Pulse Oximeters 101

Glen Wolfe

A pulse oximeter is a device that determines the oxygen saturation of a patient's blood using a sensor. It yields a computerized readout and sounds an alarm if the blood saturation becomes less than optimal.

History

In 1925, Dr Karl Matthes found that by shining red and green light through a subject's blood, he was able to calculate a reasonable approximation of oxygen saturation. This discovery lay relatively unnoticed until 1949 when Dr Earl Wood added a pressure transducer to the earlier research and obtained the saturation of arterial blood by looking at the absorption of light during the time when blood pressure was highest. Dr Wood's device was not readily accepted because his equipment was unreliable and often erratic.

Dr Robert Shaw, working with Hewlett-Packard, produced the first ear oximeter in 1964. He used several wavelengths of light to approximate blood oxygen saturation. This new device was very large and was essentially limited to a pulmonary function laboratory.

The major breakthrough in pulse oximetry (known as the fifth vital sign) came from Takuo Aoyagi while working at Nihon Kohden in 1972. Aoyagi is credited with inventing conventional pulse oximetry, which uses the ratio of red to infrared light absorption to measure oxygen saturation. It took almost 10 more years to market this invention, but in 1981 Ohmeda introduced portable pulse oximeters.

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Check Points

Pulse oximeters are monitoring devices that measure oxygen saturation of the blood.

- ✓ The most common pulse oximeter fault is the probe.
- ✓ Patient simulators that check both the device and the probe can expedite troubleshooting and repair.
- ✓ To ensure proper operation, pulse oximeter probes must be placed on a digit without nail polish or artificial nails.

How They Work

Pulse oximeters direct light at 660 nanometers (red) and 940 nanometers (infrared) through the finger (or another part of the anatomy). A photo detector on the opposite side measures the light and sends a reference of the transmitted light to the processor, which calculates the absorption. The ratio of red light to infrared light is then calculated. The ratio is evaluated against a predetermined reference and the oxygen saturation is then displayed as a percentage of oxygen saturation (SpO2).

The actual transmitting and detecting is very simple. See Figure 1 for the parts of a typical probe.

The "pulse" part of pulse oximetry comes into play because the most accurate reading is obtained by measuring only during the peak arterial pressure. Therefore it is essential to find the pulse and synchronize the readings with it.

A pulse oximeter is intended to be a monitoring device, and its results are not accurate enough to be used as a diagnostic tool. Even Aoyagi, the inventor, stated that the accuracy of pulse oximetry is at best approximately 85%. Low readings are typically verified via blood gas analysis.

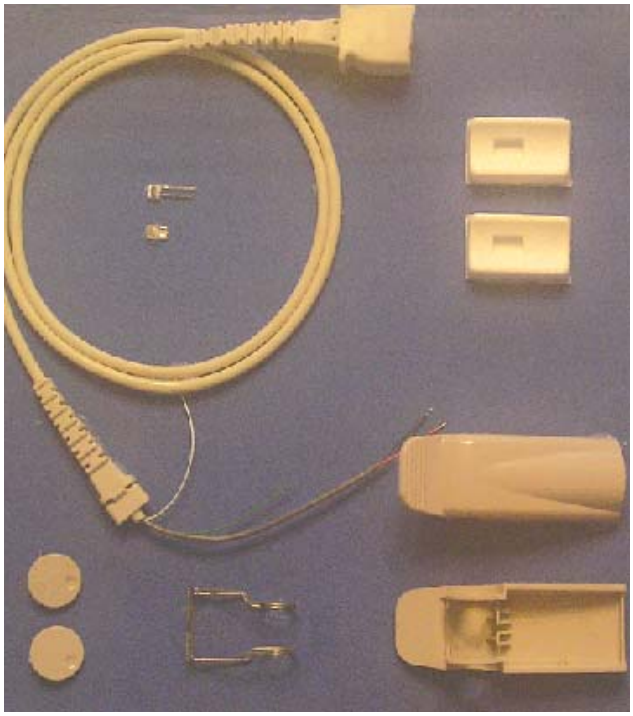

Figure 1. *Parts of a typical probe.*

Types

Pulse oximeters come in many shapes and sizes. Some are no bigger than the typical finger probe, while others are integrated into practically every make and model of physiologic monitor.

