

# Pulse CO-Oximetry



# The Evolution of Pulse Oximetry

Accurate Monitoring When You Need It Most™



**1935**  
Matthes develops first oxygen saturation meter using red and green filters



**1964**  
Shaw assembles first absolute-reading ear oximeter using eight wavelengths - HP manufactured

**1998**

In 1989, Diab & Kiani invent Signal Extraction Pulse Oximetry using adaptive filter with DST & Parallel Engines to separate the arterial signal from noise, allowing oximeters to accurately monitor patients during motion and low perfusion. Masimo SET is launched internationally in 1998.

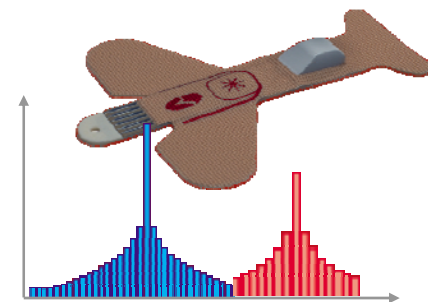


**1949**  
Wood adds pressure capsule to try to obtain an absolute oxygen saturation



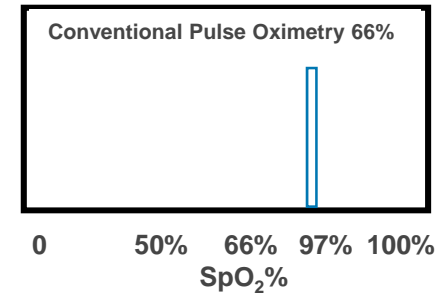
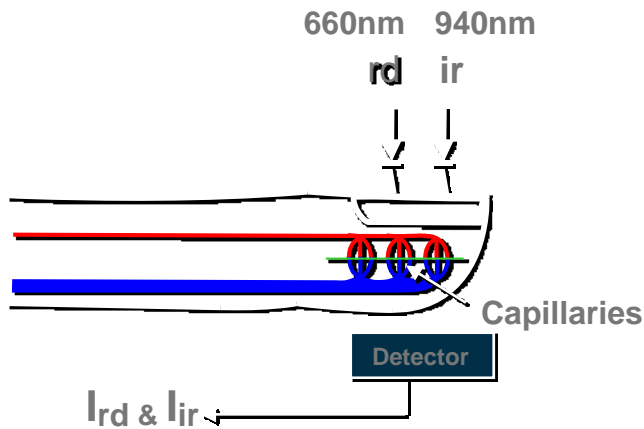
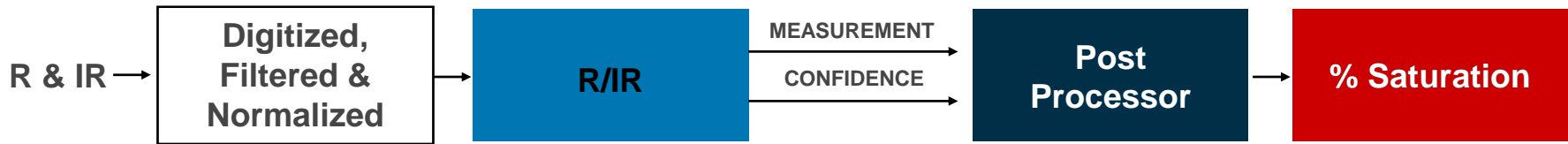
**1981**

In 1972, Aoyagi at Nihon Kohden invents conventional pulse oximetry using the ratio of red to infrared light absorption of pulsating components at the measuring site. It was commercialized by Nellcor with disposable sensors in 1981.



# Conventional Pulse Oximetry Algorithm

## Conventional Pulse Oximetry Algorithm



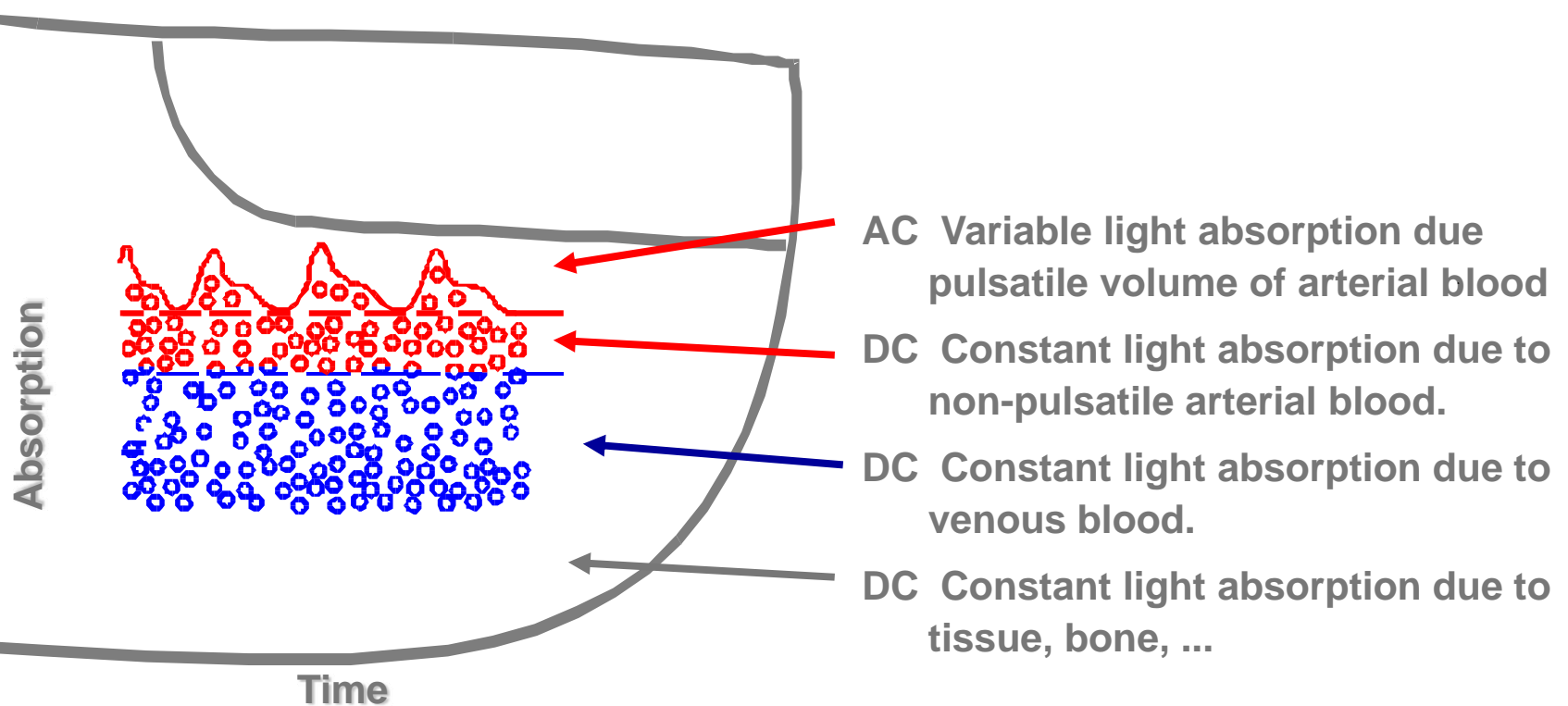
# Calibration Equation or “Look-Up Table” to convert ratio to SpO<sub>2</sub>

