baseline Spo_2 for a patient with known severe restrictive disease and more definitive methods of determination of the effectiveness of ventilation must be assessed before consideration of interventions that enhance oxygenation.
- The accuracy of Spo_2 measurements may be influenced by physiological variables, including the following:
  - Hemoglobin level
  - Presence of dyshemoglobinemias (i.e., carboxyhemoglobinemia after carbon monoxide exposure)
  - Arterial blood flow to the vascular bed
  - Temperature of the digit or the area where the oximetry sensor is located
  - Vasoconstriction
  - Venous congestion
  - Fraction of inspired oxygen (percentage of inspired oxygen)
  - Degree of ventilation-perfusion mismatch
  - Venous return at the sensor location

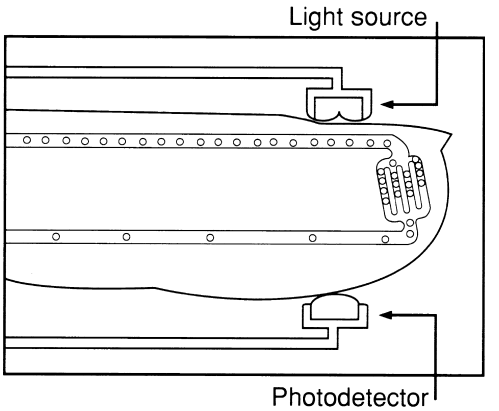

Figure 18-1 A sensor device that contains a light source and a photodetector is placed around a pulsating arteriolar bed, such as the finger, great toe, nose, or earlobe. Red and infrared wavelengths of light are used to determine arterial saturation. *(Reprinted by permission of Nellcor Puritan Bennett LLC, Boulder, CO, part of Covidien.)*

- The accuracy of Spo_2 measurements may be influenced by environmental variables, including the following:
  - Nail polish
  - Pigmentation
  - Dyes
  - Ambient light sources
  - Motion
- Discoloration of the nail bed or obstruction of the nail bed (i.e., blood under the fingernail) can potentially affect the transmission of light through the digit. Dark nail polish, such as blue, green, brown, or black,[4] has been reported to limit the transmission of light and thus affect the Spo_2, although a recent study showed that fingernail polish does not cause a clinically significant change in the pulse oximeter readings in healthy individuals.[17,18] If the nail polish cannot be removed and is believed to be affecting the accuracy of the reading, the sensor can be placed in a lateral side-to-side position on the finger to obtain readings if no other method of sampling the arterial bed is available.[5,18] Bruising under the nail can limit the transmission of light and result in an artificially decreased Spo_2 value. Pulse oximetry has not been shown to be affected by the presence of an elevated bilirubin.[2] The presence of acrylic fingernails may impair the accuracy of the pulse oximetry reading, and removal of the nail covering may be necessary to ensure accurate measurement, although unpolished acrylic nails have been proven not to affect pulse oximetry readings.[16,23]
- Standard pulse oximeters use two wavelengths and are unable to differentiate between oxygen and carbon monoxide bound to hemoglobin and falsely elevated Spo_2 measurements. Standard pulse oximetry equipment should never be used in suspected cases of carbon monoxide exposure. However, recent technology advancements in pulse oximetry have included the introduction of a monitor system that uses up to 12 wavelengths with a digit-based pulse oximeter sensor and that allows for measurement estimates of certain dyshemoglobinemias (i.e., carboxyhemoglobinemia).[12] An arterial blood gas always should be obtained to determine the accurate oxygen saturation and, if a carbon monoxide (CO) oximeter is available, measurement of carboxyhemoglobin and methemoglobin.[3]
- Dark skin has been suggested to possibly affect the ability of the pulse oximeter to accurately monitor arterial oxygen saturation by interfering with the transmission of light and thus the accuracy of the readings. One study found more frequent differences between the Spo_2 and Sao_2 in dark-skinned patients compared with lighter-skinned patients.[11]
- Certain dyes used intravenously may interfere with the accuracy of measurements, although as a result of rapid clearance the impact is limited. Dyes include methylene blue, indigo carmine, indocyanine green, and fluorescein.[8]
- A pulse oximeter should not be used as a predictive indicator of the actual arterial blood gas saturation; however, the pulse oximetry does provide information about changes in the patient's oxygenation and an early warning sign of hypoxemia. Continuous pulse oximetry monitoring in critical care settings can allow clinicians to recognize early signs of deterioration and provide early interventions that may prevent rescue events such as cardiac arrests or respiratory arrests.[22]
- Low-perfusion states such as hypotension, vasoconstriction, hypothermia, or administration of vasoconstrictive agents limit the ability of the oximeter to distinguish the true pulsatile waveform from background noise.
- The mean oxygen saturation value from the finger of an arm that has been physically restrained has been shown to be significantly different from the finger of an unrestrained arm. Therefore if physical restraints are being used, it is recommended that the pulse oximetry sensor not be placed on the finger of a restrained arm.[2]
- A pulse oximeter should never be used during a cardiac arrest situation because of the extreme limitations of blood flow during cardiopulmonary resuscitation and the pharmacological action of vasoactive agents administered during the resuscitation effort.[9]
- In vasoconstrictive states, oxygen saturation may be measured with a finger probe, but in patients with significant shifts in hemodynamic stability the ear or forehead has been shown to be reasonably resistant to the vasoconstrictive effects of the sympathetic nervous system.[1,15,21]
- Forehead sensors use reflectance and are more accurate in low-flow states but may be affected by venous congestion. Forehead sensors used in patients placed in Trendelenburg's position may require up to 20 mm Hg of external pressure to achieve accurate readings, which may be accomplished with an appropriately applied headband.[1] Disposable pulse oximeters intended for use on fingers should not be used on the forehead, as they are often inaccurate.[20]