Pulse oximeter probes also come in a variety of styles. They can be reusable or disposable. The reusable types are generally limited to either finger probes or ear clips, while disposable probes can be placed practically anywhere by using adhesive or tape. Fingers, toes, wrists, noses, and even foreheads are ideal sites for disposable probes.

Common Complaints

The simplicity of the device as well as its many forms can cause innumerable problems.

Nurses quickly realized that while a pulse oximeter could measure almost instantaneous changes in oxygen saturation, there were significant fluctuations in the readings. Any patient movement could cause erroneous readings. Therefore, only a series of readings (trending) is significant.

Patients with low perfusion do not have a good arterial pulse signal, causing the pulse oximeter to read out of sync with the pulse. The venous and arterial oxygen saturations in these patients are averaged together, resulting in artificially lower readings. Patients on vasoconstricticants also produce artificially low readings.

"The most common pulse oximeter fault is the probe itself."

Very often the clinicians can cause their own problems with pulse oximeters. A very common complaint is that readings are low or intermittently absent. These problems can often be explained by problems seen in Figure 2. This patient has two separate issues affecting her SpO2 readings. The first is that when the non-invasive blood pressure (NIBP) cuff inflates, the blood flow ceases. The "pulse" part of pulse oximetry is now disrupted, the heart rate and oxygen concentration reading are either incorrect or absent. The actual complaint for this repair call was "the unit is alarming about every 15 minutes." Because the NIBP was set to take a reading every 15 minutes, during every NIBP cycle the low saturation alarm sounded. Aside from this, the patient had inaccurate SpO2 readings due to the red nail polish, which was still on the index finger. The red light of the pulse oximeter was prevented from transmitting through the nail.

One more interesting repair call involved an urgent request to come to the cardiac cath lab. It was reported that after trying several probes, the pulse oximeter just did not work. Upon entering the suite, a disposable adhesively applied finger probe was seen stuck across the forehead of the patient. Discrete questioning revealed that the finger probes were less expensive than the forehead probes, so in order to save money, forehead probes were no longer being purchased. Forehead probes were shortly thereafter re-ordered.

Disposable finger probes can be too large or too small for a given patient. When troubleshooting a call that which indicates probe problems, you should verify that the photo detector and the light emitting diodes (LEDs) are positioned correctly.

Environmental issues can also cause inaccurate readings. A probe "just laying there" can give "ghost readings." Many times the probe is laying in such a manner that a light from the room is shining into it just enough

Figure 2. *A patient's nail polish causes inaccurate SpO2 readings.*

to affect the photo detector. These "ghost readings" often are the cause of inexplicable alarms sounding in unoccupied rooms.

The most common pulse oximeter fault is the probe itself. Many probes use extension cables that often fail at the strain relief. The probes tend to have the same problem. Some probes are repairable either by the biomedical technician or by third party repair companies that specialize in probe repair.

The variety of probe types has also caused confusion. Reusable finger probes are difficult to misuse but the disposable "stick on" types have been found attached in many incorrect places.

To ensure proper operation, pulse oximeter probes must be placed on a digit without nail polish or artificial nails. Ambient light should be restricted, and other monitoring or infusing devices should not be placed on the limb being monitored for oxygen saturation.

Preventive Maintenance

Every major test equipment manufacturer makes a pulse oximeter tester. Many of the pulse oximeter manufacturers also make their own test devices. This variety of available test equipment gives the biomedical technician many options when deciding on not only what to buy, but how to test the device.

For example, some test devices are designed to be plugged into the pulse oximeter where the probe attaches. The probe is not included in the test, only the electrical components of the pulse oximeter are tested. Most of the use, abuse, and failure of a pulse oximeter is in the patient probe. Therefore, a tester that can test the patient end of the unit seems to be more practical. There are patient simulators that are sophisticated enough to perform both electrical calibration checks and test the condition of the patient probe. These test devices are more expensive, but can aid in expediting troubleshooting and repair.

A complete preventive maintenance check should examine electrical safety, battery condition, equipment function, and probe function and condition. As with many other medical devices, the entire unit and accessories must be in good working order to provide accurate and usable information to the clinician. ■