**RD/IR Ratio at Photodetector  
correlates with SpO<sub>2</sub>**

<b>~RD/IR</b>	<b>SpO<sub>2</sub></b>
2.5	0%
1.75	20%
1.60	30%
1.50	40%
1.25	60%
1.00	82
0.75	91%
0.67	95%
0.40	100%



# Model of Light Absorption At Measurement Site Without Motion



# Conventional Pulse Oximetry

Under certain conditions:

- Wrong values - false alarms
- Missed true events
- Data dropout - loss of numbers

Consequences

- Lack of confidence
- Wrong therapy



# Sources of Artefact (Noise):

## Electronic noise

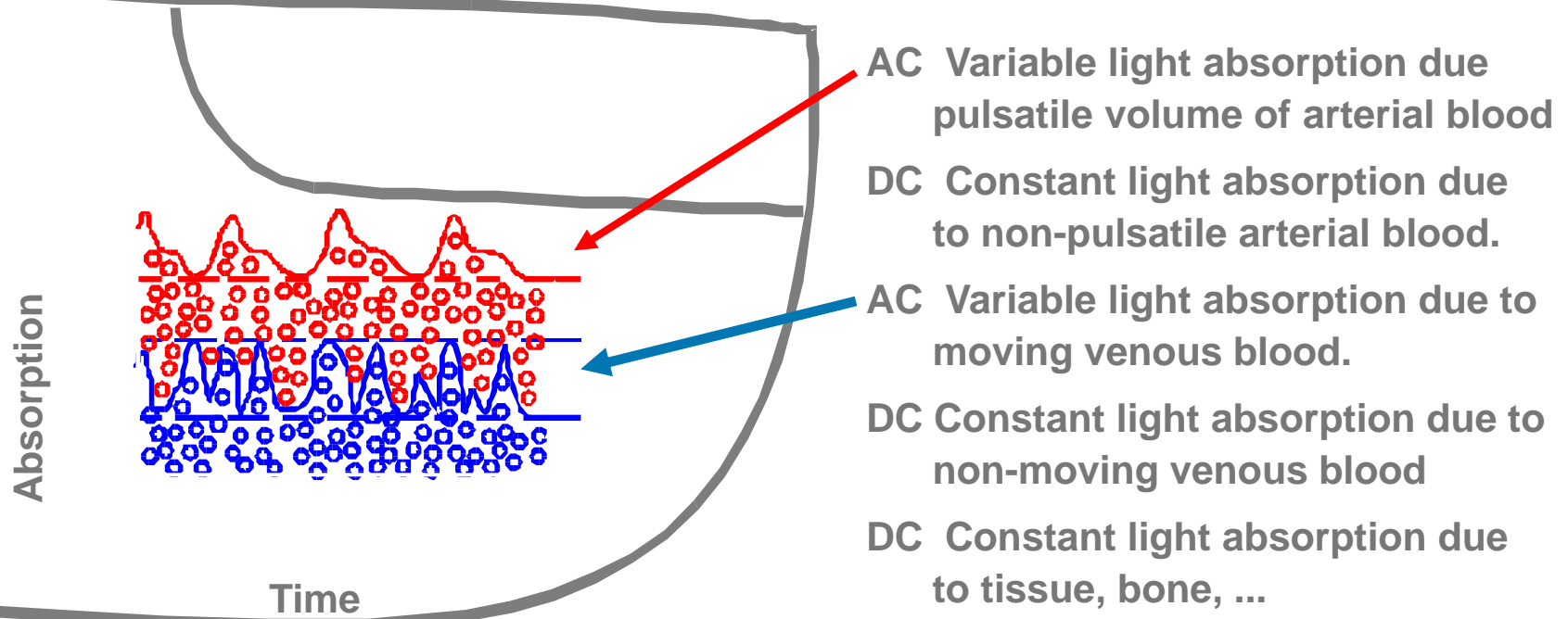
- Light piping noise
- Electromagnetic Interference

## Physiological Noise

- Tissue compression
- Sensor movement
- Venous Blood Movement (due to motion)



