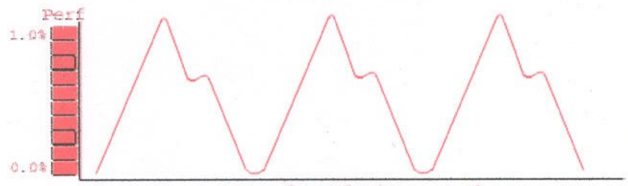
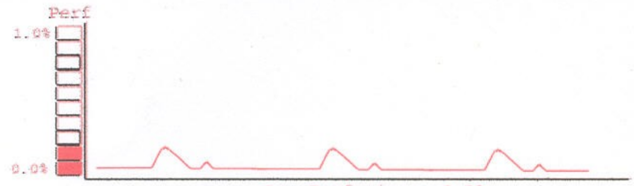
Pulse Oximetry: "**Perfusion**"



Normal Perfusion > 0.5%



Low Perfusion < 0.5%

"Perfusion" is a term used by pulse oximeter manufacturer's to describe "Signal Strength". The term "Perfusion" is also used by healthcare providers to describe blood flow. Pulse oximeter derived perfusion is only an indirect indication of blood flow. It is useful for determining whether a particular monitoring site can provide adequate signal strength for reliable SpO2 calculation.

The image above depicts a typical pulse oximeter waveform. The large waveform on the right is what a healthcare provider would expect to see on their pulse oximeter after successful sensor placement. The perfusion "meter" next to the large waveform indicates perfusion is at least 1.0% (normal level). The smaller waveform on the left is what a healthcare provider would expect to see on their pulse oximeter after a poor sensor placement. The perfusion meter next to this waveform indicates 0.2%, which is very low. The healthcare provider can easily determine low-perfusion by observing the pulse oximeter waveform, however a perfusion meter or number is a useful indication.

Pulse oximeter perfusion is signal strength. Signal strength is a ratio: It is the portion of the light being absorbed by the pulsating blood divided by all of the light transmitted (or reflected) through the monitoring site. When a pulse oximeter reports 1.0% Perfusion, it is saying that only one percent of all the light transmitted or reflected through the monitoring site by the sensor is being absorbed by the pulsating blood.

Conventional pulse oximeters cannot provide reliable blood flow information. In Figure 1, an image of a box with waves of water is shown. The still, unmoving water is analogous to the volume of blood within a pulse oximeter monitoring site. The waves are analogous to the pulsations of blood within the monitoring site. The ratio of the "height" of the waves relative to the height of the entire body of water is small. This yields a low perfusion reading on a pulse oximeter even though the volume of blood may be large (as may be the case with a hyper-volemic patient with a weak pulse).

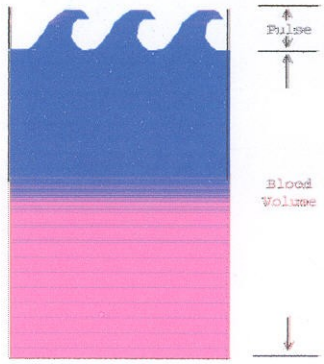


Figure 1

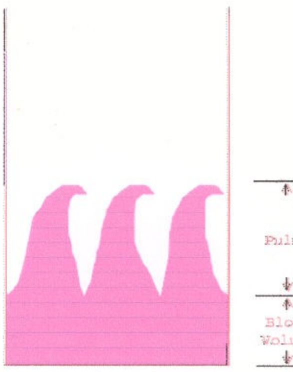


Figure 2

In Figure 2, a similar size box contains a low overall volume of water relative to the "height" of the waves within it. This yields a high perfusion reading on a pulse oximeter even though the volume of blood may be small (as may be the case with a hypo-volemic patient with a strong pulse).

