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Comparison between Calculated O_2 Saturation Values and Those Determined Directly In Vitro (Blood Gas Analyzer vs. Oxymeter)

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Introduction

Most blood gas analyzers (BGA) on the market today offer the possibility of calculating the so-called partial O_2 saturation (psO_2, %) of arterial blood from the measured values for pO_2, pH and pCO_2 using formulas derived by Kelman, Severinghaus or Siggaard-Andersen [1]. A common feature of all these methods is that an actual O_2 binding curve is derived from the acid-base status data, which together with the measured pO_2 permit calculation of the psO_2 (%). Since calculation by the BGA does not allow the actual concentrations of COHb and MetHb to be taken into account, values are obtained for sO_2 that represent the partial sO_2 (psO_2). This describes the amount of Oxy-Hb as a percentage of the sum of only oxy- plus deoxy-hemoglobin. In addition, there is a danger of erroneous calculations by the BGA since no data are available concerning shifts in the O_2 binding curve that might result in changes in acid-base status. For this reason, the O_2 saturation calculated by a representative blood gas analyzer (Ciba Corning 178) is compared with the actual sO_2 measured in vitro using a modern multi-wavelength oxymeter (CO-oxymeter 2500, Ciba Corning). This comparison of methods can also be considered to be a practical example of the diagnostic value of the partial O_2 saturation (psO_2) and the true O_2 saturation (sO_2).

Methods

Venous blood (heparinized) from 6 smokers and 8 non-smokers was first adjusted to various BE values (−10, ±0, +10 mmol/l) at 37 °C in a tonometer (IL 237, Instrumentation Laboratory) and then equilibrated using a gas mixing apparatus (Ciba Corning 192) with CO_2 partial pressures of 20, 40 and 60 mmHg, and O_2 partial pressures of 27, 40 and 90 mmHg. The O_2 saturation was on the one hand calculated for each blood sample from the values measured in triplicate for pO_2, pCO_2 and pH using a blood gas analyzer (Ciba Corning 178) and on the other hand measured with an oxymeter (CO-oxymeter 2500, Ciba Corning). Means were calculated from three separate determinations for each sample.

Results

The results are presented separately for smokers and non-smokers in figures 1 and 2; each symbol represents the mean from three separate measurements.

In the non-smokers, good agreement was obtained between the calculated, i.e. partial O_2 saturation, and the measured O_2 saturation. Calculation led to a slight underestimation of the sO_2 that represented around 1% in the upper and 2% in the lower saturation range.

In the smokers this agreement between calculated and measured O_2 saturation was no longer observed; the true O_2 saturation was clearly overestimated in the upper and underestimated in the lower saturation range. In contrast to the mean COHb concentration in non-smokers of only 1.3 ± 0.5%, the smokers (blood taken in the morning) showed a mean COHb concentration of 7.5 ± 1.4%.

Discussion

As was to be expected, the blood gas analyzer can only calculate the O_2 saturation correctly when besides Hb and O_2Hb no COHb or MetHb are present. In non-smokers a relatively good agreement is therefore obtained between measured and calculated sO_2, since in this case the partial and true sO_2 values are practically the same. Compared to the saturation values expected for blood samples with a BE of ± 0 mmol/l and a pCO_2 of 40 mmHg (corresponding to a so-called standard O_2 binding curve [3]), no significant differences were observed in non-smokers after equilibration with a given pO_2 (data not shown). For instance, the O_2