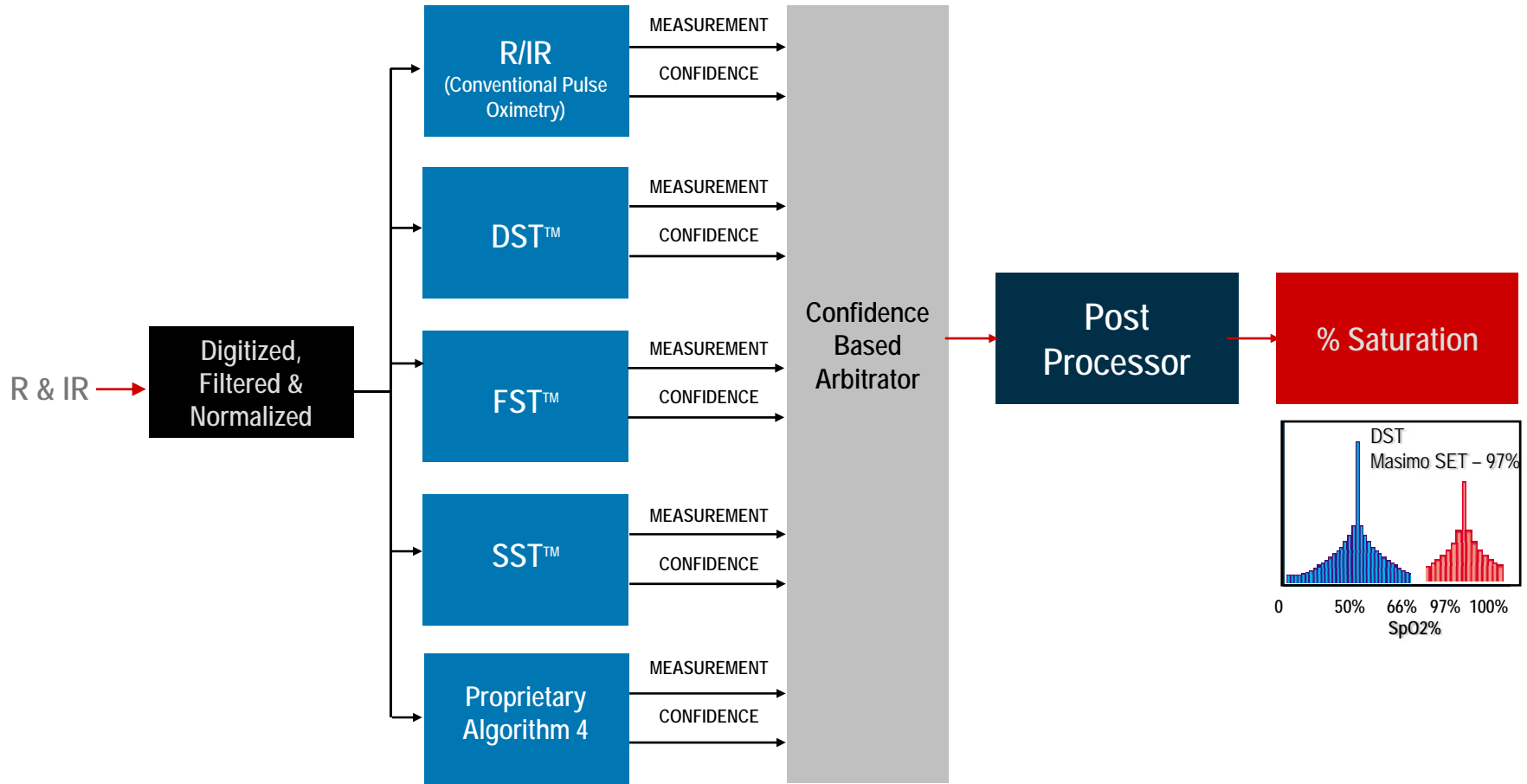
# Masimo SET Theory: Explanation of Light Absorption At Measuring Site During Motion



Result: During motion, Conventional Pulse Oximeters may display a falsely low saturation value that results from measuring both the arterial and non-arterial pulsatile components.



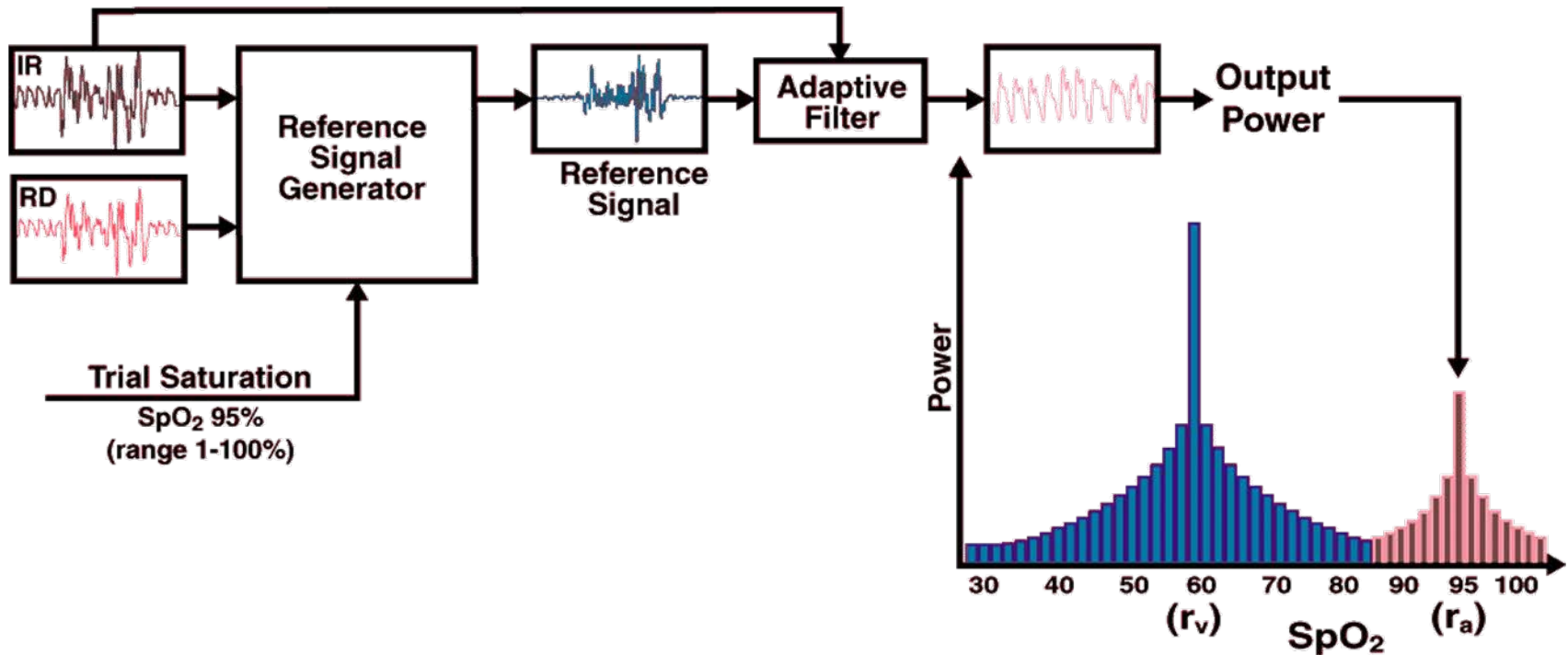
# Masimo SET's (5) Parallel Algorithms



Masimo SET "Parallel Engines"