EQUIPMENT

- Oxygen saturation monitor
- Oxygen saturation cable and sensor, which may be disposable or nondisposable
- Manufacturer's recommended germicidal agent for cleaning the nondisposable sensor (used for cleaning between patients)

PATIENT AND FAMILY EDUCATION

- Explain the need for determination of oxygen saturation with a pulse oximeter. ***Rationale:*** This explanation informs the patient of the purpose of monitoring, enhances patient cooperation, and decreases patient anxiety.
- Explain that the values displayed may vary with patient movement, amount of environmental light, patient level of consciousness (awake or asleep), and position of the sensor. ***Rationale:*** This explanation 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 respiratory status. ***Rationale:*** This explanation prepares the patient and family for other possible diagnostic tests of oxygenation (e.g., arterial blood gas).
- Explain the equipment to the patient. ***Rationale:*** This information facilitates patient cooperation in maintaining sensor placement.
- Explain the need for an audible alarm system for alerting clinicians of oxygen saturation values below a set acceptable limit, as determined by the clinician. Demonstrate the alarm system, alerting the patient and family to the possibility of alarms, including causes of false alarms. ***Rationale:*** Provision of an understanding of the use of an alarm system and its importance in the overall management of the patient's condition and of circumstances in which a false alarm may occur assists in understanding of the Spo_2 values seen at the bedside.
- Explain the need to move or remove the sensor on a routine basis to prevent complications related to the type of sensor used and monitoring site (i.e., digit, forehead, ear). ***Rationale:*** An understanding of the need to move the sensor routinely assists in patient understanding of the frequency of sensor movement.

PATIENT ASSESSMENT AND PREPARATION

Patient Assessment

- Signs and symptoms of decreased oxygenation, including cyanosis, dyspnea, tachypnea, decreased level of consciousness, increased work of breathing, agitation, confusion, disorientation, and tachycardia/bradycardia. ***Rationale:*** Patient assessment determines the need for continuous pulse oximetry monitoring. Anticipation of conditions in which hypoxia could be present allows earlier intervention before unfavorable outcomes occur.
- Assess the extremity (digit) or area where the sensor will be placed, including decreased peripheral pulses, peripheral cyanosis, decreased body temperature, decreased blood pressure, exposure to excessive environmental light sources (e.g., examination lights), excessive movement or tremor in the digit, presence of dark nail polish or bruising under the nail, presence of artificial nails, clubbing of the digit tips, and blood under the fingernails. ***Rationale:*** Assessment of factors that may inhibit accuracy of the measurement of oxygenation before attempting to obtain the Spo_2 reading enhances the validity of the measurement and allows for correction of factors as is possible.

Patient Preparation

- Verify that the patient is the correct patient using two identifiers. ***Rationale:*** Before performing a procedure, the nurse should ensure the correct identification of the patient for the intended intervention.
- Ensure that the patient understands preprocedural teachings. Answer questions as they arise, and reinforce information as needed. ***Rationale:*** This communication evaluates and reinforces understanding of previously taught information.

