Requirement for Accuracy of Pulse-oximeters in High Oxygen

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Introduction of new oximeters, using a pulse-oximetry principle, is a useful addition to our practice of anesthesia and of intensive care. While its usefulness is beyond any question, a 2% error which is what most instruments are claimed to measure becomes more significant.

In daily routine anesthesia in which we administer oxygen around 30 to 33%, we may expect a pulmonary end-capillary P_{O_2} of 170 to 180 mmHg or S_{O_2} of 99%. Normally we obtain Sa_{O_2} of 98%. The difference in saturation between pulmonary end-capillary to arterial blood is, therefore, 1%. A 2% error in reading of Sa_{O_2} is an unacceptable 200% error with regards to 1% A-a saturation difference. If we obtain a Sa_{O_2} value of 96% (Pa_{O_2} of 80 mmHg) while we are expecting 98%, we may worry because it may mean one of many things; FI_{O_2} may be lower than expected, ventilation may be inadequate or the lung is functioning poorly in oxygenating the blood. A reading 2% lower than the real value, therefore, causes unnecessary concern and possibly action. If, on the other hand, it read 2% too high yielding a value of 98% while its true value is 96%, then the practicing anesthesiologist may sit comfortably, although he should be concerned more about the ventilation and/or oxygenation of the patient. Therefore the accuracy required for an oximeter in this range is somewhat more strict than it is originally designed.

In the daily use of pulse-oximeters, we occasionally observed falsely low saturation readings, resulting a kind of concern as mentioned above. If this is inherent to this type of instruments, we have to be well aware of it and have to stop worrying. We therefore undertook a somewhat more systematic investigation.

Methods

Seven pulse-oximeters of five models (In alphabetical order: Biox Ohmeda 3700, SCI 501, Minolta SM-32, Nelcor N100, Novametrix Pulse-500) were applied to patients who had arterial lines in place. Two to five blood samples were taken from each patient. The blood gas analysis was done by a Corning 175 blood gas analyzer and its saturation was calculated by appropriate algorithm[1,2]. The in vitro saturation was determined also by an IL 282 co-oximeter. When the saturation value calculated by the blood gas values and that measured by the co-oximeter differed by more than 0.3%, the sample was abandoned. If the difference was not more than 0.3%, then the calculated value was taken as the true in vitro saturation. This value was compared with the mean of five in vivo values, simultaneously either read and written down manually or recorded for four minutes at one minute interval. When the mean value by the oximeter was not more than 99%, the in vivo Pa_{O_2} was calculated from the reversed algorithm

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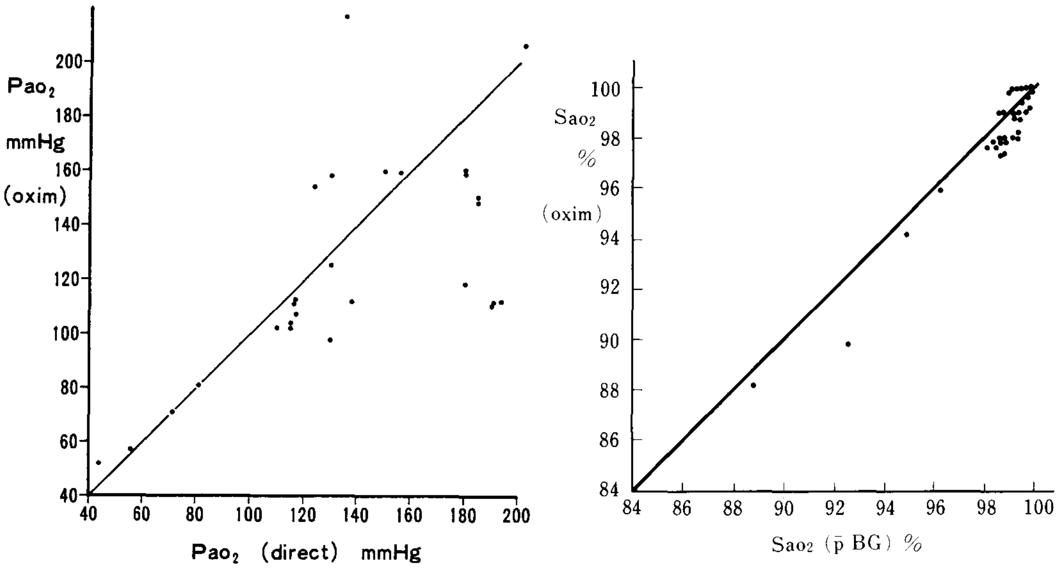

Fig. 1. A comparison between Pa_{O_2}'s directly measured (X-axis) and those calculated back from the oximeter readings (Y-axis). The insert at the upper left corner is the same data, plotted on S_{O_2}-axes. Data from an instrument producing the best agreement.