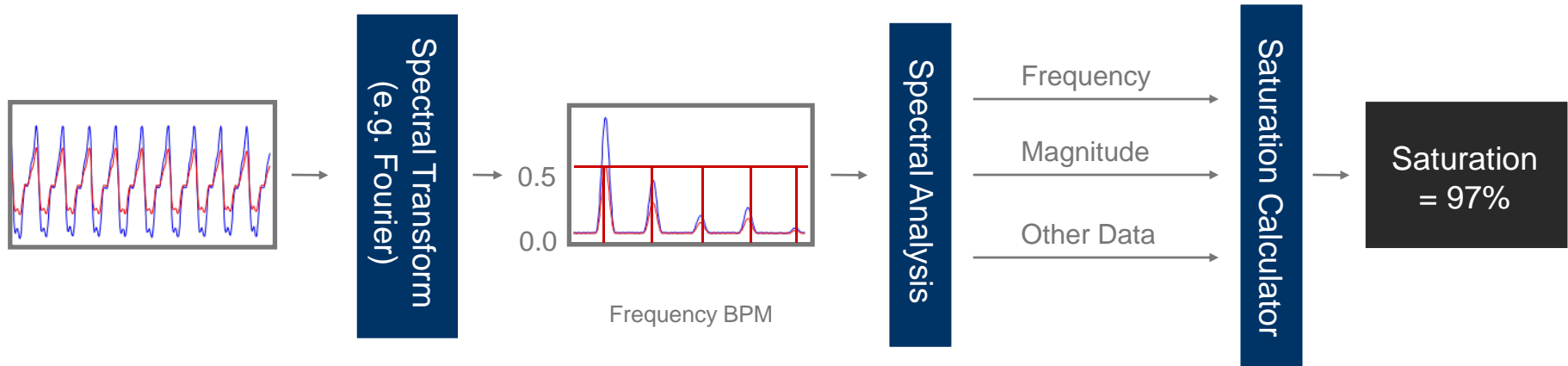
# DST Discrete Saturation Transform



DST makes only one assumption – that arterial blood has a higher oxygenation than venous – making it the most powerful pulse oximetry algorithm

# Fast Saturation Transform (FST)

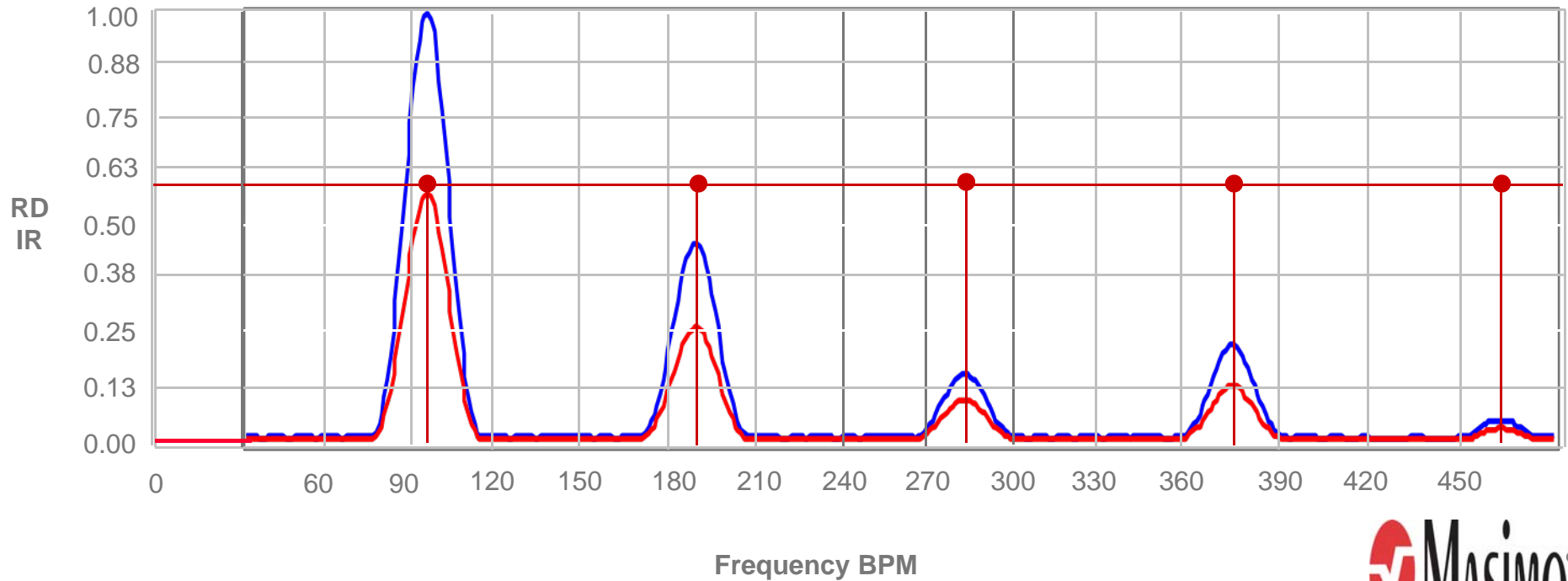
**No motion** - Subject at 97% Arterial Oxygen Saturation