Procedure for Oxygen Saturation Monitoring with Pulse Oximetry

Steps	Rationale	Special Considerations
1. HH		
2. PE		
3. Select desired sensor site. If digits are chosen, assess for warmth and capillary refill. Confirm the presence of arterial blood flow to the area monitored.	Adequate arterial pulse strength is necessary for obtaining accurate Spo_2 measurements.	Avoid sites distal to indwelling arterial catheters, blood pressure cuffs, or venous engorgement (e.g., arteriovenous fistulas, blood transfusions).

Procedure for Oxygen Saturation Monitoring with Pulse Oximetry—*Continued*

Steps	Rationale	Special Considerations
4. Select the appropriate pulse oximeter sensor for the area with the best pulsatile vascular bed to be sampled (Fig. 18-2). The digits are the most common site because of ease of application of the sensor. Consideration of other sites may produce more accurate results in conditions of extreme peripheral vasoconstriction or decreased perfusion.[1,21] **(Level C*)**	The correct sensor optimizes signal capture and minimizes artifact-related difficulties.[5,6,13,14]	Several different types of sensors are available, including disposable and nondisposable sensors, which may be applied over a variety of vascular beds, including the digit, earlobe, nasal bridge or septum, and forehead. The latter requires an appropriately placed headband. Do not use one manufacturer's sensors with another manufacturer's pulse oximeter unless compatibility has been verified.

