

Original Article

Continuous Venous Oximetry: A Comparative Study Between the CDI 100 and the Bentley OxySat II

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ABSTRACT

Two in-line oxygen saturation monitors, the CDI 100 and OxySat II, were evaluated in the clinical setting. Eighty-seven venous blood samples were drawn during 20 elective cardiopulmonary bypass procedures. Monitor readings were compared to OSM III co-oximeter values. The results revealed that saturation (%) determination was biased, -3.16 ± 2.21 SD for the CDI 100 and -0.34 ± 2.17 SD for the OxySat II. Hemoglobin (g/dl) and hematocrit (%) measurement, available only for the CDI 100, resulted in a bias of $+5.54 \pm 5.68$ SD and $+1.94 \pm 1.78$ SD, respectively. It was concluded that both monitors operated within clinically acceptable limits, with a more favorable outcome for the OxySat II.

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INTRODUCTION

Monitoring of mixed venous oxygen saturation is a major tool in the conduct of safe and physiological cardiopulmonary bypass (CPB). Saturation of venous blood mirrors the balance between oxygen supply and demand. Shifts in venous oxygen saturation may be related to patient oxygen consumption and adequacy of oxygen delivery (1-3). The purpose of this study is to investigate the accuracy and general clinical performance of two in-line oxygen saturation monitors.

METHOD

Twenty elective cardiac patients scheduled for procedures requiring CPB were included (Table 1). The CPB circuit consisted of a Sarns roller pump^a, Dideco 7500 membrane oxygenator and venous reservoir^b. The priming solution contained 1800 ml Ringer's Acetate, 15 g mannitol and 7500 IU heparin. CPB was performed at moderate hypothermia ($31.5 \pm 1.2^\circ\text{C}$). Pump flow was regulated to meet a venous oxygen saturation exceeding 70%.

PRINCIPLE OF MEASUREMENT

The CDI 100 and the OxySat utilize a similar method in determining oxygen saturation. Infra-red light pulses pass through an optical window into the blood stream. By means of reflectance spectrophotometry, the characteristics of the oxy- and deoxy-hemoglobin spectra are calculated, and values for saturation (%), hematocrit (%) and hemoglobin (g/dl) are thereby derived.

MONITOR SET-UP AND BLOOD SAMPLING

The monitors included for this study were the CDI 100^a and the OxySat II^c. Both instruments present hemoglobin-oxygen saturation, while the CDI 100 also measures hemoglobin and hematocrit concentrations. The OSM III^d co-oximeter was used as the reference to evaluate saturation and hemoglobin readings (4). The hematocrit was compared with results obtained from Hettich hematocrit centrifuge^e.

The tested monitors were prepared according to the manufacturers' instructions. The OxySat II optical reference test was performed in each case (Table 2). The re-calibration feature available for the CDI 100 was not put to use. Two cuvettes, one from each monitor, were inserted into the venous line approximately 5 cm apart at the inlet of the venous reservoir.

Five blood samples were drawn from the venous line of each patient using glass syringes. Each syringe was capped and stored in ice. Reference analysis was carried out after a com-

Table 1
Patient demographics.

N=20	Mean	Range
Age (years)	66.7	50-80
CPB Time (minutes)	116.7	67-202
Aortic Cross Clamp Time (minutes)	72.7	31-133

Table 2
Reference test of the OxySat II.

	Calibration Reading	p
Bias	0.71	<0.05
Precision	± 1.09	

Table 3
Statistics in summary.

n=87	Mean	Range	Bias	Precision	Slope	Intercept	p
CDI 100 Saturation (%)	76.03	65-84	-3.16	2.21	0.84	15.57	<0.001
Hemoglobin (g/l)	87.84	70-106	+5.54	5.68	1.04	-8.74	<0.001
Hematocrit (g/dl)	27.01	21-33	+1.94	1.78	1.06	-3.57	<0.001
OxySat II Saturation (%)	78.86	68-87	-0.34	2.17	0.88	9.65	0.150

pleted series of sampling. Centrifugal spinning was performed instantaneously.