# FST™ (Fast Saturation Transform)

No Motion Subject at 97% Arterial Oxygen Saturation

Output

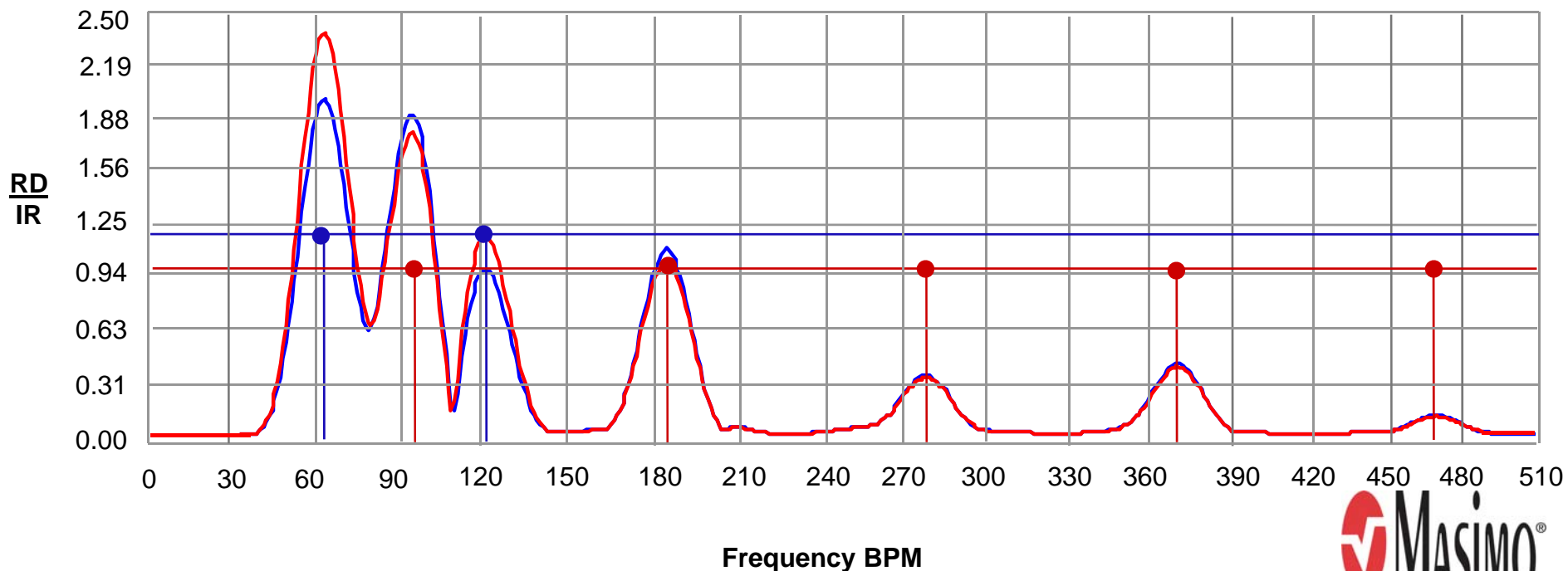


# FST™ (Fast Saturation Transform)

**Motion - Subject at 95% Arterial Saturation, 60% Venous Saturation**

**Output**

**Frequency Domain Data**



# Limitations of Pulse Oximetry

- Conventional pulse oximetry can not distinguish between MetHb, COHb, and O<sub>2</sub>Hb
  - Conventional pulse oximetry technologies use only two wavelengths of light and lack the technology to establish dyshemoglobin levels—as a result they overestimate SpO<sub>2</sub> saturation in the presence of dyshemoglobins



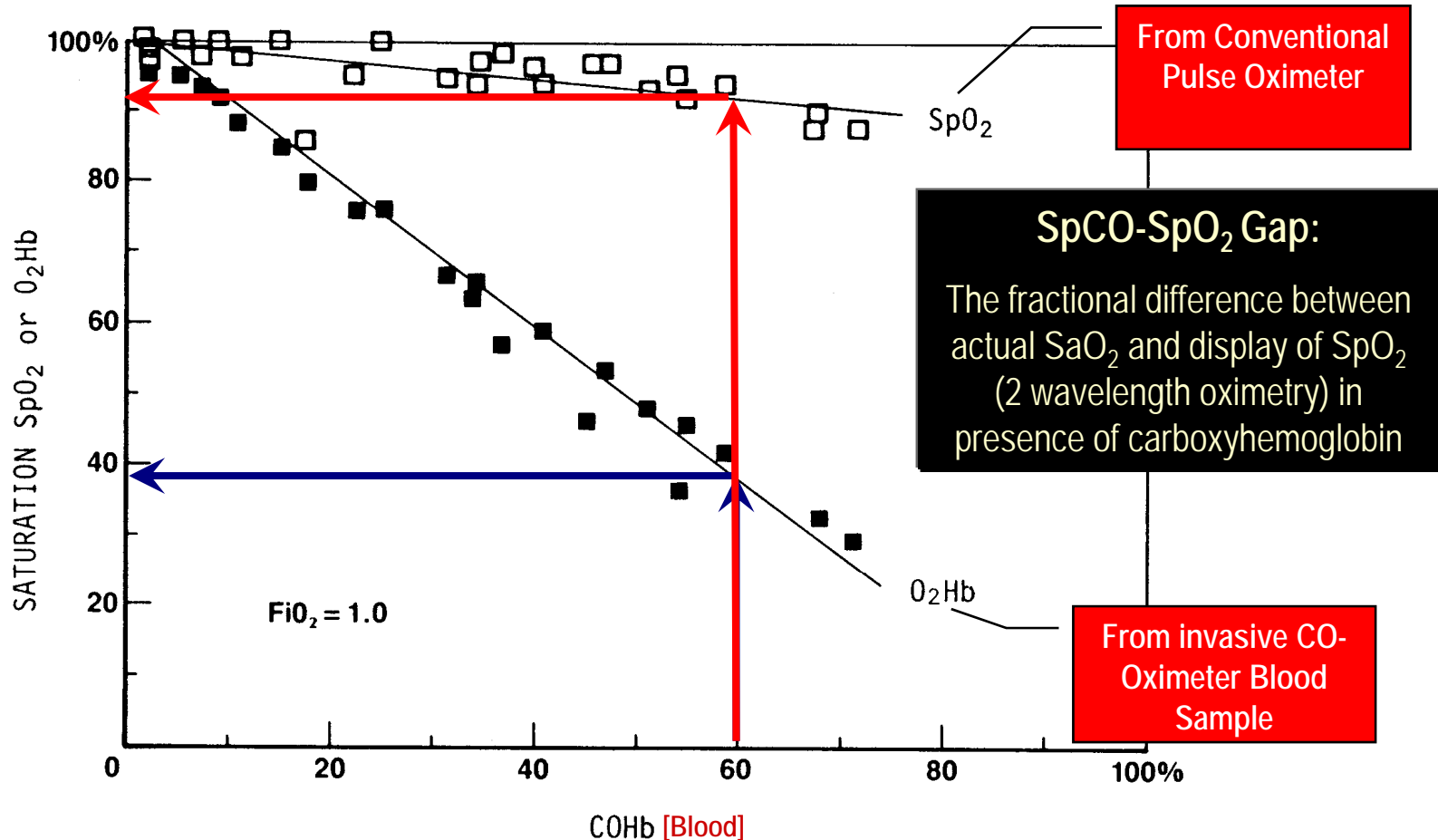
# CO Is Most Common Cause of Poisoning

Carbon monoxide injures and kills more people than any other poison, and poisoning deaths are on the rise since 1999

