Measurement of Carboxyhemoglobin and Methemoglobin by Pulse Oximetry; A Human Volunteer Study

Barker SJ, Curry J, Redford D, Morgan S. *Anesthesiology* 2006; 105(5): 892-897

Introduction

Until recently, all pulse oximeters on the market used two wavelengths of light to estimate arterial hemoglobin saturation. These two-wave length technologies do not have the capability to distinguish dyshemoglobins from oxygenated hemoglobin resulting in erroneous SpO_2 readings when dyshemoglobins are present in the blood. Masimo Corporation has developed a new, 8-wavelength Pulse CO-Oximetry platform, Masimo Rainbow SET, which is designed to measure carboxyhemoglobin (SpCO) and methemoglobin (SpMet) as well as traditional SpO_2 values. This study tests the accuracy and reliability of Masimo Rainbow SET Pulse CO-Oximetry in measuring these dyshemoglobins in human volunteers.

Methods

Twenty healthy volunteers (two groups of 10) were fitted with peripheral venous and radial arterial cannuli and monitored by a three-lead electrocardiograph and automated sphygmomanometer. Each subject also wore six Masimo Rainbow sensors (on digits 2, 3 and 4 of both hands), each connected to a different Rainbow SET Pulse CO-Oximeter.

Carboxyhemoglobin Group

The ten subjects of the carboxyhemoglobin group wore a tight fitting breathing mask connected to an anesthesia machine for the delivery of a controlled mixture of air and CO. After obtaining baseline values, subjects breathed approximately 500 ppm of CO until they reached a maximum COHb level of 15%, at which point the F_iO_2 was changed to 100% until subjects reached a COHb level of 10%, then the mask was removed and they breathed room air. During baseline, CO administration and recovery, blood samples were taken every 10 minutes, via the radial artery cannula, for analysis by laboratory CO-Oximetry. Data was pooled for the 10 subjects to determine bias, precision, linear regression and the correlation coefficient for the data collected from the Rainbow SET Pulse CO-Oximeter compared to the average of the readings from three laboratory CO-Oximeters.

Methemoglobin Group

The ten subjects of the methemoglobin group were given an intravenous infusion of sodium nitrite at a rate of 6 mg/min to a total dose of 300 mg to induce methemoglobinemia. Prior to nitrite administration, during treatment and during recovery, blood samples were taken every 10 minutes, via the radial artery cannula, for analysis by laboratory CO-Oximetry. Recovery phase lasted until the methemoglobin level of each subject had decreased by at least 5% from its peak value. Data was pooled for the 10 subjects to determine bias, precision, linear regression and the correlation coefficient for the data collected from the Rainbow SET Pulse CO-Oximeter compared to the average of the readings from three laboratory CO-Oximeters.

Results

Figure 1.

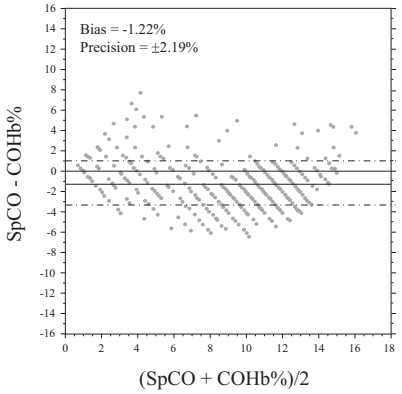

Figure 2.

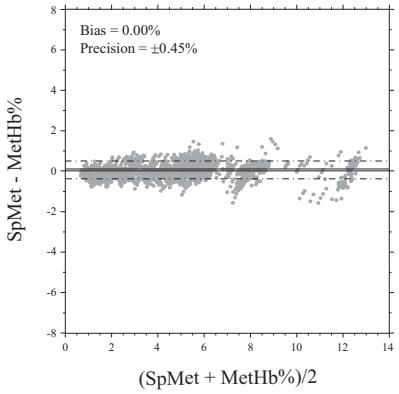

Fig 1. Bias plot of (SpCO - COHb%) verses (SpCO + COHb%) / 2
Pooled data for 10 subjects. SpCO is the Rainbow Pulse CO-Oximetry measurement of carboxyhemoglobin; COHb% is the average of three laboratory CO-Oximeters' measurements of carboxyhemoglobin. Lines show values of bias (solid) +/- precision (long/short dash).

Fig 2. Bias plot of (SpMet - MetHb%) versus (SpMet + MetHb%)/2
Pooled data for 10 subjects. SpMet is the Rainbow Pulse CO-Oximetry measurement of methemoglobin; MetHb% is the average of three laboratory CO-Oximeters' measurements of methemoglobin. Lines show values of bias (solid) +/- precision (long/short dash).

The pooled data for the ten subjects of the carboxyhemoglobin group show that Rainbow Pulse CO-Oximetry has a bias of -1.22 and a precision of 2.19 for SpCO, when compared to the average COHb reading from a laboratory CO-Oximeters. The Rainbow Pulse CO-Oximetry had a bias of 0 and a precision of 0.45 when calculated from the pooled SpMet readings, compared to the average MetHb reading collected from a laboratory CO-Oximeter. The precision of Rainbow Pulse CO-Oximetry SpCO measurement is about the same as that specified for conventional pulse oximeters. The precision of Rainbow Pulse CO-Oximetry SpMet measurement is approximately the same as a laboratory CO-Oximeter, when used within the ranges covered by this study.

Discussion

Carbon monoxide poisoning is the most common type of fatal poisoning in the United States with at least 5,000 fatalities and accounting for 49,000 ER visits annually in the U.S. alone. Methemoglobinemia, another potentially fatal dyshemoglobin disorder, can be caused by the use of commonly prescribed drugs like dapsone, benzocaine and other "caine" sprays as well as dehydration, sepsis, or accidental ingestion or inhalation of industrial chemicals. A retrospective study conducted at Johns Hopkins Bayview Medical Center found 138 cases of acquired methemoglobinemia over a 28 month period, including one fatality and three near fatalities'. Despite the high incidence of these two dyshemoglobin disorders, methods for measuring COHb and MetHb have been limited to time and labor consuming invasive blood tests done in hospitals and laboratories with laboratory CO-Oximeters. However, less than half the hospitals in the US have the capability to measure COHb and MetHb via laboratory analysis.[2] Masimo Rainbow SET Pulse CO-Oximetry provides an inexpensive and easily integrated method for solving this serious public health deficiency.

Authors' Conclusions

"Masimo Rainbow SET [Pulse CO-Oximetry] seems to be a major advance …We have found it to be capable of detecting and measuring both methemoglobin and carboxyhemoglobin. It represents a significant improvement in our oxygenation monitoring capability."

1 Ash-Bernal R, Wise R, Wright S. Acquired Methemoglobinemia. A Retrospective Series of 138 Cases at 2 Teaching Hospitals. Medicine. 2004; 83:265-273.

2 Hampson, N. Carboxyhemoglobin Measurement by Hospitals: Implications for the Diagnosis of Carbon Monoxide Poisoning. Journal of Emergency Medicine. 2006 Jul; 31(1): 13-6.