



## A NEW GENERATION OF PULSE OXIMETER FOR THE PULMONARY FUNCTION LABORATORY

by Jim Harvey MS, RPFT, RCP

The accurate reporting of diffusion capacity in the pulmonary function laboratory is dependant upon the predicted values being corrected for changes in hemoglobin and carboxyhemoglobin. According to the new ATS/ERS Pulmonary Function Testing Guidelines, the actual diffusion capacity results should never be adjusted for hemoglobin and carboxyhemoglobin. Only the predicted values should be adjusted. The philosophy is that the actual data should always be presented in its pure form. Diffusion capacity is a direct measurement of the condition of the alveolar capillary membrane. We are measuring the passive diffusion or transfer, as the Europeans call it, of carbon monoxide across the layers of the alveoli and capillaries. After transferring across these membranes, the carbon monoxide chemically binds to hemoglobin to form HbCO or carboxyhemoglobin. If the hemoglobin is significantly higher or lower than a normal value, the resultant DLCO value will be falsely higher or lower respectively. In all pulmonary function laboratories, the predicted DLCO should be corrected for the patient's true hemoglobin and carboxyhemoglobin values.

**An important improvement in the reporting of diffusion capacity results is on the way**

ment in the reporting of diffusion capacity results in the pulmonary function laboratory. A company in California, Masimo, has developed a device which will be able to report total hemoglobin and oxygen content. They already have a device on the market which can report carboxyhemoglobin, and methemoglobin.

We now depend on hemoglobin and carboxyhemoglobin measurements taken from arterial blood gas results or from clinical lab data or in some cases, performing finger pokes and centrifugation for hemoglobin. In many labs the DLCO predicted values are not adjusted for hemoglobin because it is too much trouble to obtain a measurement.

Pulse oximeters have been around for 44 years and have always been, to me, a mysterious and fascinating instrument. I always am amazed that shining light through a finger tip can produce so much data, such as O<sub>2</sub>Sat%, heart rate, and other parameters. The history of pulse oximeters goes back to 1935 when Matthes developed the first 2-wavelength ear oxygen saturation meter using red and green filters. He later switched to red and

infrared light sources. This first oximeter was never produced commercially. In 1964 Shaw assembled the first practical oximeter which was ear based and made use of eight wavelengths of light. It was commercialized by Hewlett Packard and its use was limited to pulmonary function laboratories mainly due its high cost and large size. How many of you remember lugging around those huge machines with their cumbersome ear probes attached to cumbersome head bands? The first oximeter which was a pulse oximeter with the ability to read heart rate was developed in 1972 by Aoyagi using the ratio of red to infrared light absorption of the pulsating components at the measuring light. It was commercialized by Biox in 1981 and by Nellcor in 1983.

Prior to the introduction of pulse oximeters, the only way of determining a patient's oxygenation was by an arterial blood gas sample. The resultant single point measurement typically takes 20 to 30 minutes to send and be processed by the clinical laboratory or much less time if analyzed by the pulmonary function technologist using point of care testing. As we know, without oxygenation, damage to the brain starts in five minutes and brain death, another ten minutes. With the introduction of pulse oximetry, a non-invasive, continuous measure of a patient's oxygenation was possible, revolutionizing the practice of anesthesia and, according to anesthesia journals of the time, lowering the United States patient mortality as a consequence of undetected hypoxemia at over 10,000 deaths per year with a large portion of these resulting in death.

By 1987, the standard of general anesthesia in the United States included pulse oximetry. From the operating room, the use of pulse oximetry rapidly spread throughout the hospital. Of course pulse oximetry is not a substitute for an arterial blood gas as it, at least for now, gives no indication of carbon dioxide levels, blood pH, or sodium bicarbonate levels. Falsely low readings may be caused by hypoperfusion of the extremity being monitored, often due to vasoconstriction secondary to cold or vasopressor agents or due to incorrect sensor application or movement. Falsely high or low measurements may occur when hemoglobin is bound to something other than oxygen. In cases of carbon monoxide poisoning, the falsely high reading may result in not recognizing-

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ing hypoxemia and death. With high carboxyhemoglobin levels, the oxyhemoglobin is reported as normal and the person reading the device believes that the patient is receiving sufficient oxygen and is not hypoxic. Pulse oximetry only reads the percentage of bound hemoglobin. It can be bound to other gases and results in the same response as hemoglobin bound to oxygen. Methemoglobin can cause pulse oximetry reading in the low 90's or mid 80's. Cyanide poisoning can also produce a falsely high reading since it reduces oxygen extraction from arterial blood.

How do pulse oximeters work? Pulse oximeters consist of light emitting diodes attached to one side of the probe and light collecting sensors attached to the other side. Oxygenated hemoglobin in blood absorbs light at 660nm which is red light. Deoxygenated hemoglobin blood absorbs light at 940nm which is infrared. The sensor is placed on a thin part of the patient's anatomy, usually a fingertip or earlobe, or in the case of a neonate, across a foot. The light is shone through and although there are impediments such as skin, bone, muscle, and perhaps even finger nail polish and skin pigments, the light which travels through, even though diffusely, is picked up by the light collecting sensors. The devices are calibrated to, in a sense, ignore the intervening structures. The relative absorption of light by oxyhemoglobin and deoxyhemoglobin is processed by the microprocessor in the device and an oxygen saturation is reported. At the same time the device measures the blood pulsations in the finger or ear and is able to ignore local noise from the tissues. The measurement of the blood pulsations produces heart rate and ultimately, the perfusion index. The result is a measurement of the patient's oval oxygenation status.

The new pulse oximeter also gives a graphical display of perfusion index (PI). PI is a measurement of blood perfusion through the tissues through which the pulse oximeter light is being transmitted. In this measurement, both red (R) and infrared (IR) lights sources are utilized. A constant amount of light (DC) from the light source of the pulse oximeter is absorbed by the skin, other tissues, and non pulsatile or non flowing blood, while a variable amount of light (AC) is absorbed by the pulsating arterial flow. The calculation of the PI is determined by the following equation:

$$PI = AC/DC \times 100\%$$

For the calculation of PI, the IR pulsatile signal is indexed against the nonpulsatile IR signal and expressed as a percentage. The IR signal is used because it is less affected by changes in arterial saturation than R signal.

In patients who are in critical condition, or who are in anesthesia, or who are undergoing surgery the, PI, an indication of the general perfusion status throughout the body, is a useful measurement. In the neonatal acute care setting, a low PI as been shown to be an objective and accurate measure of acute illness.

This new pulse oximeter, at this point, is the only device which can readily measure carboxyhemoglobin, methemoglobin, and hemoglobin. This device will prove very useful in any pulmonary function laboratory when performing diffusion capacity measurements, monitoring carbon monoxide poisoning, and monitoring smoking cessation.

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