- Difficult to diagnose - symptoms are similar to other conditions



# SpO<sub>2</sub> & Carboxyhemoglobin



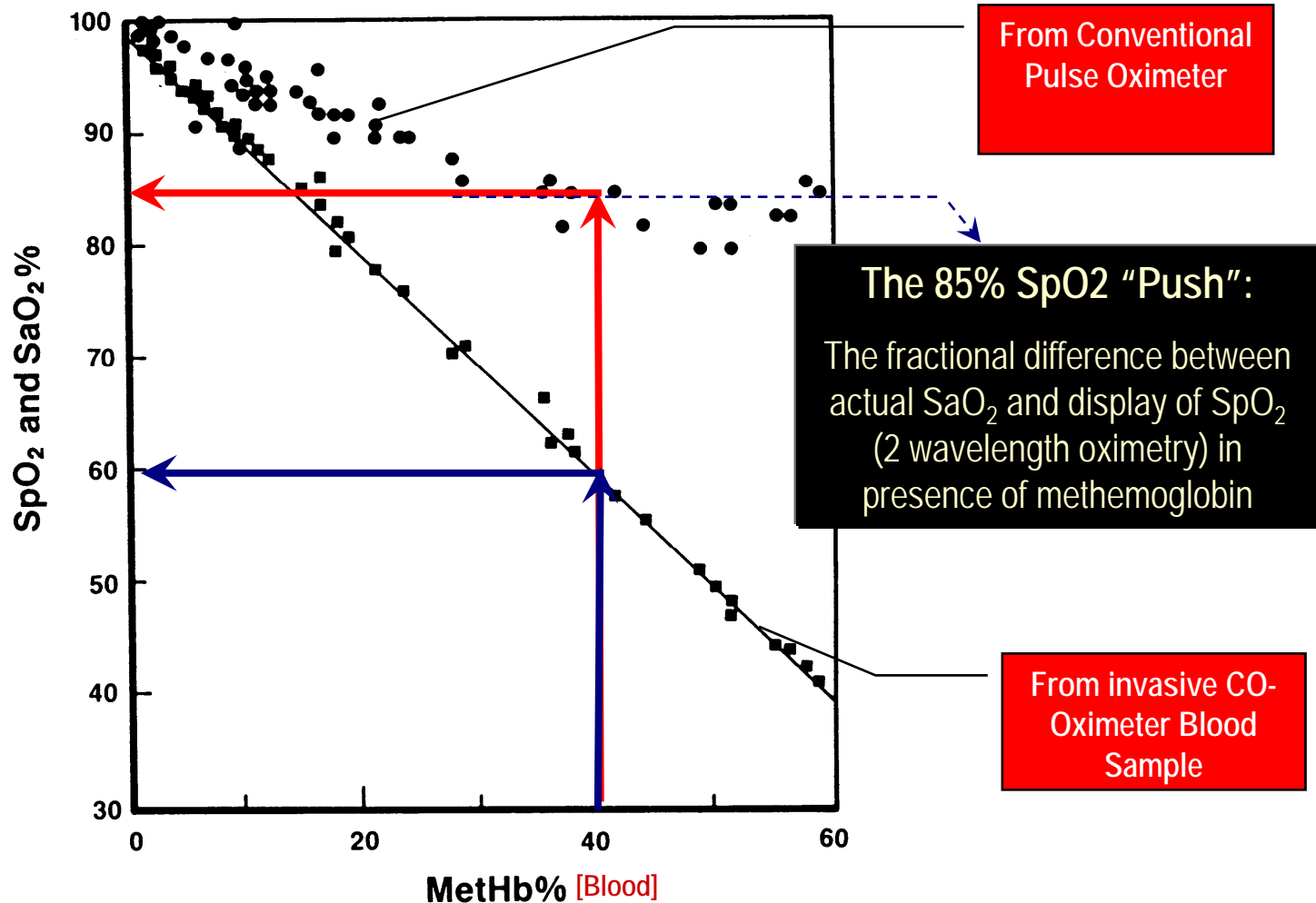
Barker SJ, Tremper KK. The Effect of Carbon Monoxide Inhalation on Pulse Oximetry and Transcutaneous PO<sub>2</sub>. *Anesthesiology* 1987; 66:677-679



# Methemoglobinemia

- Methemoglobin is formed when the hemoglobin is converted to a form that cannot bind  $O_2$ 
  - In Methemoglobin the ferrous ( $Fe^{+2}$ ) irons of hemoglobin are oxidized to the ferric ( $Fe^{+3}$ ) state
- Main Causes; Local anaesthetics and NO ventilation

# SpO<sub>2</sub> & Methemoglobin



Barker SJ, Tremper KK, Hyatt J. Effects of Methemoglobinemia on Pulse Oximetry and Mixed Venous Oximetry. *Anesthesiology* 1989;70:112-117



