Title: EFFECTS OF METHEMOGLOBINEMIA ON PULSE OXIMETRY AND MIXED VENOUS OXIMETRY

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Introduction. Pulse oximeters and saturation-monitoring pulmonary artery catheters use light absorption at two wavelengths to determine the relative proportions of oxygenated and reduced hemoglobin. In the presence of more than two hemoglobin species, it is not clear a priori how these devices will behave. In an animal study in 1986,1 we showed that the pulse oximeter overestimates arterial oxygen saturation (SaO2) in the presence of carboxyhemoglobin (COHb). The pulse oximeter "sees" COHb as though it were roughly 90% oxyhemoglobin and 10% reduced hemoglobin. The goal of the present study is to determine the behavior of the pulse oximeter and the mixed venous saturation PA catheter in the presence of various levels of methemoglobin.

Methods. Four dogs were anesthetized with sodium pentobarbital, intubated, and mechanically ventilated at normocapnia. Each dog had arterial and pulmonary artery catheters inserted through a femoral incision. The PA catheter was an Oximetrix model SP-5107H, capable of monitoring mixed venous saturation by two-wavelength oximetry. Each dog was also monitored by three pulse oximeters with probes applied to the tongue: Nellcor N-100, Ohmeda 3700, and Novametrix 500. Two transcutaneous electrodes were applied to the chest: one Novametrix 850 combined O2/C02 probe, and one Novametrix 807 oxygen probe. Arterial blood samples were analyzed by a Radiometer ABL-2 blood gas analyzer and an IL-282 Co-Oximeter. The latter had been modified and calibrated for dog hemoglobin. Baseline values of all variables were established at FIO2 = 1.0, 0.20, 0.15, and 0.11. Methemoglobinemia was then induced in incremental levels by aerosol injection of 20% benzocaine solution into the endotracheal tube. At each methemoglobin (MetHb) level, a complete data set was recorded for each of the four FIO2 values given above.

Results. Previous studies have shown that pulse oximeter accuracy is roughly the same in the dog as in the human if no dyshemoglobins are present.1 Data from the present study for MetHb = 0 support this conclusion. As MetHb is gradually increased to levels as high as 70%, the pulse oximeter saturation (SpO2) becomes progressively greater than the IL-282 saturation (SaO2). Figure 1 shows both SpO2 and SaO2 plotted versus MetHb with FIO2 = 1.0 for the Nellcor N-100. Note that at MetHb = 70%, the SpO2 has leveled off at about 84%. At the same MetHb level, the Ohmeda SpO2 is 87% and the Novametrix SpO2 is 82%. If we further deoxygenate the blood at fixed MetHb by lowering FIO2, we find that the slope of the SpO2-SaO2 relation decreases with increasing MetHb. At the highest MetHb levels (60-70%), SpO2 reads 75-83% for all values of SaO2. Mixed venous saturation (SvO2) is overestimated by the Oximetrix PA catheter by an even larger amount, such that SvO2 actually reads higher than SpO2 even when MetHb is greater than 60%. Transcutaneous PO2 falls almost linearly with increasing MetHb, starting from 400-500 mmHg at zero MetHb (FIO2 = 1.0) and falling to the 20-40 mmHg range at 70% MetHb.

Discussion. Having data at only two wavelengths, the pulse oximeter can distinguish only two species: oxygenated and reduced hemoglobin. We have seen previously that COHb is interpreted by the pulse oximeter as being about 90% oxyhemoglobin. The pulse oximeter response to methemoglobin is more complex, in that SpO2 both overestimates SaO2 and also becomes less sensitive to SaO2 changes as MetHb increases. The slope of the SpO2-SaO2 relationship is only 0.12 for MetHb greater than 60%. The behavior of the Oximetrix PA catheter is similar but the SvO2 error is even larger. Finally, it has been stated that the pulse oximeter actually measures "functional" saturation, defined as O2Hb/Hb measured by COHb. However, plotting the present data in this form shows almost no relationship between SpO2 and functional saturation.

References.

Figure 1. SpO2 (Nellcor) and SaO2 (IL-282) versus MetHb at FIO2 = 1.0. Linear regression shown for SaO2.