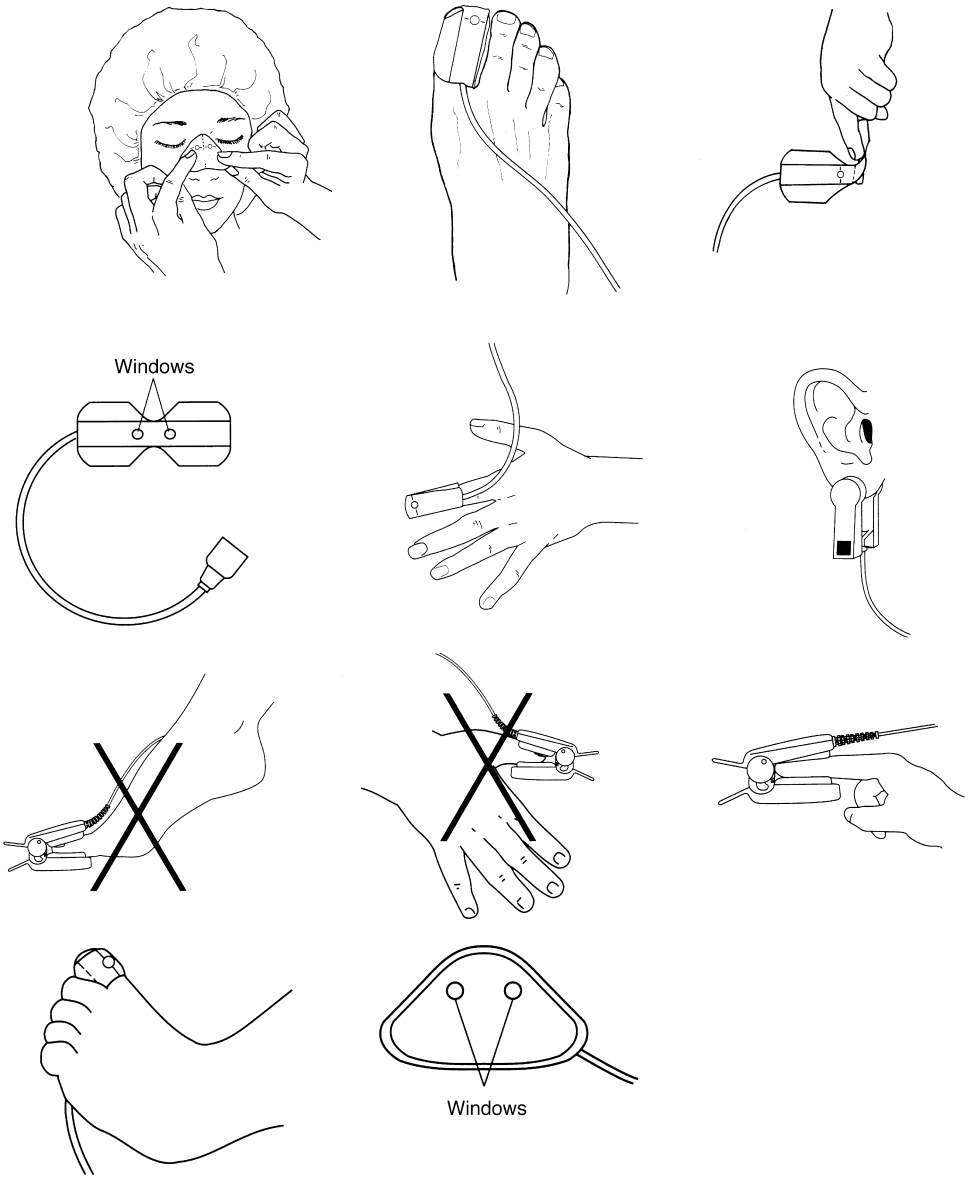

Figure 18-2 Sensor types and sensor sites for pulse oximetry monitoring. Use "wrap" or "clip" style sensors on the fingers (including thumb), great toe, and nose. The windows for the light source and photodetector must be placed directly opposite each other on each side of the arteriolar bed to ensure accuracy of Spo_2 measurements. Choice of the correct size of the sensor helps decrease the incidence of excess ambient light interference 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 decreases the possibility of excess ambient light interference and optical shunting. *(Reprinted by permission of Nellcor Puritan Bennett LLC, Boulder, CO, part of Covidien.)*

*Level C: Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized controlled trials with inconsistent results.

Procedure continues on following page

Procedure for Oxygen Saturation Monitoring with Pulse Oximetry—*Continued*

Steps	Rationale	Special Considerations
5. Plug oximeter power cord into grounded wall outlet if the unit is not portable. If the unit is portable, ensure sufficient battery charge by turning it on before use. Plug patient cable into monitor.	With use of electrical outlets, grounded outlets decrease the occurrence of electrical interference.	Portable systems have rechargeable batteries and depend on sufficient time plugged into an electrical outlet to maintain the proper level of battery charge. When system is used in the portable mode, always check battery capacity.
6. Apply the sensor in a manner that allows the light source (LEDs) to be: A. Directly opposite the light detector (photodetector). **(Level C*)**	To determine a pulse oximetry value properly, the light sensors must be in opposing positions directly over the area of the sample.[6,7,21]	
B. Shielded from excessive environmental light. **(Level C*)**	Light from sources such as examination lights or overhead lights can cause falsely elevated oximetry values.[10,14,21]	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 blinding the light sensor. Troubleshoot by reapplying the sensor or shielding the sensor with a towel or blanket or moving the sensor to a different monitoring site.
C. Positioned so that all sensor-emitted light comes into contact with perfused tissue beds and is not seen by the other side of the sensor or without coming into contact with the area to be read.	If the light from the sensor's LEDs bypasses the tissue bed and is detected at the photodetector, the result is either a falsely high reading or no reading.	Known as *optical shunting,* the light bypasses the vascular bed; shielding the sensor does not eliminate this if the sensor is too large or not properly positioned.
7. Gently position the sensor so that it does not cause restriction to arterial flow or venous return. **(Level C*)**	The pulse oximeter is unable to distinguish between true arterial pulsations and fluid waves (e.g., venous engorgement or fluid accumulation).[5,6,13]	Restriction of arterial blood flow can cause a falsely low value and lead to vascular compromise, causing potential loss of viable tissues. Edema from restriction of venous return can cause venous pulsation. Elevation of the site above the level of the heart reduces the possibility of venous pulsation. Moving the sensor to another site on a routine schedule also reduces tissue compromise. Never place the sensor on an extremity that has decreased or absent sensation because the patient may not be able to identify discomfort or the signs and symptoms of loss of circulation or tissue compromise.
8. Plug sensor into oximeter patient cable.	Connects the sensor to the oximeter, which allows Spo_2 measurement and analysis of waveforms.	

*Level C: Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized controlled trials with inconsistent results.