# Traditional: Invasive, Delayed, Noncontinuous



# Using CO-Oximetry to Measure COHb and MetHb

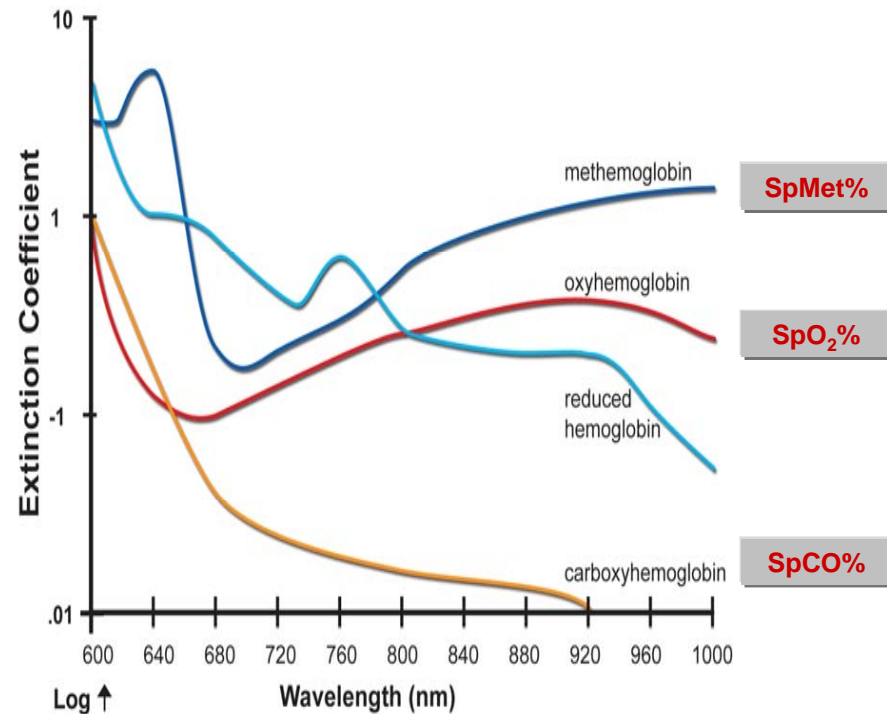
## Problems associated with blood tests

- Risk of infection
- Wait for results
- Can be uncomfortable
- Non-continuous measurements
- CO-Oximeters are simply not available in many hospitals



# Multiple Wavelength CO-oximetry

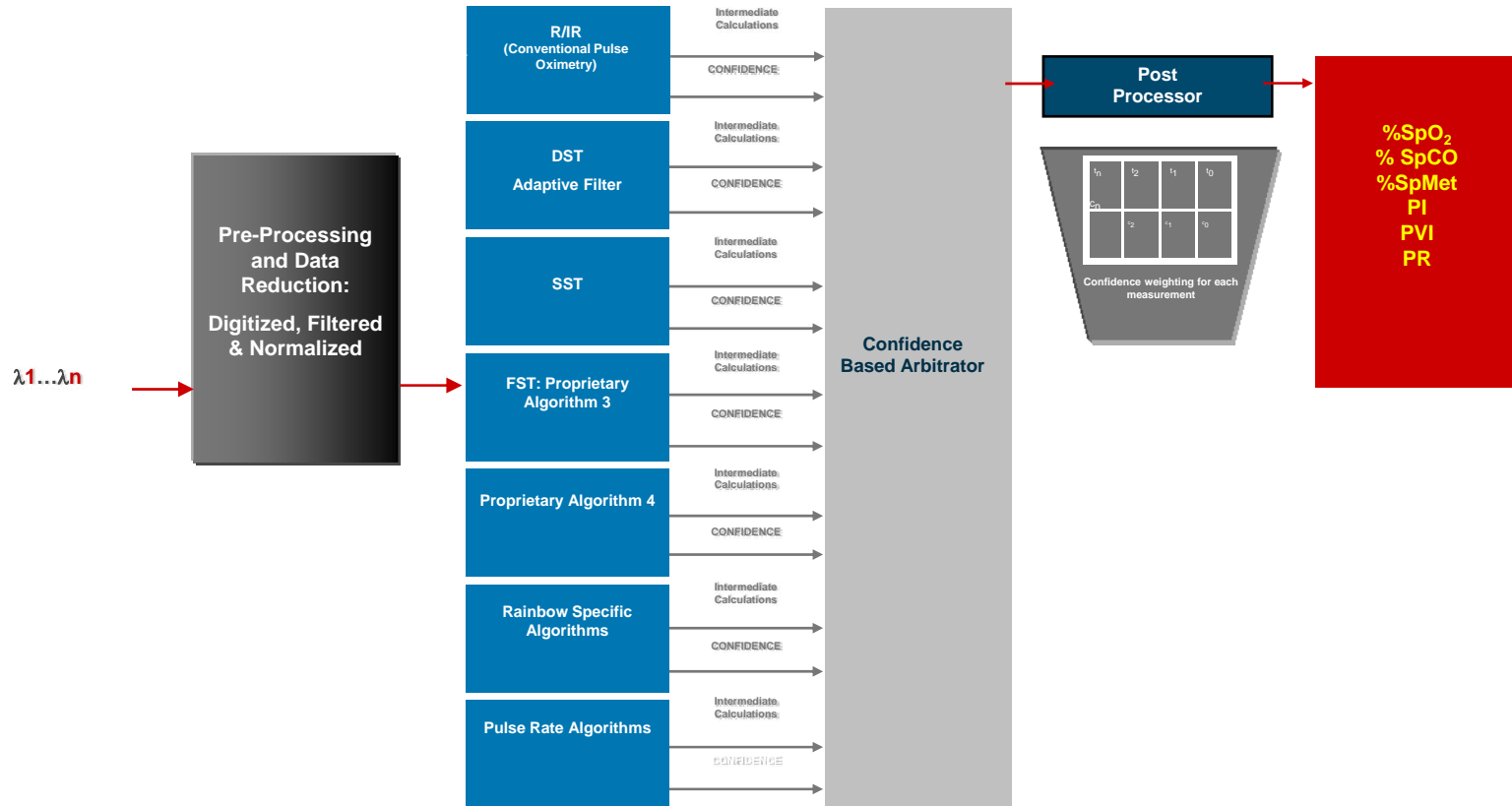
Rainbow SET uses multiple (7+) wavelengths to accurately determine the dyshemoglobins SpCO and SpMet, as well as SpO<sub>2</sub>, Perfusion Index, and Pulse Rate



Oxygenated Hb and reduced Hb absorb different amounts of Red (RD) and Infrared (IR) Light  
*(Two-wavelength oximeters cannot measure dyshemoglobins)*



# The Sound Science of Rainbow Technology



Based on Masimo SET Pulse Oximetry Technology  
with Added Rainbow Technology Algorithms  
*(Expanded understanding of your patients' oxygenation status)*