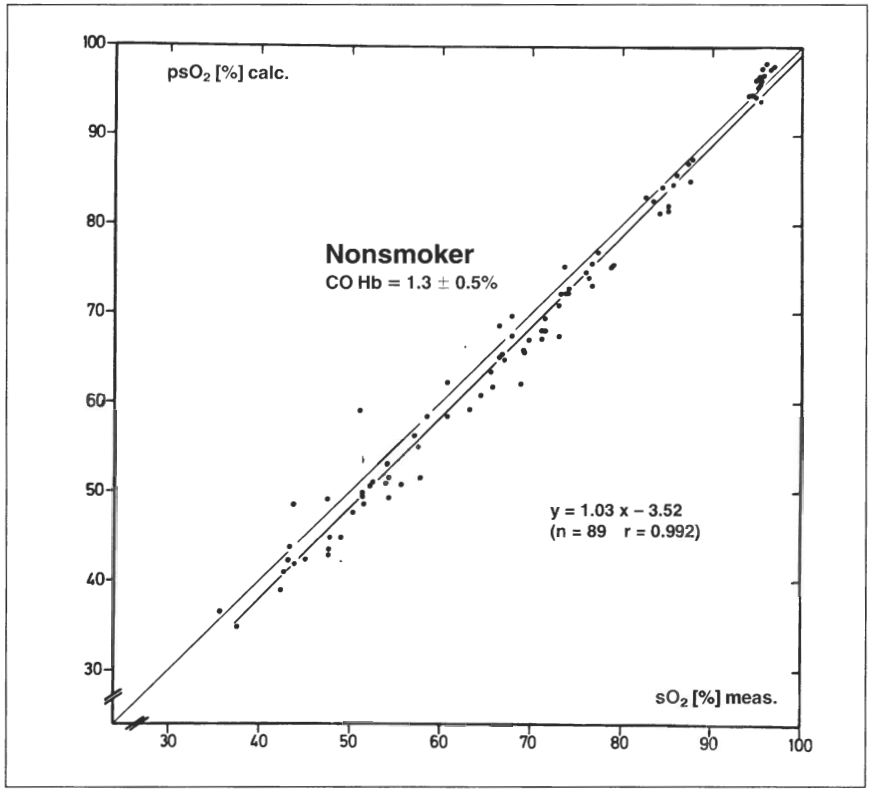

Fig. 1. Comparison between the psO_2 calculated from the pO_2, pCO_2 and pH using a blood gas analyzer (calculated psO_2, %), and the actual sO_2 measured in a CO-oxymeter (measured sO_2, %) in blood obtained from non-smokers (mean COHb concentration 1.3 ± 0.5%). The line drawn assuming identical values for psO_2 and sO_2 is shown together with the regression line for the calculated psO_2. Each symbol represents the mean of three individual values.

saturation at a pO_2 of 27 mmHg gave a mean value of 52.8% compared with an expected value of between 50 and 51% based upon the standard O_2 binding curve; the value calculated from the blood gas analyzer data was, instead of 52.8%, just 50.9% (cf. regression line in fig. 1).

Thus the methods used and the data obtained in the absence of COHb and MetHb permit the calculation of sO_2 with a blood gas analyzer despite the slight underestimation of sO_2 obtained by calculation (cf. fig. 1).