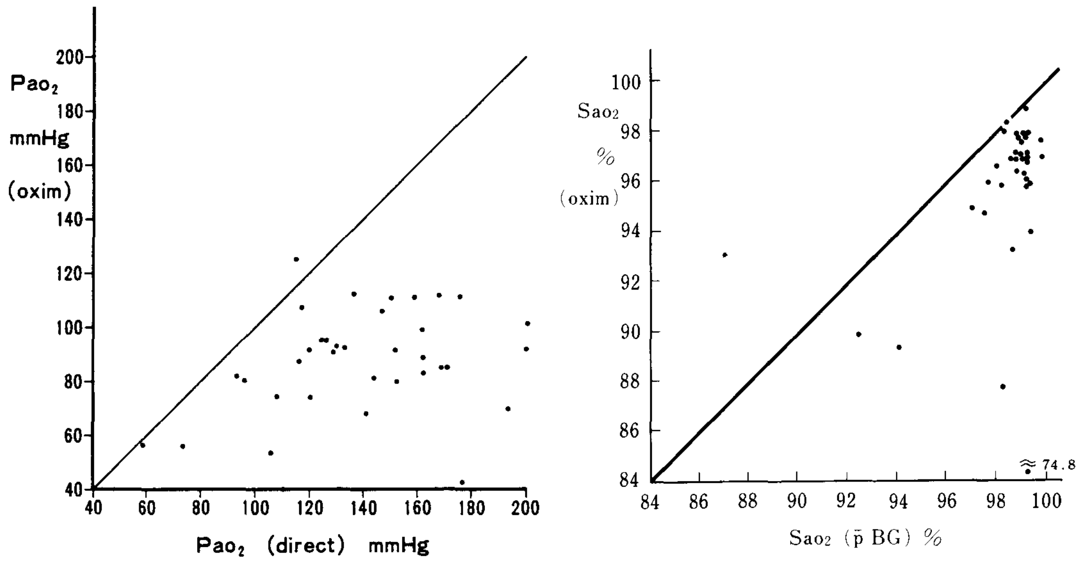

Fig. 2. A similar comparison as in figure 1, except that the data are taken from an instrument yielding the worst agreement.

while using the in vivo saturation, the body temperature and the in vitro pH, and Pa_{CO_2}.

Results

Figure 1 indicates the result from an instrument which produced the best agreement between the in vitro and in vivo values. Expressed in Pa_{O_2}, the agreement may not appear too impressive, but satisfactory. Figure 2 indicates the result from another instrument which yielded the poorest agreement. In this instrument, the saturation readings were consistently and considerably lower than the true Sa_{O_2}. While the actual Pa_{O_2}'s are between 100 and 200 mmHg, the Pa_{O_2} values calculated from the oximeter readings are only between 70 and 110 mmHg. This particular instrument showed falsely low readings so often that we eventually abandoned its use. Other five instruments achieved results between the two extremes; not quite so good as figure 1 but not so bad as figure 2.

Discussion

One may argue that a saturation of 96% instead of 98% is adequate during anesthesia. That may be true, but, with a 2% error, the true value may then be 94%. Therefore, the real problem is not the level of saturation with which one may be satisfied, but is the error which we may allow in this range. It is certainly less than 2%.

We would not mention model names of individual instruments since the performance of instruments may differ not only from one model to another but also from one instrument to another of the same model.

All the instruments tested claim the accuracy of 2% saturation. Judging from its operating principle the accuracy can be made better in the range of approaching saturation. As shown in the Results, indeed, some instruments are much better than others. We do request the companies that they may continue their effort to improve the accuracy of their instruments in the range of high oxygen. In the mean time, we should be aware of the problem. We suggest the users to check occasionally the in vivo readings against the blood gas analysis.

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