LIMITATIONS IN PREDICTING pO_2 FROM sO_2 MEASURED BY PULSE OXIMETRY

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THE IMPORTANCE OF MONITORING PO_2

The partial pressure of oxygen, pO_2 in the tissue, is the main driving force for the cell oxygenation. The pO_2 has to be high enough to secure an adequate oxygenation. On the other hand, too much oxygen (too high pO_2) is toxic to some organs, especially in the premature newborn infant.

It is therefore important to regulate pO2 closely to avoid adverse reactions to either too much or too little oxygen. Continuous monitoring is necessary to provide information for this regulation. Many hospitals use pulse oximetry, others use transcutaneous monitors and some use both.

PULSE OXIMETRY

In the mid 1980s more and more NICU's started to use pulse oximeters. The technology became popular due to the ease of use (no calibrations or site changes) and a number of NICUs stopped using tc monitors and relied totally on pulse oximeters for monitoring the oxygen status on the neonates.

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HOW RELIABLE IS THE PULSE OXIMETER?

There have been several studies recently which have looked more closely at the information supplied by pulse oximeters.

• Grace RF—Med J. Aust. May 16, 1994, 160(10) p638-44:

This paper reviewed articles written since 1985 appraising pulse oximetry. The authors found the pulse oximeter to be an imperfect device, with numerous potential limitations. They concluded that its reliability diminishes as the clinical situation denotes from the norm, possibly when accuracy is most needed.

• Thrush D; Hodges MR—South Med J April 1994, 87(4) p518-21:

Accuracy of pulse oximetry during hypoxia is under discussion here. Oxygen saturation readings from pulse oximeters were compared with those from arterial blood samples analyzed with a co-oximeter. Significant deterioration in the accuracy was observed as SaO_2 decreased. There were 14 cases of hypoxia not detected by the pulse oximeter. In conclusion, the accuracy of pulse oximetry deteriorates as hypoxia worsens.

• Poets CF; Southall DP—Pediatrics May 1994, 93(5) p737-46:

Non-invasive monitoring of oxygenation in infants and children is the topic here. Both transcutaneous monitoring and pulse oximeters are evaluated and the conclusion is that ideally both should be used in combination, particularly in critically ill pre-term neonates.

•Bucher HU; Keel M; et al—Lancet May 7, 1994, 343(8096) p1135-6:

Artificial problems with pulse oximeters were investigated. Increased pressure on tissue due to inappropriate sensor attachment produced errors of greater than 3% in 25% of the subjects being tested. Venous congestion also induced errors in 30% o the subjects. The conclusion was that pulse oximeter values nee to be scrutinized for these errors.

Even the best pulse oximeter was incorrect or inaccurate about one-third of the time.

• **Rodriguez LR; Kotin N; et al—Pediatrics May 1994, 93(5) p810-3:**

The authors undertook a study to quantify if pediatric house staff is knowledgeable of pulse oximetry and their ability to interpret the information. Only 17% of the 134 pediatric staff questioned knew anything about the oxyhemoglobin dissociation curve. Only 36% were able to answer questions correctly relating to the accuracy of pulse oximeters. The results showed that there was a marked variability in the staff knowledge of all aspects of the oximetry.

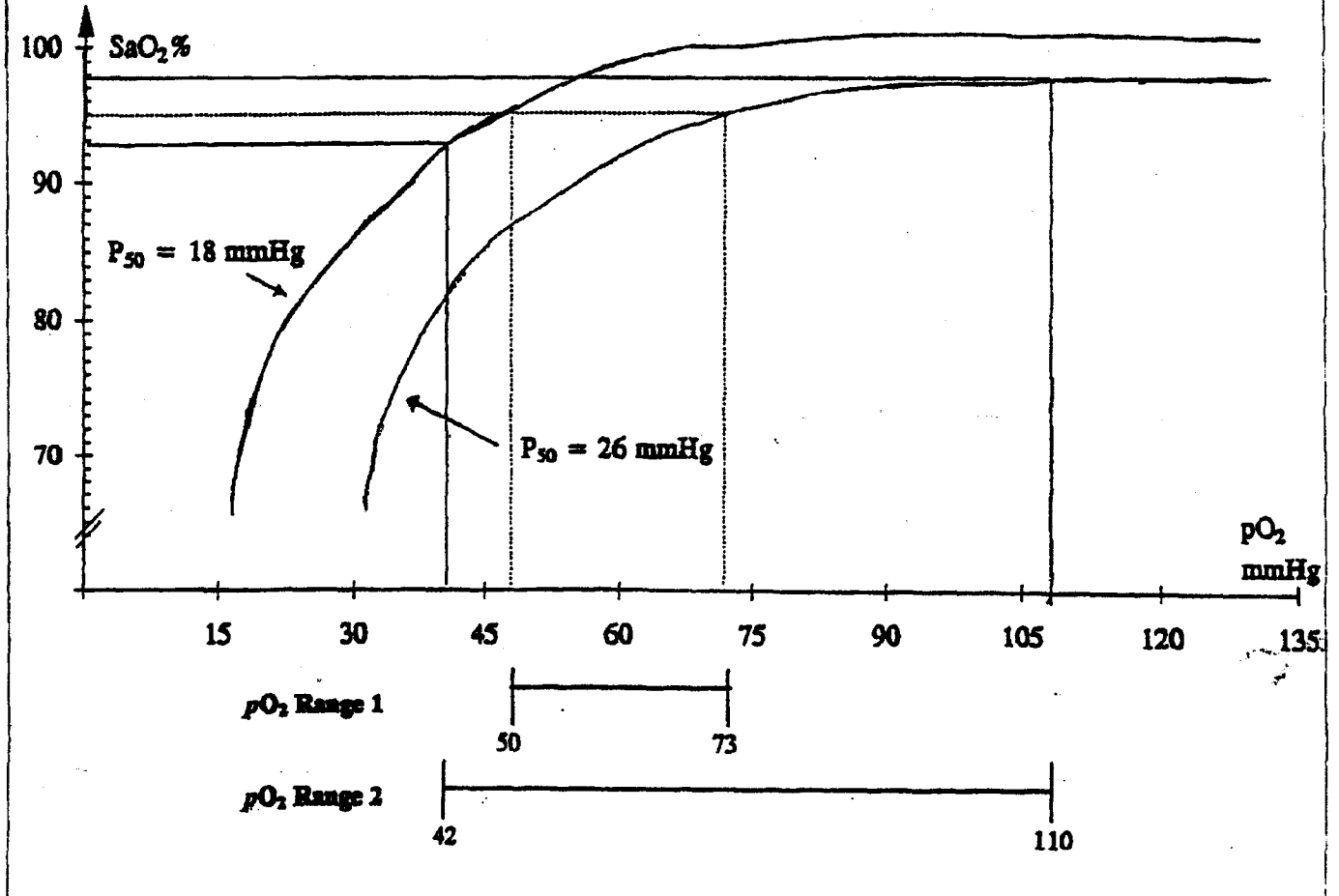
• **BBI Newsletter Vol. 17, No. 12 December 1994, p205:**