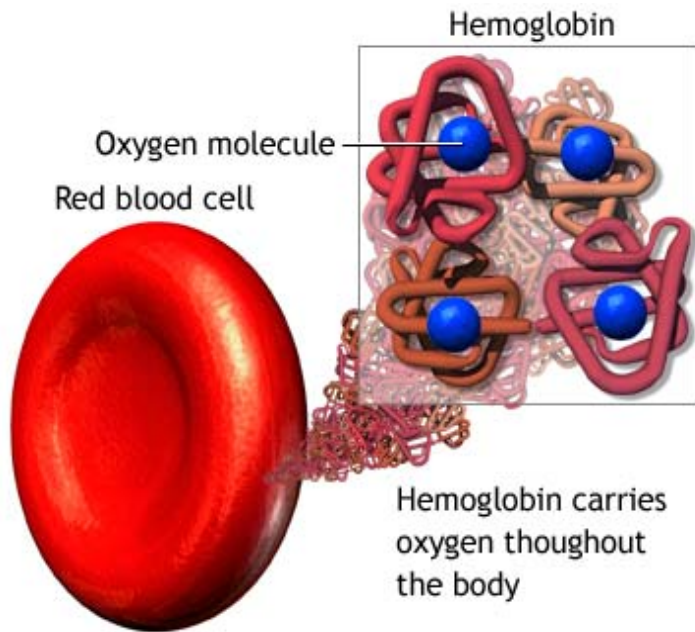


# The future of Pulse CO-oximetry

- Pulse CO-oximeters measure how much of the haemoglobin is carrying O<sub>2</sub>
  - Patient with low level of Hb (<8 gm/dl) can have SpO<sub>2</sub> values of 98%
- The amount of haemoglobin (gm/dl) is required to estimate the amount of O<sub>2</sub> in the body.



# Total Hemoglobin (Hb)



- Most frequently-ordered lab test
  - 400M+ times per year in Europe
- Hb more frequent than SpO<sub>2</sub>

# Current Methods to Measure Total Hemoglobin



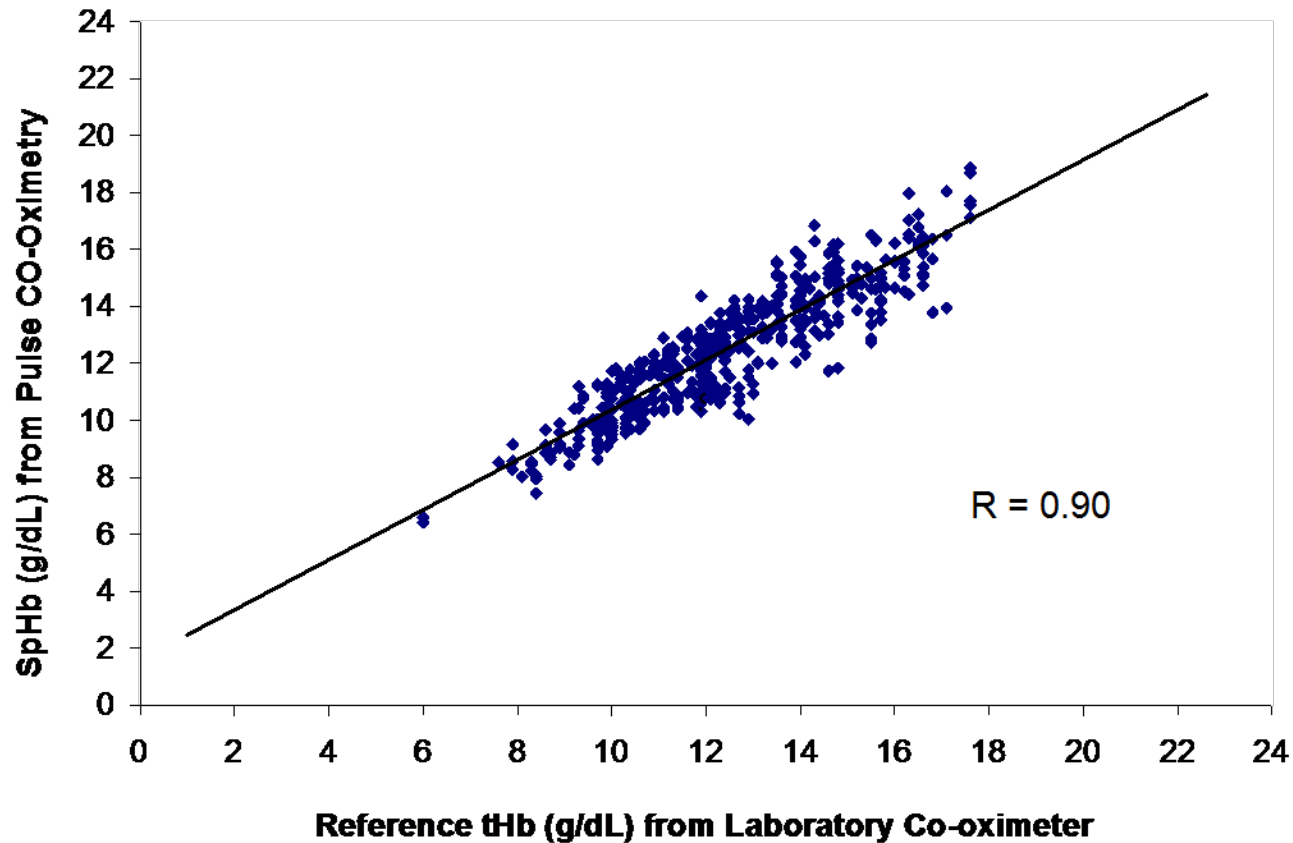
# Pulse CO-oximetry

Using a Pulse CO-oximeter with 12 wavelengths of light we can measure;

- Total Haemoglobin (Hb)
- Oxygen Content (SaOC)
- Hematocrit (Early 2008)



# SpHb Accuracy



N=492 data points collected on adults using reusable sensors



# Differences Between SpHb and tHb

tHb Range	$\leq 1.0$ g/dl	$\leq 1.5$ g/dl	$\leq 2.0$ g/dl
6 – 18 g/dl	69%	<b>91%</b>	97%
<10 g/dl	<b>80%</b>	97%	100%

- Exceptional 91% of all data points within 1.5 g/dL
- In the most critical range below 10 g/dl
  - 97% within 1.5 g/dl
  - 80% of all data points within 1 g/dl





Questions?