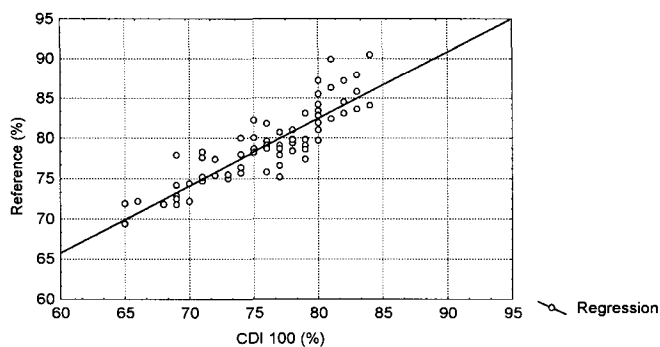
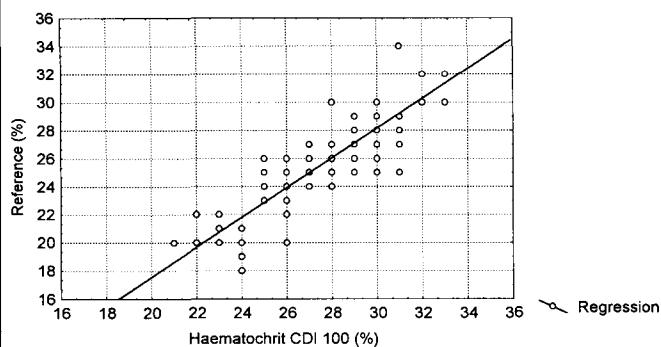
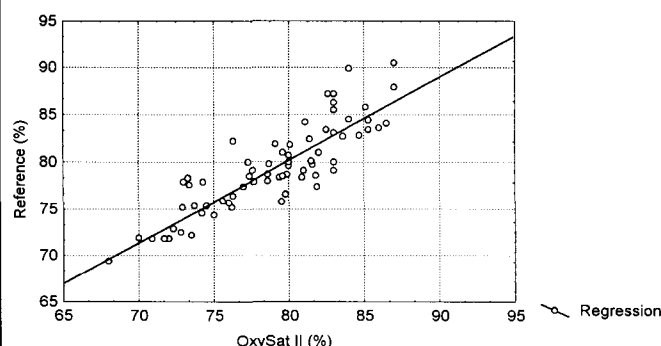
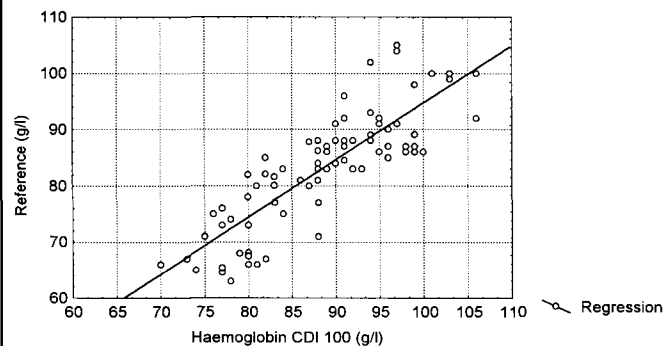
Overall performance is presented as scatter plots. *Bias* is defined as the mean difference between monitor-reference readings and the standard deviation as the *precision* (5). Student's t-test for dependent samples is used to determine the bias significance. A p value < 0.05 is regarded as statistically significant.

RESULTS

A total of 87 samples were collected with a mean of 4.35 from each patient. Saturation bias for the CDI 100 and OxySat II were -3.16 (p<0.001) and -0.34 (p=0.150), respectively. Precisions were similar: ± 2.21 and ± 2.17 S.D. Linearity as determined by the slope revealed comparable findings (Table 3). Correlation coefficients reached 0.883 and 0.879 as presented in Figures 1 and 2.

Hematocrit and hemoglobin results are presented in Figures 3 and 4. The correlation coefficient for the hemoglobin was slightly lower 0.839 as compared to 0.856 for the hematocrit evaluation. Bias for the hemoglobin reading was +5.54 and +1.94

a 3M Health Care, Ann Arbor, MI 48103
 b Dideco S.p.A., Mirandola, Italy
 c Baxter Health Care Corporation-Bentley Division, Irvine, CA 92714
 d Radiometer, Copenhagen, Denmark
 e Hettich, Tuttlingen, Germany

Figure 1Saturation Scattergram CDI 100. Correlation: $r = 0.883$.**Figure 3**Hematocrit Scattergram CDI 100. Correlation: $r = 0.856$.**Figure 2**Saturation Scattergram OxySat II. Correlation: $r = 0.879$.**Figure 4**Hemoglobin Scattergram CDI 100. Correlation: $r = 0.839$.

for the hematocrit. Both hematocrit and hemoglobin seem to be overestimated in a linear fashion, with a slope close to 1 (Table 3).

DISCUSSION

The tested monitors, the CDI 100 and the OxySat II, both perform with clinically acceptable accuracy. The CDI 100 seems to somewhat underestimate the true saturation level. The obtained bias of -3.16% for this instrument may be corrected with in-line recalibration, especially when results for slope and precision are obliging. However, an in-line recalibration may accentuate bias even further, as a true reference point is often difficult to establish (6).

The CDI 100 is new on the market and its clinical performance is not yet well documented. The OxySat II has been used for several years and our findings correspond well with other investigators (7,8).

Interference of temperature has not been considered. Firstly, the temperature range is well defined and has a similar distribution between the different measurements. Secondly, the technique employed with reflectance spectrophotometry is not influ-

enced by changes in temperature (9).

The bias for the CDI 100 could theoretically be explained by an error in sampling methodology (10). Ambient air coming in contact with low saturated venous blood would typically increase its saturation and balance the obtained bias value. On the other hand, the bias for the OxySat II is nearly nil and does not support such a theory. More likely, the detected bias for the CDI 100 may be referred to the calibration procedure of the instrument or a lack of sensitivity in differentiating oxyhemoglobin from deoxyhemoglobin (11).

The outcome for the hemoglobin and hematocrit measurements exposed an almost equal bias and precision. This is what would be expected, as these parameters are reflecting the concentration of the same blood component. However, bias is only fast within clinically expectable limits. The combined error of inferior accuracy and precision may lead to clinical misjudgements. Once again, the CDI 100 offers the option of a recalibration. This may be an adequate solution as the monitor seems to have a linear response, just with a simple offset.

The ideal blood gas monitor for CPB is still not available. The CDI 100 and the SatCrit (Cobe Instruments Inc., USA) (12) are, in that respect, definitely a step in the right direction. The

combined information of saturation and hemoglobin readings gives valuable feedback concerning the oxygen carrying capacity and extraction. Simply by knowing the pump flow, one would also be able to calculate the actual oxygen consumption and oxygen utilization, i.e. oxygen consumption divided by oxygen delivery ($C_{(a-v)} / Ca_{O_2}$). The information gained from venous saturation alone may not suffice, as shown in the critically ill patient. The informative value of both venous saturation and oxygen utilization is in that respect superior, especially as an indicator of cardiac function (13). Its clinical implication in CPB is still to be evaluated.

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