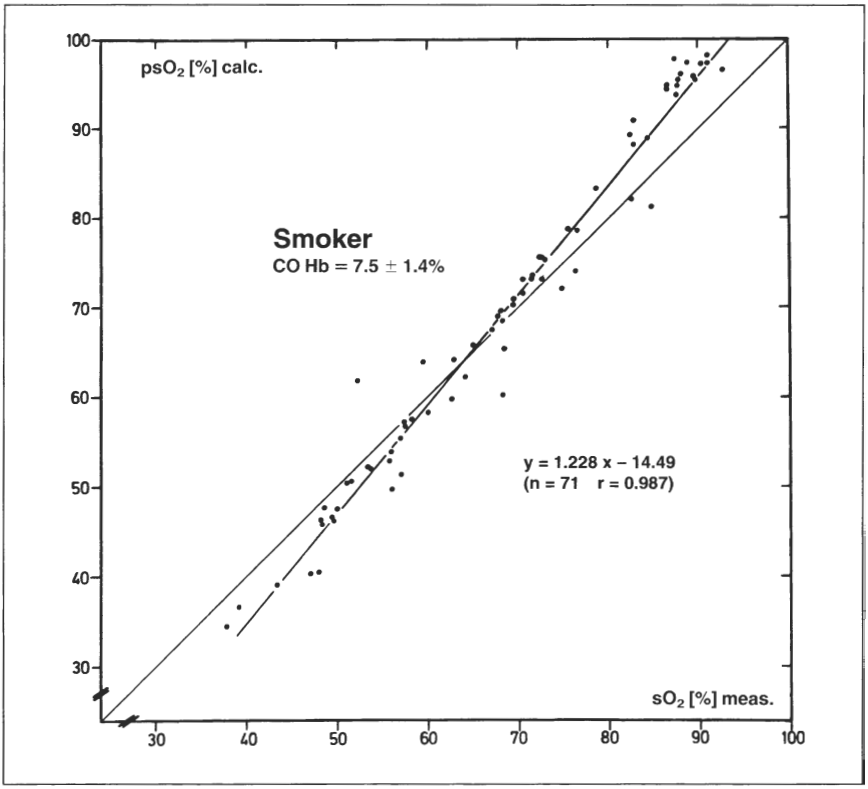

Fig. 2. Comparison between the psO_2 calculated from the pO_2, pCO_2 and pH using a blood gas analyzer (calculated psO_2, %), and the actual sO_2 measured in a CO-oxymeter (measured sO_2, %) in blood obtained from smokers (mean COHb concentration 7.5 ± 1.4%). The line drawn assuming identical values for psO_2 and sO_2 is shown together with the regression line for the calculated psO_2. Each symbol represents the mean of three individual values.

The situation changes in more than one sense in the presence of significant concentrations of COHb or MetHb (MetHb has not been investigated here). In contrast to the non-smokers investigated (COHb 1.3%), the smokers displayed a mean COHb concentration of 7.5% (in blood samples taken in the morning). As was to be expected, the measured true sO_2 (CO-oxymeter) of such blood samples, dropped from 97% to 89%, when these had been equilibrated at pCO_2 = 40 mmHg and BE ± 0 mmol/l with a pO_2 of 90 mmHg. Calculation of the sO_2, however, must

lead, on the basis of the regression line shown in figure 2, to a significant overestimation, i.e. of 94.8% instead of the actual value of 89%. This overestimation of the sO_2 in the upper saturation range obtained by calculation in smokers is due to the fact that only the so-called partial sO_2 (psO_2) can be calculated, and not the true sO_2.

The second problem encountered in calculating the psO_2 from the pO_2, pCO_2 and pH is the fact that only the shift in the O_2 binding curve which is due to changes in the acid-base status can be taken into account. In the case of the smokers, however, there was an independent leftward shift of the O_2 binding curve due to CO, which should be described by a characteristic calculated factor (not presented here).

Blood samples that have been equilibrated at a pO_2 of 27 mmHg (pCO_2 = 40 mmHg, BE = ± 0 mmol/l) should show an sO_2 of 46% in the case of a normal O_2 binding curve and a COHb concentration of 7.5%. The actual mean value measured in the CO-oxymeter was 54.3%, indicating a significant leftward shift. However, instead of the measured value of 54.3%, the blood gas analyzer yields a value of 52.2% (cf. regression line in fig.32) since it calculates the sO_2 on the assumption of a standard O_2 binding curve. The underestimation of the saturation in the lower saturation range in smokers is therefore due to the fact that, instead of the actual O_2 binding curve, only a standard O_2 binding curve can be used as a basis for calculation.

The relatively large scatter of the data shown in figures 1 and 2 is not so much due to variation among the values measured in the CO-oxymeter, but rather to that of the values calculated by the blood gas analyzer. Since calculation of the saturation is based upon measured values for pO_2, pCO_2 and pH, all of which display experimental scatter, these variations can accumulate in the final calculation.

The comparison by Breuer et al. [1] of measured and calculated values of O_2 saturation can only in part be referred to here. Thus, these authors compared the partial, calculated sO_2 (based upon a total of three calculation formulas) with the values measured in the Hem-oxymeter OSM 2 (Radiometer), also representing the partial sO_2. Since this older equipment only uses two wavelengths it can optimally only measure the partial sO_2 if COHb cannot be detected photometrically.

The comparison of methods published by Marian et al. [2] does not allow a comparison between calculated (blood gas analyzer IL 1302, Instrumentation Laboratory) and measured (CO-oxymeter Ciba Corning) O_2 saturation values since the actual measured values are not presented

(the report that the calculated sO_2 is 2.7% higher than the measured sO_2 cannot be assigned to any particular range; no information is given on cCOHb).

Summary

The (partial) O_2 saturation calculated by a blood gas analyzer from measured values for pO_2, pCO_2 and pH is compared with the actual sO_2 values measured in smokers and non-smokers using a CO-oxymeter after equilibration of blood samples. Whereas good agreement was found between calculated and measured saturation values in non-smokers, calculation of the saturation in smokers leads to a significant overestimation in the upper saturation range and to a significant underestimation of the sO_2 in the lower saturation range, compared to the measured (true) values.

References

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