Procedure for Oxygen Saturation Monitoring with Pulse Oximetry—*Continued*

Steps	Rationale	Special Considerations
9. Turn instrument power switch on.	Applies power to the device.	Allow adequate time for self-testing procedures and for detection and analysis of waveforms before values are displayed. The time required to perform the self-test and adequately warm depends on specific manufacturer.
10. Determine accuracy of detected waveform by comparing the numeric heart rate value with that of a monitored heart rate or an apical heart rate or both. **(Level M*)**	If arterial blood flow through the sensor is insufficient, the heart rate values may vary significantly. If the pulse rate detected with oximeter does not correlate with the patient's heart rate, the oximeter is not detecting sufficient arterial blood flow for accurate values.	This problem occurs particularly with the use of the fingers and the toes in conditions of low blood flow. Consider moving the sensor to another site, such as the earlobe or the forehead (be sure the sensor type is appropriate for the monitoring site).Rotate the site of a reusable sensor every 4 hours; replace an adhesive disposable sensor every 24 hours.[13]
11. Set appropriate alarm limits.	Alarm limits should be set appropriate to the patient's condition.	Oxygen saturation limits should be 5% less than the patient's acceptable baseline. Heart rate alarms should be consistent with the cardiac monitoring limits (if monitored).
13. Cleanse nondisposable sensor, if used, between patients with manufacturer's recommended germicidal agent.	Reduces transmission of microorganisms to other patients.	
12. Discard used supplies and remove PE		
13. HH		

*Level M: Manufacturer's recommendations only.

Expected Outcomes

- All changes in oxygen saturation are detected
- The number of oxygen desaturation events is reduced
- The need for invasive techniques for monitoring oxygenation is reduced
- False-positive pulse oximeter alarms are reduced

Unexpected Outcomes

- Accurate pulse oximetry is not obtainable because of movement artifact
- Low-perfusion states or excessive edema prevents accurate pulse oximetry measurements
- Disagreements occur in Sao_2 and oximeter Spo_2

Procedure continues on following page

Patient Monitoring and Care

Steps	Rationale	Reportable Conditions
		These conditions should be reported if they persist despite nursing interventions.
1. Evaluate laboratory data along with the patient for evidence of reduced arterial oxygen saturation or hypoxemia.	Spo_2 values are one segment of a complete evaluation of the patient's oxygenation status and supplemental oxygen therapy. Data should be integrated into a complete assessment to determine the overall status of the patient. If Spo_2 is used as an indicator of Sao_2, an arterial blood gas with CO oximetry should be done to determine whether the values correlate consistently.	• Inability to maintain oxygen saturation levels as desired
2. Evaluate sensor site every 2–4 hours (if a disposable sensor is used) or every 2 hours (if a reusable or nondisposable sensor is used). Rotate the site of a reusable sensor every 4 hours; replace an adhesive disposable sensor every 24 hours[13] or per manufacturer's recommendations if the securing mechanism is compromised or soiled. Never apply additional adhesive tape to secure a sensor. **(Level M*)**	Assessment of the skin and tissues under the sensor identifies skin breakdown or loss of vascular flow, allowing appropriate interventions to be initiated. Application of additional tape may constrict blood flow at the monitoring site and result in both inaccurate monitor readings and further compromised local skin perfusion.	• Change in skin color • Loss of warmth of tissue unrelated to vasoconstriction • Loss of blood flow to the digit • Evidence of skin breakdown from the sensor • Change in color of the nail bed, which indicates compromised circulation to the nail
3. Monitor the sensor site for excessive movement, which results in motion artifact.	Excessive movement at the monitoring site may result in unreliable saturation values. Moving the sensor to a less physically active site may reduce the risk of motion artifact; use of an adhesive versus reusable sensor may also help as a result of better fit. If the digits are used, ask the patient to rest the hand on a flat or secure surface.	• Inability to obtain pulse oxygen saturation levels
4. Compare and monitor the actual heart rate with the pulse rate value from the pulse oximeter to determine accuracy of values.	The two numeric heart rate values should correlate closely. A difference in pulse rate values reported with pulse oximeter may be from excessive movement, poor peripheral perfusion at the monitoring site, or loss of pulsatile flow detection.	• Inability to correlate actual heart rate and pulse rate from oximeter

Documentation

Documentation should include the following:

Patient and family education
Indications for use of pulse oximetry
Patient's pulse rate with Spo_2 measurements
Fio_2 delivered (if patient is receiving oxygen)
Patient clinical assessment at the time of the saturation measurement
Sensor site
Simultaneous arterial blood gases (if available)
Recent hemoglobin measurement (if available)
Skin assessment at sensor site
Pulse oximeter monitor alarm settings
Events precipitating acute desaturation
Unexpected outcomes
Nursing interventions

References and Additional Readings

For a complete list of references and additional readings for this procedure, scan this QR code with any freely available smartphone code reader app, or visit http://booksite.elsevier.com/9780323376624.