Work done at the University of California at Irvine reports on the accuracy of several brands of pulse oximeters during low perfusion states. Even the best pulse oximeter was incorrect or inaccurate about one-third of the time. There were considerable differences between the brands for motion artifact sensitivity and for recover time after seeing a desaturation below the operating range.

• **Mike V; Krauss AN; Ross GS—Soc. Sci. Med. 1996, 42(9) p1247-58:**

One NICU director comments on the lack of understanding of pulse oximeter measurements and the way babies are kept over-saturated. Generally the impact of keeping very tiny babies

Figure 1. pO_2 Range Variation.



More care is needed in interpreting sO_2 readings and avoiding the risks of both hypoxia and hyperoxia.

at saturations of 98-99% for long periods is ignored. The oxygen tension at these levels of saturation could be extremely high but the associated dangers are being overlooked.

THE OXYGEN DISSOCIATION CURVE

The relationship between pO_2 and sO_2 is characterized by the Oxygen Dissociation Curve (ODC).

The exact position of the ODC can be expressed by the p50 value. This is the pO2 at 50% saturation level. In the neonate, the p50 is normally 18-26 mmHg and may change fast because of the rapid changes in neonatal physiology.

INACCURACY OF PULSE OXIMETERS

Clinicians should be aware of the inaccuracy of pulse oximeters. In the 90-100% range, the typical inaccuracy is ± 3%, and at lower ranges the inaccuracies are even worse.[1] As shown in Figure 1, this makes the range of pO_2 values corresponding to a sO_2 of 95% unacceptably wide (range 2). Due to technical uncertainty and the uncertainty of the position of the ODC curve, a sO_2 of 95% could mean a pO_2 of anything between 42 and 110 mmHg. Table I gives examples of the relationships at different levels of sO_2.

DIFFERENT PULSE OXIMETERS USE DIFFERENT ALGORITHMS

Different brands of pulse oximeters use different algorithms for the calculations of sO_2. Two different pulse oximeters may give simultaneous readings differing 2% because of this.[2] Putting such differences on top of the above described inaccuracy means that a sO_2 of 95% may correspond to a range of pO_2 of 39 to above 150 mmHg.

CONCLUSION

In neonatology, it may be difficult to predict pO_2 from pulse oximeter readings. Transcutaneous monitoring of oxygen may be a better alternative in certain situations. The technology has proven to be reliable and accurate for trending the oxygen status of the patient.

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REFERENCES

1. Health Devices. Vol. 18 No. 6, June 1989. Special issue on pulse oximeters.
2. Thilo EH et al. J. Pediatr. 1993, 122: 620-36.

Table I. Relationship between sO_2 and pO_2.

sO_2 measured by pulse oximetry	Range in pO_2 due to clinical variations in the ODC ($p50$: 18-26 mmHg or 2.4-3.5 kPa)	Range in pO_2 due to clinical variations in the ODC (p50: 18-26 mmHg or 2.4-3.5 kPa) and inaccurancy of pulse oximeters (±3%)
%	mmHg (kPa)	mmHg (kPa)
90	39-57 (5.2-7.6)	36-65 (4.8-8.7)
95	50-73- (6.7-9.8)	42-110 (5.6-14.7)
98	76-110 (10.1-14.7)	50-above 150 (6.7-20.0)