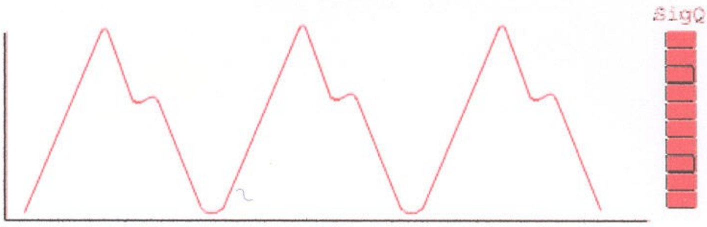
Low-Perfusion Performance

A pulse oximeter's Low-Perfusion Performance is determined by the lowest signal-strength it is capable of reliably calculating SpO2 and Pulse Rate from (within specified accuracy). Typically, a "Low-Perfusion" pulse oximeter is capable of calculating SpO2 on signal-strengths much less than 0.2% Perfusion. Low-perfusion Performance combined with pulse-oximeter-displayed perfusion and waveform can improve healthcare providers' decisions.

Pulse Oximetry: "Signal Quality"

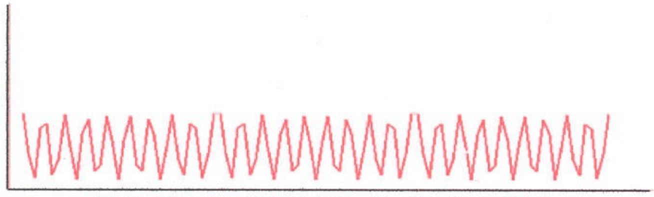
"Signal Quality" is a term used to describe the ratio of "Noise" within a pulse oximeter waveform relative to the physical pulse rate information. Signal Quality is literally the Signal-to-Noise Ratio.

At left, the top waveform is a clean (noise-free) pulse oximeter waveform a healthcare provider would expect to see on their pulse oximeter after a successful sensor placement. The signal quality "meter" next to it is completely filled in.



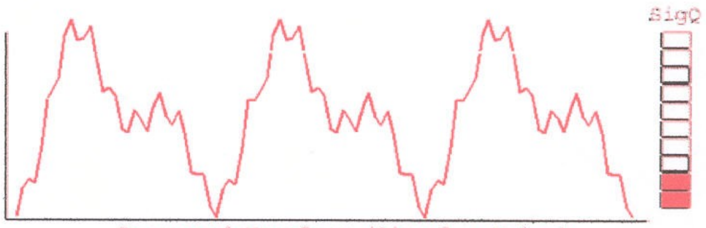
Pulse Oximeter Waveform (Signal)

The second waveform is pure noise. This can be introduced into the pulse oximeter signal from motion exterior to the patient (e.g. ambulance, helicopter, or jogging). This noise can also be the result of motion internal to the patient, such as tremor.



Outside Interference or Motion (Noise)

The third waveform is the result of the addition of the first (top) and second waveforms. The healthcare provider can easily determine the pulse oximeter monitoring site is "noisy" by observing the pulse oximeter waveform, however a Signal Quality meter or number is a useful indication.



Corrupted Waveform (Signal + Noise)

A signal quality meter or number is derived by calculating the "energy" of the pulse rate portion of the pulse oximeter waveform relative to the entire "energy" content of the pulse oximeter waveform. It is known by pulse oximeter manufacturers and healthcare providers that a pulse oximeter waveform, properly termed "photoplethysmogram", contains respiratory rate and sympathetic and parasympathetic autonomic activity information. In a photoplethysmogram free of noise, the signal quality would be calculated as:

$$\text{SigQ} = \frac{(\text{Energy of Pulse Rate Signal})}{(\text{Energy of Pulse Rate Signal} + \text{Respiratory Rate} + \text{Autonomic Activity})}$$

where energy is loosely analogous to amplitude. In the presence of noise, the SigQ number decreases because some of the total energy of the photoplethysmogram is contained within the noise:

$$\text{SigQ} = \frac{(\text{Energy of Pulse Rate Signal})}{(\text{Energy of Noise Signal} + \text{Pulse Rate} + \text{Respiratory Rate} + \text{Autonomic Activity})}$$

Motion Artifact Rejection

A pulse oximeter that can correctly calculate SpO2 and Pulse Rate in the presence of noise is said to be capable of Motion Artifact Rejection. Modern pulse oximeters achieve motion artifact rejection through the use of complex algorithms and digital signal processing. Motion Artifact Rejection combined with pulse oximeter displayed signal quality indications and waveform can improve healthcare providers' decisions.